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CONTENTS TO VOLUME XVI.

Number 91.

Page

ART. I.—Observations on the Genus Romingeria; by C. E. BEECHER. (With Plates I–V) 1

II.—Comparative Study of Some Isomorphous Triple Thiocyanates; by J. C. BLAKE 12

III.—Studies in the Cyperaceæ; by T. HOLM 17

IV.—Chrysocolla: A Remarkable Case of Hydration; by C. M. PALMER 45

V.—Inquiry into the Cause of the Nebulosity around Nova Persei; by F. W. VERY 49

VI.—Heat of a Change in Connection with Changes in Dielectric Constants and in Volumes; by C. L. SPEYERS .. 61

VII.—Notes on the Genus Baptanodon, with a Description of a New Species; by W. C. KNIGHT 76

VIII.—Characters of Pteranodon; by G. F. EATON. (With Plates VI and VII) 83

IX.—Codonotheca, a New Type of Spore-Bearing Organ from the Coal Measures; by E. H. SELLARDS. (With Plate VIII) 87

X.—Note on the Dates of Publication of Certain Genera of Fossil Vertebrates; by L. P. BUSH 96

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics—Spinthariscope, W. CROOKES: Properties of Sodium Sulphate Solutions, MARIE and MARQUIS: Radio-active Lead, HOFMANN and WÖLFL, 99.—Colloidal Silver, HANRIOT: Iodides of Caesium, H. W. FOOTE: Quantitative Chemical Analysis by Electrolysis, A. CLASSEN, 100. —Chemisches Praktikum, A. WOLFRUM, 101.

Geology and Natural History—United States Geological Survey, 101.—New York State Museum, F. J. H. MERRILL, 102.—Geological Survey of New Jersey, 103.—Maryland Geological Survey: Geography and Geology of Minnesota, C. W. HALL, 104.—Plumasite, an oligoclase-corundum rock near Spanish Peak, Cal., A. C. LAWSON: Experimental Garden in Cuba, E. F. ATKINS, 105.

Miscellaneous Scientific Intelligence—United States Coast and Geodetic Survey, O. H. TITTMAN: National Bureau of Standards, S. W. STRATTON: Scientific Writings of George Francis Fitzgerald, J. LARMOR, 106.

Obituary—J. PETER LESLEY, 106.

Number 92.

Page

ART. XI.—Mechanics of Igneous Intrusion. (Second Paper); by R. A. DALY 107

XII.—Stellar Revolutions within the Galaxy: by F. W. VERY 127

XIII.—Little Cottonwood Granite Body of the Wasatch Mountains; by S. F. EMMONS 139

XIV.—Contribution to a List of the Fauna of the Stafford Limestone of New York; by M. TALBOT 148

XV.—Formula of Bornite; by B. J. HARRINGTON 151

XVI.—Iodometric Determination of Gold in Dilute Solution; by R. N. MAXSON 155

XVII.—Radioactivity of Thorium Minerals; by G. F. BARKER 161

XVIII.—Significance of Silicic Acid in Mountain Streams; W. P. HEADDEN 169

SCIENTIFIC INTELLIGENCE.

Geology and Mineralogy—U. S. Geological Survey: Batrachian and other footprints from the Coal Measures of Joggins, N. S., G. F. MATTHEW: Ueber Artinit, ein Neues Mineral der Asbestgruben, von Val Lanterna, L. BRUGNATELLI, 185.—Minerals from Leona Heights, Alameda Co, California, W. T. SCHALLER; Palacheite, a new mineral, A. S. EAKLE, 186.

Number 93.

Page

JOSIAH WILLARD GIBBS (with a Portrait, Plate IX) 187

ART. XIX.—Origin of Coral Reefs as shown by the Maldives; by J. S. GARDINER 203

XX.—Heat of Combustion of Hydrogen; by W. G. MIXTER 214

XXI.—Determination of Uranium and Uranyl Phosphate by the Zinc Reductor; by O. S. PULMAN 229

XXII.—Certain River Terraces of the Klamath Region, California; by O. H. HERSHEY 240

XXIII.—Occurrence of the Texas Mercury Minerals; by B. F. HILL 251

XXIV.—Eglestonite, Terlinguaite and Montroydite, New Mercury Minerals from Terlingua, Texas; by A. J. MOSES 253

XXV.—New Lilac-Colored Transparent Spodumene; by G. F. KUNZ. (With Plate X) 264

SCIENTIFIC INTELLIGENCE.

Geology and Mineralogy—Geology of Ascutney Mountain, Vermont, R. A. DALY: Wisconsin Geological and Natural History Survey, U. S. GRANT, 267.—Preliminary Note upon the Rare Metals in the Ore from the Rambler Mine, Wyoming, T. T. READ, 268.

Obituary—W. C. KNIGHT: HAMILTON LANPHERE SMITH: M. RENARD, 268.

Number 94.

Page

Art. XXVI.—New Cone of Mont Pelé and the Gorge of the Rivière Blanche, Martinique; by E. O. Hovey. (With Plates XI–XIV) ... 269

XXVII.—Colors of Allotropic Silver; by J. C. Blake ... 282

XXVIII.—Notes on the Development of the Biserial Arm in Certain Crinoids; by A. W. Grabau ... 289

XXIX.—Notes on the Geology of the Hawaiian Islands; by J. C. Branner. (With Plate XV) ... 301

XXX.—Recent Tuffs of the Soufrière, St. Vincent; by E. Howe ... 317

XXXI.—Discovery of Fossil Insects in the Permian of Kansas; by E. H. Sellards ... 323

XXXII.—Note on the Constants of Coronas; by C. Barus 325

XXXIII.—Note on a Radio-active Gas in Surface Water; by H. A. Bumstead and L. P. Wheeler ... 328

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics—Radium and Helium, W. Ramsay: Action of Salts of Radium upon Globulins, W. B. Hardy, 329.—Chlorine Smelting with Electrolysis, J. Swinburne: Mazza Separator for Gases, Signor Mazza, 330.—Double Salt of Potassium and Barium Nitrates, W. K. Wallbridge: Light Waves and their Uses, A. A. Michelson: Sub-Mechanics of the Universe, O. Reynolds, 331.

Geology and Mineralogy—U. S. Geological Survey, 332.—Correlation of Geological Faunas; Shifting of Faunas as a Problem of Stratigraphic Geology, H. S. Williams, 334.—Pseudoceratites of the Cretaceous, A. Hyatt: Publications of the Earthquake Investigation Committee: The Lilac-colored Spodumene from California, C. Baskerville: Tabellen zur Bestimmung der Mineralien mittels äusserer Kennzeichen von Albin Weisbach, F. Kolbeck: Purchase of the Siemaschko Collection of Meteorites, 335.—Meteoritenkunde, E. Cohen: Meteorites from New South Wales, 336.

Miscellaneous Scientific Intelligence—Ostwald's Klassiker der Exakten Wissenschaften, 336.

Number 95.

Page

ART. XXXIV.—Mineralogical Notes; by C. H. WARREN .. 337

XXXV.—Studies of Eocene Mammalia in the Marsh Collection, Peabody Museum; by J. L. WORTMAN. (With Plates XVI and XVII) 345

XXXVI.—Triadenum Virginicum (L.) Rafin. A morphological and anatomical study; by T. HOLM. (With figures in the text) 369

XXXVII.—Ephemeral Lakes in Arid Regions; by C. R. KEYES 377

XXXVIII.—Note on the Identity of Palacheite and Botryogen; by A. S. EAKLE 379

XXXIX.—Colloidal Gold: Adsorption Phenomena and Allotropy; by J. C. BLAKE 381

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics—Utilization of Atmospheric Nitrogen for Agricultural and Industrial Purposes, Dr. FRANK: Use of Calcium Cyanamide for Producing Alkaline Cyanides, G. ERLWEIN, 388.—Separation of Gaseous Mixtures by Centrifugal Force, CLAUDE and DEMOUSSY: Investigations on Double Salts by Physical Means, H. W. FOOTE, 389. — Ausgewählte Methoden der Analytischen Chemie, A. CLASSEN: Physical Chemistry in the Service of the Sciences, J. H. VAN'T HOFF and A. SMITH: Penetrative Solar Radiations, R. BLONDLOT, 390.—Spectra of the Cathode light in Gaseous Compounds of Nitrogen and Carbon, H. DESLANDRES: Dark Cathode Space, G. C. SCHMIDT: Observations of Slow Cathode Radiations with the help of Phosphorescence, P. LENARD, 391.—Discharge of Electricity from Hot Platinum, H. A. WILSON: Penetrating Radiation from the Earth's Surface, H. L. COOK: Mathematical Papers of the late George Green, 392.—Electric and Magnetic Circuits, E. H. CRAPPER, 393.

Geology and Mineralogy—United States Geological Survey, 394.—Geological Survey of Canada, 395.—Elements of Geology, J. LECONTE: Chemical Analyses of Igneous Rocks; Published from 1884–1900, with a Critical Discussion of the Character and Use of Analyses, H. S. WASHINGTON, 396. —Californite (Vesuvianite), G. F. KUNZ, 397.—Native Bismuth and Bismite from Pala, California, G. F. KUNZ, 398. — Production of Precious Stones in 1902, G. F. KUNZ, 399.

Miscellaneous Scientific Intelligence—Report of the U. S. National Museum under the direction of the Smithsonian Institution for the year ending June 30, 1901, 399.—Fauna and Geography of the Maldive and Laccadive Archipelagoes, J. S. GARDINER: Catalogue of the Collection of Birds' Eggs in the British Museum (Natural History), E. W. OATES and S. G. REID: Hand-list of the Genera and Species of Birds, R. B. SHARPE: Cold Spring Monographs, Nos. I and II, 400.

Number 96.

Page

ART. XL.—Polar Climate in Time the Major Factor in the Evolution of Plants and Animals; by G. R. WIELAND. 401

XLI.—Note on the Composition of Bredig's Silver Hydrosols; by J. C. BLAKE 431

XLII.—Behavior of Red Colloidal Gold Solutions toward the Electric Current and toward Electrolytes; by J. C. BLAKE. 433

XLIII.—Is the Peak of Fernando de Noronha a volcanic plug like that of Mont Pelé; by J. C. BRANNER 442

XLIV.—Studies in the Cyperaceæ, XX; by T. HOLM 445

XLV.—Action of Ultra-Violet Light upon Rare Earth Oxides; by C. BASKERVILLE 465

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics—New Method for the Determination of the Faintest Traces of Arsenic, A. GAUTIER: Influence of Small Quantities of Water in bringing about Chemical Reactions between Salts, PERMAN, 467.—Determination of Argon in the Atmosphere, MOISSAN, 468.—New Method for Detecting Chlorides, Bromides and Iodides, BENEDICT and SNELL: Quartz Glass, H. HERAEUS, 469.—Absorption of Ultra-Violet Rays by Ozone, E. MEYER: Induced Thorium Activity, F. v. LERCH, 470.—Effect of Pressure on Arc Spectra, J. E. PETAVEL and R. S. HUTTON, 471.

Geology and Mineralogy—United States Geological Survey, 471.—Nebraska Geological Survey: Geological Structure of Monzoni and Fassa, M. M. O. GORDON: North American Plesiosaurs, S. W. WILLISTON, 473.—Spodumene from Pala, California, W. T. SCHALLER, 474.

Miscellaneous Scientific Intelligence—National Academy of Sciences: American Association: Annual Report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures and conditions of the Institution for the year ending June 30, 1902: Physico-Chemical Review, M. RUDOLPHI, 475.

Obituary—ROBERT HENRY THURSTON: HENRY CARRINGTON BOLTON, 475.

INDEX TO VOL. XVI, 476.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. I.—*Observations on the Genus Romingeria;* by Charles E. Beecher. (With Plates I–V.)

Introduction.

The type species of the genus *Romingeria* (*R. umbellifera* Billings) has been known since 1859, but on account of its rarity and fragmentary occurrence it has failed to attract more than casual attention. In many ways the genus should be considered as one of the most interesting and remarkable of fossil corals. Several large and well-preserved colonies, recently found by the writer in the Corniferous limestone near Leroy, New York, emphasize the importance of reviewing the characters of the type, especially since it has been confused with other species and also because some details not hitherto observed are now to be noted.

Eight species have at various times been referred to *Romingeria*, mostly upon very insufficient grounds; hence the original conception of the genus has become obscured and is without much present significance. If the original description and figure of Billings be taken as a starting point, the subsequent vicissitudes of this genotype will be appreciated.

In 1859, Billings[1] described three species of *Aulopora*,—*A. cornuta*, *A. filiformis*, and *A. umbellifera*. The original diagnosis of the latter is reproduced herewith:

"Aulopora umbellifera (Billings).

"The mode of growth of this remarkable species is sufficient to distinguish it at once from all other described forms of the *genus*. The parent stems are about one line in diameter, and remain single and straight for the distance of one fourth, or half an inch, when they give off branches in all directions, sometimes ten or twelve at once. These are at first oblique or somewhat parallel with the main tube, and are connected laterally; they then radiate like the spokes of a wheel, at right angles to the parent corallites, each soon giving birth to a similar circlet of new tubes.

"It may be that this species should constitute a new *genus;* but as I have not been able to ascertain wherein its internal structure differs from *Aulopora*, I have disposed of it as above, provisionally.

"*Locality and formation.*—Lot 6, con. 1, Wainfleet. Corniferous."

Rominger,[2] in 1876, was the first to adopt the suggestion of Billings as to the generic import of *A. umbellifera.* He showed its distinct value, and proposed the genus *Quenstedtia*, with this species as the type. Under it he considered *A. cornuta* Billings, as consisting of fragments of *A. umbellifera* Billings, in which only from one to three branches or buds are given off. The species *Q. niagarensis* was also defined by Rominger at the same time.

Three years later (1879) Nicholson published his general work on the "Tabulate Corals,"[3] and substituted the name *Romingeria* for *Quenstedtia*, which proved to be preoccupied. No change was made by Nicholson in the specific synonymy, and the identity of *A. umbellifera* and *A. cornuta* was accepted by him, though in his description of *R. umbellifera* he includes characters never present in what the writer believes to be Billings's species *sensu strictu.* His illustration especially resembles that given by Billings for his *A. cornuta*, though the statement is made that there were specimens in his hands apparently belonging to *A. cornuta* and agreeing with *Aulopora* proper rather than with *Romingeria.* However, as Nicholson's redescription of *R. umbellifera* seems to be based largely on his own material, as represented in his figures, it appears highly probable that the generic reference to *Romingeria* was correct. The discrepancies between his description and what is now believed to clearly represent the original species, can be best explained on the supposition that Nicholson did not have true *R. umbellifera*, but did have representatives of what is apparently a distinct, though allied, species of *Romingeria*, which is not uncommon in the Upper Helderberg limestones at the Falls of the Ohio and elsewhere, and is the form commonly, though erroneously, identified with *R. umbellifera.*

Davis,[4] in the volume of plates illustrating Kentucky fossil corals, dated 1885* (though apparently not published before

*This volume bears the title of "Kentucky Fossil Corals. A Monograph of the Fossil Corals of the Silurian and Devonian Rocks of Kentucky. By William J. Davis. [In Two Parts. Part II.] Frankfort, Kentucky, 1885. Copyrighted 1887." This "monograph," or more properly an illustrated catalogue, as it has proved to be, consists of a letter of transmittal and thirteen pages of index to the plates. The plates and explanations number one

1887), figures a species of *Romingeria* which he identifies with *R. umbellifera.* Through the kindness of Professor R. T. Jackson, the writer has been enabled to study the original specimens in the Davis collection now in the Museum of Comparative Zoology, and they prove not to be typical of that species but of the form previously mentioned as generally referred to it. Davis also applies four new specific names in connection with *Romingeria.* The original examples of three of the species appear not to be congeneric, while the fourth is a *Romingeria.*

In a revision of the Canadian paleozoic corals, published by Lambe in 1899,[8] there is included under *Romingeria* the single species *R. umbellifera* Billings, sp. A reëxamination of the type showed the presence of mural pores, together with the convex tabulæ. No septal spines were observed.

To review briefly the history and synonymy of the genotype of *Romingeria*, it may be stated that in 1859 Billings described the species *Aulopora umbellifera.* This was made the type of *Quenstedtia* by Rominger in 1876, who also considered *A. cornuta* Billings as synonymous. On account of this generic name having been used previously, Nicholson, in 1879, substituted *Romingeria.* His description was apparently founded upon two species, *R. umbellifera* and *R.* sp., the latter being the one illustrated by him. Davis (1887) figures a species of *Romingeria* which he identifies with the type. It is here considered as distinct. Two other very clearly defined forms are also added in the present paper,—*R. Jacksoni*, sp. nov., and *R. minor*, sp. nov.

Observations on Romingeria umbellifera.

PLATES I–V.

The specific characters of this type have been pretty fully and accurately stated in the description by Billings and Rominger, but as yet the illustrations published simply give one or two umbels without much suggestion as to the appearance of a large colony and without any details of internal structure.

The number of buds given off by the parent corallite at each period of proliferation is stated by Nicholson and Rominger to be from five to twelve, and one would be led to believe that twelve was the maximum attained by few, while the common number was somewhere between five and twelve.

hundred and thirty-nine, illustrating about a thousand different specimens. One hundred and seventy species are given names and marked as new species. They are without description of any sort. Seven new generic terms are proposed without definition. They are supposed to be corals, though some of them certainly are not (*e. g.*, *Nicholsonia*=*Hederella*, a Bryozoan), and all of them are probably synonyms of well-known genera (*e. g.*, *Antholites* and *Procteria*=*Pleurodictyum*).

In a careful count of one hundred discrete whorls, the writer has found that 41 per cent contain twelve buds, 28 per cent contain eleven, 16 per cent ten, 6 per cent nine, 5 per cent eight, and 4 per cent seven buds. In no instance has any number greater than twelve or less than seven been observed in separate umbels. The very unusual condition represented in the specimen, figures 8, 9, Plate I, shows two verticels crowded together so as to unite, and eleven corallites are suppressed in consequence. Of the fifteen remaining corallites, two (*a*, *b*,) are the parents, while six pertain to one umbel and seven to the other.

The frequency polygon is shown in text, figure 1. This indicates that what Billings meant by "sometimes ten or twelve" buds really means that 85 per cent of all the umbels have from ten to twelve buds springing from the parent corallite, and that twelve is the most common and therefore the characteristic number. There is a rapid falling off in the numbers below ten, and specimens with less than that must be considered as abnormal or pathologic.

1

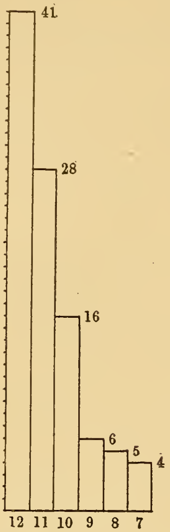


FIGURE 1.—Frequency polygon of *Romingeria umbellifera;* showing the number of buds in a hundred umbels; the abscissa shows the variation in the number of buds per umbel (seven to twelve), and the ordinate the number of individuals representing each. 41 per cent of the umbels have twelve buds, 28 per cent eleven, 16 per cent ten, 6 per cent nine, 5 per cent eight, and 4 per cent seven.

The length of the internodes or the distance between the whorls measured along the corallites varies from 8 to 23^{mm}. Since the budding period is simultaneous for the whole corallum, and takes place on the same horizontal plane, it is evident that the internodes measured along one of the older parent corallites are shorter than along one of its daughter corallites, which rise obliquely from their origin to the next budding zone.

The corallites measure from 2 to $2{\cdot}25^{mm}$ in diameter throughout most of their length. Just before starting to bud the tube enlarges to a diameter of 2·50 to 3^{mm}, and within the whorl of buds the parent corallite abruptly contracts to about $1{\cdot}5^{mm}$ in diameter. The buds all spring from the beveled periphery of the parent corallite, with which they communicate by means of a large initial pore, figures 2, 3, Plate I. Both buds and parent corallites develop tabulæ, usually convex, and most numerous within the region of the verticel. In other portions of the corallum they seem to be quite infrequent. Immediately above the row of initial pores there is a tabula in the parent corallite, sometimes showing a number of septal ridges which may correspond to the number of buds and are sometimes continued upward for a short distance as rows of septal spines, figures 3, 4, Plate I. No evidence of septa has been observed in any other portions of the corallites in the present collection. The buds before separating usually communicate with each other by one or two mural pores, as shown in figure 6, Plate I, but in no instance except in the initial pore previously mentioned has a bud within the umbel been seen to bear pores leading into the parent corallite. Also, whenever the corallites of the same or different verticels come in contact away from the whorls, the walls may be perforated by a pore, figure 7, Plate I.

The examination of a large mass of this coral, measuring nine inches or more in diameter (230^{mm}), shows its almost geometrical regularity in a striking degree. It is seen to be composed of a number of distinct superimposed horizontal zones or stories, separated by a distance of from 15 to 20^{mm}. The division planes consist of closely arranged rosettes formed by the whorls of buds given off at regular intervals in the upward growth of the corallum. Between the division planes or from the floor to the ceiling of each story are to be seen the simple columns of the individual corallites with their Corinthian-like capitals, which are to develop into a verticel of daughter corallites at the division plane above, Plate IV.

In a large corallum, each umbel of thirteen corallites (one parent and twelve buds) generally occupies a space of about 170 square millimeters. The size of this area was determined by enumerating the umbels occurring in several areas measuring 50 x 50^{mm}. The average showed fifteen umbels for this space, containing in the aggregate one hundred and ninety-five corallites.

One specimen measuring 100 x 200^{mm} on the horizontal surface has approximately 1500 corallites on each zone. Three zones are complete for the same area and together contain about 4500 corallites. Now if each of the 1500 corallites of the bottom zone gave origin to twelve buds the next zone would contain 19,500 corallites, and the same process would demand 253,500 corallites for the third zone. This shows a suppression of 243,000 corallites on two zones.

The suppression of corallites seems to be due principally to two causes: (*a*) The crowding of the umbels together in the same plane and thus aborting many of the buds, which only grow to be a few millimeters in length or are entirely suppressed; and (*b*) the inability of many of the corallites to reach the next zone of budding before all the available space is taken up by verticels from other rapid growing and more favored corallites. Whenever the growth and budding are not seriously restricted as to space, it is found that from ten to twelve buds are almost invariably given off.

Altogether, the probabilities against the successful attainment of maturity with the growth of a single cycle of buds are seldom equaled among corals. In ordinary proliferation in a compound coral, a bud is developed when by a divergence of the corallites through growth a space is made to receive it, but in *Romingeria* the buds are thrown off without any reference to their future possibilities. If the pores of *Favosites* are considered as potential buds, then the amount of suppression in that genus is infinitely greater than in *Romingeria.* It should be noted, however, that in *Favosites* whenever a corallite once appeared it usually continued to grow until the death of the whole colony.

A diagram of two successive periods of proliferation for a single corallite of *R. umbellifera* is shown in Plate V, figure 1. The third zone of buds would number 2,197 corallites, the fourth 28,561, and so on, according to the permutation of the number 13.

Corallites subjected to pressure in the matrix often exhibit a tendency to split into longitudinal plates corresponding to the twelve mesenteries or primary septal divisions, figure 5, Plate I. The twelvefold nature of the walls may be developed in this way without any evidence of septa being preserved.

Romingeria commutata, sp. nov.

Plate V, Figures 4, 5.

Romingeria umbellifera Davis, Kentucky Fossil Corals, pl. 76, fig. 1, 1887.

The specimens identified by Davis with the type of the genus have already been referred to as probably distinct. The growth of the corallum is lax and the budding of the corallites is irregular, not producing the storied appearance typical of *R. umbellifera.* No regularly developed 10–12 rowed umbels are present in the Kentucky specimens, which seem to give off bundles of buds rather than to form perfect rosettes. There is also a much stronger development of the 8–10 rows of trabeculæ, which are not confined wholly to the budding region, but may extend for considerable distances along the corallites and also appear at the accidental points of contact of two corallites where adventitious mural pores are usually found, Plate V, figures 4, 5. The corallites are a little larger than in *R. umbellifera* from Leroy, New York, and the length of the internodes is often much greater, sometimes measuring 30^{mm} or more.

Formation and locality.—The type specimen is in the collections of the Museum of Comparative Zoology, Catalogue Number 8849, Kentucky Fossil Corals, Plate 76, figure 1, and is from the Corniferous limestone (Devonian) at the Falls of the Ohio, Louisville, Kentucky.

Romingeria Jacksoni, sp. nov.

PLATE V, FIGURES 2, 10–15.

Corallum consisting of slender, cylindrical, discrete corallites, measuring from ·7 to $\cdot 8^{mm}$ in diameter. At intervals of from 5 to 10^{mm} a whorl of seven buds is given off from each corallite. The buds are closely appressed to the parent for a distance of 1 or 2^{mm} and then turn outward often nearly at right angles for 2 or 4^{mm}, thence extending upward to the next budding zone. The walls of the parent corallite are expanded just before the buds appear, and abruptly contract within the verticel to a little less than their normal diameter. On the exterior the corallites are marked by fine concentric striæ. Tabulæ infrequent, most common in the region of the umbels. Septa or septal spines not observed. A large apical initial pore connects each daughter corallite with the parent, and adjacent corallites often show communicating pores, as in *R. umbellifera.*

Occasionally the corallites become agglomerated into a mass resembling a *Favosites*, though around the periphery the branches are discrete and give off the usual umbels of seven buds each. A section of the closely grouped corallites is represented in figure 10, Plate V, showing their prismatic form.

This very distinct and normal species of *Romingeria* can be readily recognized from *R. umbellifera* by the smaller diameter of the corallites, the relative greater length of the internodes, and especially by the number of buds in each verticel. In *R. umbellifera*, out of a hundred umbels only four contained seven buds, while 85 per cent had from ten to twelve, with twelve as the characteristic number. The present collections contain eighteen umbels of *R. Jacksoni*, and each one of these is composed of seven buds besides the parent corallite. From *R. minor*, this species is distinguished by its larger size and by the number of buds in a single verticel, which in that form number five.

The specific name is given in honor of Professor R. T. Jackson of Harvard University.

Formation and locality.—In the cherty layers of the Corniferous limestone (Devonian), near Leroy, Genesee County, New York.

Romingeria minor, sp. nov.

Plate V, Figures 3, 6–9.

Besides the species already noted, there is another form in the present collection, which, though minute, seems to agree in all essential external generic features with the genotype. Only a few umbels of this species have been observed, but they are so constant in their characters and so distinct from the other species, that there is little hesitancy in describing them as new.

The corallites are cylindrical, measuring but ·3 to ·4^{mm} in diameter. The umbels contain five buds each. The buds are contiguous to the parent for a distance of ·5^{mm}, and then turn out abruptly at right angles. The specimens are mostly filled with silica, and evidences of tabulæ and trabeculæ are obscured.

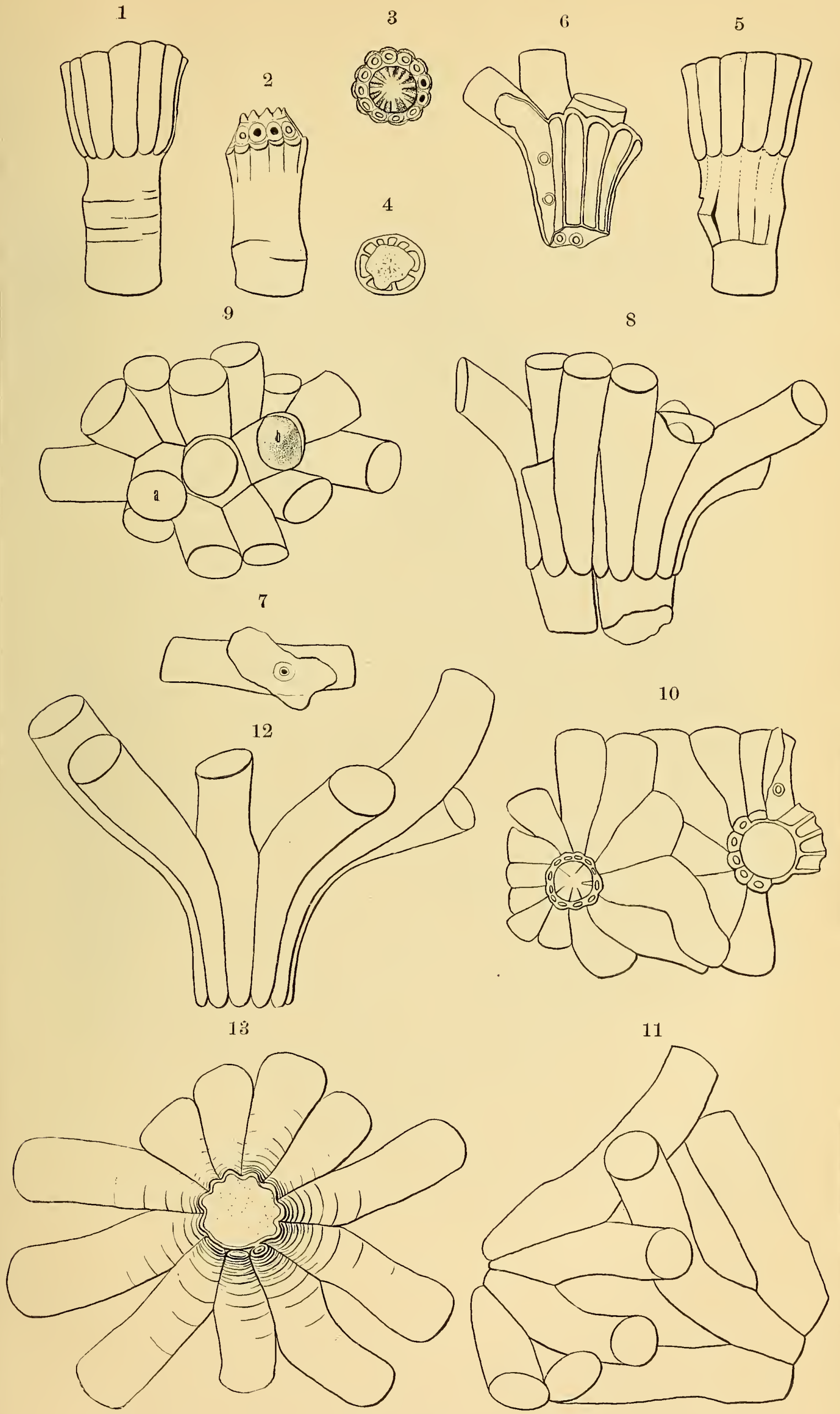
The diminutive size and the small number of buds in each umbel distinguish this species from the known members of the genus *Romingeria*.

Formation and locality.—In the Corniferous limestone (Devonian), near Leroy, New York.

Any discussion of the affinities of *Romingeria* with other genera of paleozoic tabulate corals must include the consideration of a number of genera, some of whose taxonomic positions are almost equally uncertain. On the one hand we are led to compare it with *Aulopora* and related forms, and on the other it appears that we are dealing with a type which in many ways is connected with *Favosites*. At the same time, certain genera often classed with the Bryozoa, as *Clonopora* and *Vermipora*, have close resemblances with it in some essential features, and should be treated in the same connection.

The main purpose of the present article is to make some contribution to the knowledge of the structure and habit of what are believed to be characteristic species of the genus *Romingeria*, and not to enter into a critical comparison with other genera. Some few remarks can not well be avoided, however, and the writer would again cite *Aulopora* as expressing a very simple type from which by progressive modifications a considerable number of more highly developed genera could be easily derived.

In a study of the ontogeny of *Pleurodictyum*, it was shown by the writer,[6] and also by Girty in *Favosites*,[7] that the initial corallite soon gave origin to a single bud which was connected with the parent by a large initial pore, and in this condition it was homologous with a young colony of *Aulopora* consisting of



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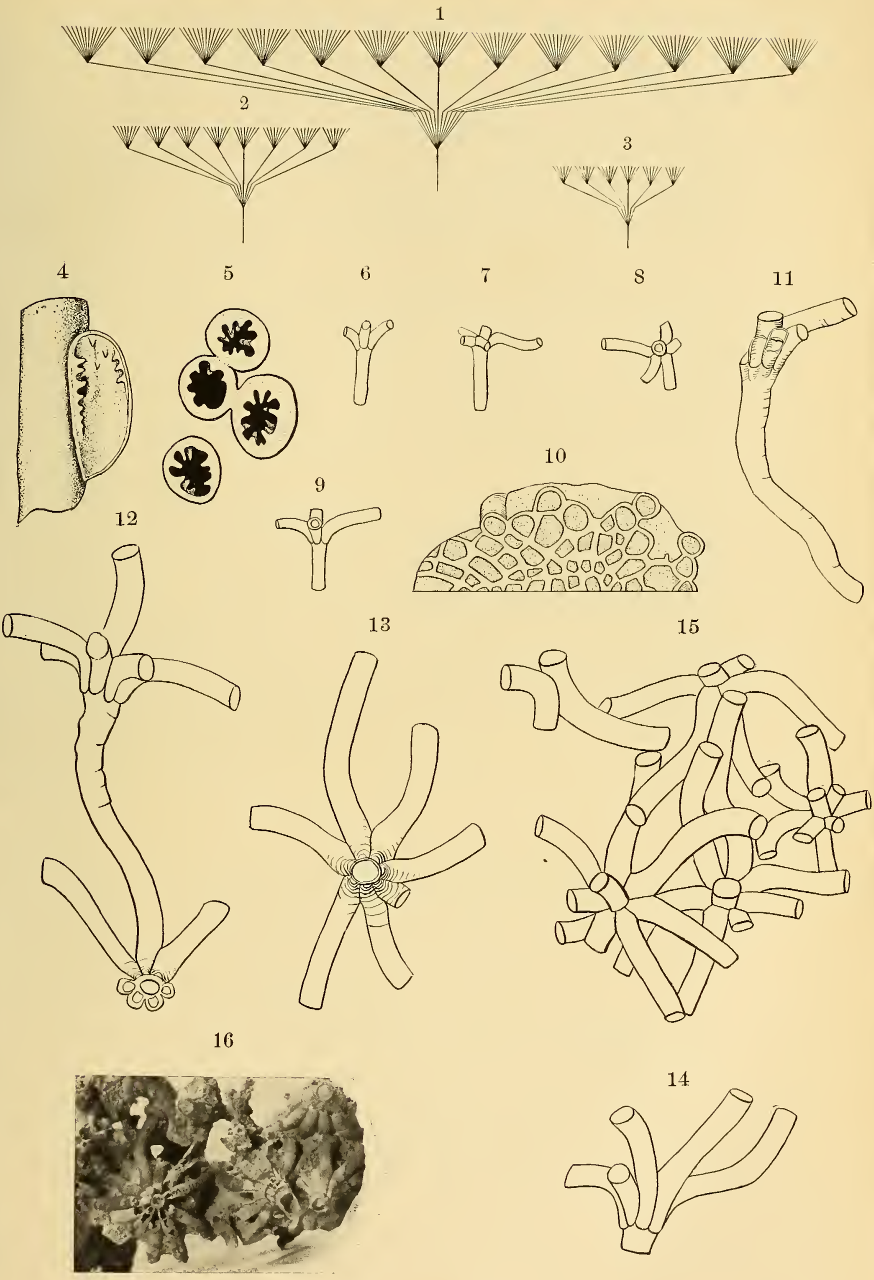

ROMINGERIA.

but two corallites. In *Pleurodictyum lenticulare* as in *Aulopora* no tabulæ are present, and the only structures within the tubes are rows of trabeculæ. It was also shown[5,6] that the pores in the Favositidæ may be likened to aborted buds which attained no further development than the formation of a pore. The corallites in *Aulopora* generally give off one or two buds and then soon reach their limit of growth, while in *Romingeria* the corallites may grow to indefinite lengths and repeatedly send off whorls of buds.

It is well known that many species of *Favosites* develop faint septal longitudinal ridges or rows of spines. Typically these number twelve, thus agreeing with the characteristic number of buds and septa in *R. umbellifera.* The correspondence in the number of septa and mesenteries indicates that from each interseptal space buds may arise, so that *Favosites* has twelve proliferation potentialities at each complete cycle of budding.

Girty[7] has fully discussed these features in *Favosites*, and has shown that what should be considered as the archetypal form consists of an initial corallite with six primary radially arranged buds. Six interstitial cells constitute the next generation, and complete the cycle of twelve radii of gemmation.

These points of similarity in the budding habit of *Favosites* and *Romingeria*, together with the identity of most of their internal structures, clearly indicate their genetic affinities and point to their common origin.

Paleontological Laboratory, Yale University Museum, June 6, 1903.

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EXPLANATION OF PLATES.

Plate I.

Romingeria umbellifera Billings, sp.

Figure 1.—Side view of portion of a normal corallite, with a circle of twelve buds at the summit. × 4.

Figure 2.—Side view of a corallite, with the buds removed; showing the large initial pores connecting the parent with the daughter corallites, and the abrupt constriction of the parent at the budding zone. The serrations of the summit are produced by the proximal ends of the septal ridges, and correspond in number with the buds. × 4.

Figure 3.—Top view of the preceding; showing the twelve initial pores connecting the buds with the parent corallite, and the twelve septal lines extending over the tabula of the parent corallite. × 4.

Figure 4.—A section of a corallite just above the budding zone; showing eight distinct septal spines. The center is filled with silica and the full extent of the septa obliterated. × 4.

Figure 5.—A specimen similar to figure 1, in which, from compression, the walls of the parent corallite have been split into vertical plates, corresponding to the septal divisions. × 4.

Figure 6.—Side view of an umbel from which all but two of the buds have been stripped, leaving their inner walls attached to the central or parent corallite. Two pores are shown on the left side of the figure, communicating between adjacent buds, and two of the initial pores are represented at the base. × 4.

Figure 7.—Showing point of contact of two corallites and the formation of a mural pore. × 4.

Figure 8.—Side view of two closely appressed umbels, causing a suppression of some of the buds. × 4.

Figure 9.—Top view of the preceding; showing fifteen corallites. *a* and *b* are the two parent corallites. Eleven buds have been suppressed. × 4.

Figure 10.—Basal view of two adjacent normal umbels of twelve buds each, in close contact, so that there are no interstices between the corallites. × 4.

Figure 11.—Showing the loose interlocking of the corallites from two adjacent umbels. × 4.

Figure 12.—Side view of an umbel containing eleven buds. × 4.

Figure 13.—Basal view of the same. × 4.

Corniferous limestone, near Leroy, New York.
Collection, Yale University Museum.

Plate II.

Romingeria umbellifera Billings, sp.

Figure 1.—Basal view of a colony; showing the characteristic appearance of normal growth. Two-thirds natural size.

Corniferous limestone, near Leroy, New York.
Collection, Yale University Museum.

Plate III.

Romingeria umbellifera Billings, sp.

Figure 1.—An oblique basal view of the specimen on the preceding plate; showing more distinctly the umbellate habit of growth. Above three-fourths natural size.

Corniferous limestone, near Leroy, New York.
Collection, Yale University Museum.

Plate IV.

Romingeria umbellifera Billings, sp.

Figure 1.—Side view of a portion of a colony ; showing the storied effect, with supporting columns, produced by the regular proliferation periods in this species. $\times \frac{3}{2}$.

Plate V.

Figure 1.—Proliferation diagram of *Romingeria umbellifera* Billings, sp. ; showing two generations of normal budding. The parent corallite is in the center.

Figure 2.—Proliferation diagram of *Romingeria Jacksoni* Beecher.

Figure 3.—Proliferation diagram of *Romingeria minor* Beecher.

Romingeria commutata Beecher.

Figure 4.—A portion of two branches in contact, with the walls of one broken away ; showing the connecting mural pore and the rows of spinules. $\times 4$.

Taken from specimen No. 8849, Collection of Museum of Comparative Zoology.

Type of figure 1, Plate 76, Kentucky Fossil Corals, W. J. Davis.

Corniferous limestone, Falls of the Ohio.

Figure 5.—The broken ends of four corallites from the same specimen ; showing the strong lines of trabeculæ on the interior. $\times 4$.

Romingeria minor Beecher.

Figure 6.—Side view of an umbel of this species. $\times 4$.

Figure 7.—Side view of an umbel ; showing the buds extending out at right angles to the parent corallite. Type. $\times 4$.

Figure 8.—Top view of the preceding ; showing the normal number of five buds in the verticel. $\times 4$.

Figure 9.—Side view of an umbel similar to the preceding. $\times 4$.

Corniferous limestone, near Leroy, New York.

Collection, Yale University Museum.

Romingeria Jacksoni Beecher.

Figure 10.—A longitudinal section of a corallum in which the corallites are prismatic, except on the exterior. The peripheral corallites turn outward on some parts of the specimen (not shown) and develop normal umbels. $\times 4$.

Figure 11.—Side view of a corallite, with a broken circlet of buds at the top. One of the buds shows the initial pore, and the adjacent bud preserves a portion of a tabula. $\times 4$.

Figure 12.—Two umbels taken from the specimen figure 14 ; showing characteristics of this species. $\times 4$.

Figure 13.—Base of an umbel ; showing the normal number of seven buds. $\times 4$.

Figure 14.—Side view of the preceding. $\times 4$.

Figure 15.—Top view of a portion of a colony ; showing the general habit of growth. Type. $\times 4$.

Corniferous limestone, near Leroy, New York.

Collection, Yale University Museum.

Romingeria umbellifera Billings.

Figure 16.—Basal view of a portion of the specimen shown on Plate IV ; showing the disposition of the umbels. Natural size.

Corniferous limestone, near Leroy, New York.

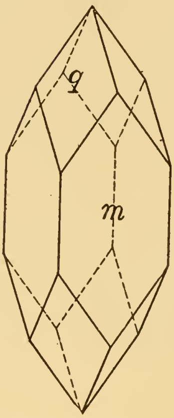
Collection, Yale University Museum.

ART. II. — *A Comparative Study of Some Isomorphous Triple Thiocyanates;* by J. C. BLAKE.

FOUR triple thiocyanates, recently prepared by Wells and others,* have been studied crystallographically. These salts have compositions represented by the following formulas:

$$Cs_3Ag_2Ba(SCN)_7$$
$$Cs_3Cu_2Ba(SCN)_7$$
$$Cs_3Ag_2Sr(SCN)_7$$
$$Cs_3Cu_2Sr(SCN)_7$$

1



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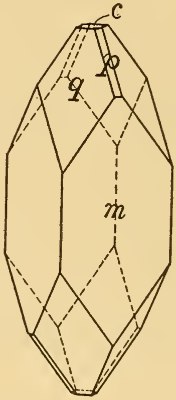

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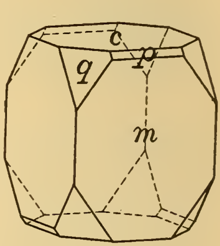


The crystals are well suited for optical investigation, and are especially interesting because the sphenoidal group of the tetrahedral system, to which they belong, has few representatives, either natural or artificial, and because the salts are isomorphous and hence offer a new field for the comparative study of the physical and chemical properties involved. Unfortunately the number of salts belonging to the series which have been prepared is as yet too small to throw much light on the relative variations which change of composition induces, or to lend much weight to the conclusions reached.

The following forms have been observed:

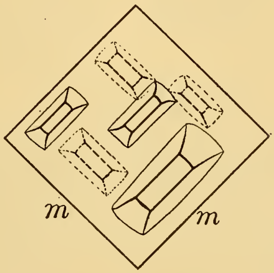
c (001)	*m* (110)	*q* (201)
a (100)	*p* (111)	

The general habit of the crystals is indicated by the illustrations, figures 2 and 3 showing the sphenoid *p* (111). The

* Am. Chem. Jour., xxviii, 245.

sphenoidal character of the crystals was more fully established for all of the salts of the series by the binary character of the etchings on basal cleavage surfaces. The basal cleavage is a pronounced feature of all the salts, hence basal sections for etching and for optical examination could readily be obtained. The etched figures, in no case very distinct, were best obtained by using dilute ammonium hydroxide as the solvent. The characters obtained are sketched in figure 4, and exhibit plainly the binary symmetry of the vertical axis. Moreover, on opposite faces of the same basal section the figures were orientated at right angles to one another, as indicated by full and dotted lines in the figure. In this way the sphenoidal character of the silver-barium salt was established, although the sphenoidal

4



faces, *p* (111) were not present on any of the crystals observed. Indeed, the sphenoidal character of this salt, the first one of the series which was prepared and studied, was unsuspected until after the other salts had been examined.

The crystals studied were from one millimeter to one centimeter in thickness, with the proportionate lengths represented in the figures, and exhibited some tendency to arrange themselves in parallel groups. One large individual of the silver-strontium salt in particular seemed to be made up of a collection of smaller ones in parallel position, the separate pyramidal faces, *q* (201), being readily discernible. The crystals are clear and colorless when not tinged with impurities, and, with the exception of the silver-strontium salt, give good reflections with the goniometer.

Basal sections of all of the salts, when examined with the polariscope, exhibit the normal interference figure of uniaxial crystals, and, when tested with the mica plate, the salts were proved to be optically negative. The well developed pyramidal faces, *q*, 201, and q'', $\bar{2}01$, of the several salts served as prisms whereby the indices of refraction were determined for sodium light.

$Cs_3Ag_2Ba(SCN)_7$.

The crystals of this salt have the habit shown in figure 1, consisting of the prism, *m* (110), and the pyramid of opposite order, *q* (201), although the basal plane, *c* (001), only slightly developed, is sometimes present. Its external form gives no indication of its sphenoidal character. The following angles were measured, the asterisk marking the fundamental measurement:

		Measured.	Calculated.
$q \wedge q''$,	$201 \wedge \bar{2}01$	122° 14′*	
$q \wedge q'$,	$201 \wedge 021$	76° 30′	76° 30′
$m \wedge q$,	$110 \wedge 201$	51° 45′	51° 45′

Vertical axis $c = 0{\cdot}9063$.
Indices of refraction for sodium light:

$\omega = 1{\cdot}7761$; $\epsilon = 1{\cdot}6788$. Difference $= 0{\cdot}0973$.

$Cs_3Cu_2Ba(SCN)_7$.

The crystals of this salt sometimes have the same habit as that of the silver-barium compound, figure 1, but usually they are modified by the sphenoidal faces, *p* (111), and the base, *c* (001), as shown in figure 2. In one crop of crystals more than twenty individuals were examined, and no variation was observed in the distribution of the *p* faces, truncating the alternate edges of the pyramid of the second order, *q* (201), thus clearly establishing the sphenoidal character of the crystallization. Another lot of crystals presented a very different, almost cubical appearance, owing to the large development of the basal plane, *c*, figure 3, with the pyramid of the second order *q*, and the sphenoid, *p*, only slightly developed. Here, again, there was no variation in the distribution of the faces of the sphenoid, *p*, replacing the alternate edges between *c* and *m*. On one crystal a single but well-developed face of the prism of the second order, *a* (100), was observed, this being the only observation of this form on any of the salts of the series. The following angles were measured:

		Measured.	Calculated.
$q \wedge q''$,	$201 \wedge \bar{2}01$	122° 52′*	
$q \wedge q'$,	$201 \wedge 021$	76° 44′	76° 47′
$m \wedge q$,	$110 \wedge 201$	51° 38′	51° 37′
$c \wedge p$,	$001 \wedge 111$	52° 23′	52° 24′

Vertical axis $c = 0{\cdot}9183$.
Indices of refraction for sodium light:

$\omega = 1{\cdot}8013$; $\epsilon = 1{\cdot}6882$. Difference $= 0{\cdot}1131$.

$Cs_3Ag_2Sr(SCN)_7$.

The habit of this salt is the same as that of the silver-barium compound, except that the sphenoidal faces, *p* (111), were observed on two crystals out of twenty, as in figure 2. The reflections were only fair at the best, although fifty or sixty individual crystals, obtained from four or five different crops, were examined. Hence the optical data obtained are valueless for comparison with those of the other salts studied, although they are sufficiently characteristic to bring this salt clearly within the series. The following angles were measured:

		Measured.	Calculated.
$q \wedge q''$,	$201 \wedge \bar{2}01$	122° 46'*	
$q \wedge q'$,	$201 \wedge 021$	76° 35'	76° 44⅓'
$m \wedge q$,	$110 \wedge 201$	51° 42'	51° 38'
$c \wedge p$,	$001 \wedge 111$	52° 29'	52° 21'

Vertical axis $c = 0{\cdot}9165$.

$Cs_3Cu_2Sr(SCN)_7$.

The habit of these crystals is much like that of the copper-barium salt, but the sphenoidal faces, *p* (111), and the base, *c* (001), are generally more largely developed than in figure 2, the *p* faces being often as large as the faces of the pyramid of the second order, *q* (201). Indeed, the sphenoidal faces are more pronounced and more generally present on this than on any other salt of the series. The following angles were measured:

		Measured.	Calculated.
$q \wedge q''$,	$201 \wedge \bar{2}01$	122° 44'*	
$q \wedge q'$,	$201 \wedge 021$	76° 41'	76° 43½'
$m \wedge q$,	$110 \wedge 201$	51° 39'	51° 38'
$c \wedge p$,	$001 \wedge 111$	52° 18'	52° 20'

Vertical axis $c = 0{\cdot}9158$.
Indices of refraction for sodium light:

$$\omega = 1{\cdot}8535\ ;\ \epsilon = 1{\cdot}6982. \quad \text{Difference} = 0{\cdot}1553.$$

Comparative Study.

It will be observed that the indices of refraction are high, and that the birefringence is likewise high. Further, the relative values of the indices of refraction for the ordinary and extraordinary rays confirm the evidence obtained by use of the mica plate that the material is optically negative. The regularity of the physical and chemical variations is made evident in the following table of collected results:

Salt.	Molec. weight.	Development of *p* (111).	*c*	ω	ε	Birefringence.
Cs–Ag–Ba	1042·5	Absent	0·9063	1·7761	1·6788	0·0973
Cs–Cu–Ba	998·2	Slight	0·9183	1·8013	1·6882	0·1131
Cs–Ag–Sr	993·3	Slight	0·9165*	-----	-----	--- -
Cs–Cu–Sr	949·0	Large	0·9158	1·8535	1·6982	0·1553

The salts have been arranged in order of decreasing molecular weight. It will be noticed that as the heavier metals are replaced by lighter ones, both indices of refraction, as well as the birefringence, grow successively greater, although the opposite behavior might have been expected. The development of the sphenoidal form, *p* (111), shows a similar regularity; whereas the lengths of the vertical axis show the inverse relation, except for that of the silver-barium salt. Hence one might conclude that: (1) Similarity of the atomic weights of the basic elements, as in the case of the cæsium-silver-barium compound, tend to decrease both the indices of refraction and the birefringence, and also to suppress the sphenoidal form; (2) Neither the chemical composition nor the optical properties bear a simple relation to the length of the vertical axis.

Attempts to obtain other members of the series for further comparison, as by substituting rubidium for cæsium, have so far been unsuccessful.

The kind advice and supervision of Prof. S. L. Penfield is gratefully acknowledged; also the kindness of Prof. H. L. Wells and his assistants in supplying the crystals examined.

Mineralogical Laboratory of Sheffield Scientific School,
Yale University.

* Repeated attempts to obtain the indices of refraction were unsuccessful, apparently on account of the great solubility of the material and the consequent difficulty of separating the crystals from the concentrated mother liquor in good condition for crystallographic study. The crystal faces were always somewhat uneven, and the reflections consequently blurred; hence the length of the vertical axis, also, is less reliable than the values given for the other salts.

ART. III.—*Studies in the Cyperaceæ;* by THEO. HOLM. XIX. The genus *Carex* in Colorado. (With figures in the text, drawn by the author.)

HAVING given an account of some critical species of *Carex* from this State in previously published papers, we now present a more general sketch of the genus, as represented in the Rocky Mountains of Colorado, including a synopsis of the species, some notes on those which are new or little known together with their geographical distribution. We have not, however, succeeded in getting together all the vast material that exists from this State, collected by various explorers during nearly half a century, but we have brought together as much as possible, including our own collections made during two summer excursions in these mountains, which may, perhaps, give an adequate idea of the representation of the genus in Colorado.

In cases where species have been described only preliminarily and rather incompletely we have inserted a diagnosis; besides that certain corrections have been made in regard to the structure of the flower, rhizome, etc.

The flora of Colorado is comparatively little known, and it is really surprising to see from the map how many and wide areas are still unexplored. Nevertheless many and large collections have been gathered from these mountains, and the results published in the shape of "lists" in various publications. We have thought, therefore, that any contribution to the knowledge of this most interesting flora might be of some use for future studies; besides that the notes upon the geographical distribution might be of interest from this point of view, demonstrating the existence of arctic and even circumpolar species on the higher peaks of these mountains. And the genus *Carex*, when compared with the other large genera which we have studied in Colorado, gives really an excellent idea of the character of the vegetation in these regions with representatives of northern and southern types, boreal and alpine, endemic and such as are common to the mountains of both worlds. We should not, however, have been in the position to offer such data in regard to the distribution or in regard to the habit of many species, if it were not for the exquisite collections presented to the writer through the kindness of Mr. James M. Macoun of Ottawa. No species can be properly understood unless studied from several stations, and as remote as possible. The Canadian *Carices* exhibit many characteristics, which are less pronounced in their southern representatives or, at least, their homologues, a fact that becomes only too evident when we remember the predominance of the genus in northern and colder regions. The study of *Carex atrata* L., for instance, offers an excellent example of the danger in considering specimens from a few stations: the species in Colorado embraces two types and the Canadian three, of which only the one, the typical *atrata*, is common to both regions; of these, *C. ovata* Rudge seems restricted to the northeastern corner of this continent. Nevertheless all four types have at various times been considered identical. Several instances of a similar nature might easily be enumerated, and it is, altogether, a most difficult task to segregate or combine species in a genus as large as *Carex*. The proposition of a few new species is the result of a careful study of allies and homologues, yet the species themselves are only of some interest as far as concerns their characteristics modified, but nevertheless referable to some allied type or types with which they may have developed.

It seems altogether as if the Rocky Mountains have been the center of development of a number of types, many of which are endemic, while others participated in the migration along with the arctic plants towards the North where they became distributed; some of these have even become circumpolar.* But besides these two elements of vegetation, that may be considered as having originated in the Rocky Mountains themselves, a third one and perhaps the most interesting is composed of arctic plants which having been forced southward during the glacial epoch, remained there, making their homes on the lofty mountain summits, where they are yet in existence. These northern and southern types are especially alpine or subalpine and may, at least to some extent, throw some light upon the great problem of the origin and distribution of the arctic flora.

A. *Synopsis of the Species.*

VIGNEÆ

Brachystachyæ Holm.

Carex canescens L. 39°–41° (Hall and Harbour, C. C. Parry); Trapper's Lake (C. S. Crandall); common in bogs near Bob Creek, La Plata Mts., alt. 10,500 ft. (Baker, Earle and Tracy); Marshall Pass, alt. 10,000 ft. (C. F. Baker).

C. tenella Schk. 39°–41° (Hall and Harbour, C. C. Parry); Bob Creek, La Plata Mts., alt. 10,500 ft. (Baker, Earle and Tracy); moist, shaded places in Spruce-woods on mts. near Pagosa Peak, alt. 9000 ft. (C. F. Baker); in swamp, Graymont (C. S. Crandall); common in swamps on Mt. Elbert, alt. 10,000 ft. and along Quail Creek near Steven's Mine, alt. 10,500 ft. (the author).

* Compare: A. G. Nathorst: Polarforskningens Bidrag til Forntidens Växtgeografi (in Nordenskiölds Studier och Forskningar. Stockholm, 1883.) See also: Same author in Engler's bot. Jahrb., 1891, p. 218, etc.

Neurochlœnæ Holm.

C. nardina Fr. Mt. Elbert, alt. 12,000 ft. (the author).

Argyranthæ Holm.

C. Deweyana Schw. 39°–41° (Hall and Harbour, C. C. Parry).

Astrostachyæ Holm.

C. gynocrates Wormskj. South Park (I. Wolfe).
C. stellulata Good. var. Wet Mountain Valley (T. S. Brandegee).

Acanthophoræ Holm.

C. occidentalis Bail. La Plata River, alt. 9,000 ft., and Mt. Hesperus, alt. 10,000 ft. (Baker, Earle and Tracy).
C. Hookeriana Dew. Hills about Trinidad (C. S. Crandall); dry meadows at Dix (Baker, Earle and Tracy); moist places, Los Pinos (C. F. Baker).
C. Hoodii Boott. Four mile Hill, Routt County (C. S. Crandall).

Xerochlœnæ Holm.

C. marcida Boott. Moist meadow, College farm and river-flats at Ft. Collins (C. S. Crandall) ; Durango, alt. 6,500 ft. (Baker, Earle and Tracy) ; abundant in moist meadows near Pagosa spring (C. F. Baker).
C. Sartwellii Dew. 39°–41° (Hall and Harbour, C. C. Parry); South Park (T. C. Porter).
C. Douglasii Boott. 39°–41° (Hall and Harbour, C. C. Parry) ; near Long's Peak (J. M. Coulter) ; river-flats at Ft. Collins and in swamps on the plains near Ft. Collins (C. S. Crandall); La Plata River, alt. 9,000 ft. (Baker, Earle and Tracy) ; Gunnison, common in meadows (C. F. Baker) ; in the Spruce-zone, headwaters of Clear Creek, alt. 10,000 ft. (the author).

Phænocarpæ Holm.

C. teretiuscula Good. Hamor's Lake (Baker, Earle and Tracy).

Cephalostachyæ Holm.

C. fœtida All. Little Kate Mine, alt. 11,500 ft. (Baker, Earle and Tracy).
C. stenophylla Wahl. 39°–41° (Hall and Harbour, C. C. Parry).

Athrostachyæ Holm.

C. athrostachya Olney. Mt. Massive, alt. 11,000 ft. (the author).
C. festiva Dew. 39°–41° (Hall and Harbour, C. C. Parry) ; Ute Pass (T. C. Porter); White House Mt. and Mt. Lincoln, alt. 12,000 ft. (J. M. Coulter); Pike's Peak (W. M. Canby); La Plata River, alt. 9,000 ft. (Baker, Earle and Tracy) ; Gunnison (C. F. Baker) ; Georgetown and Silverplume (P. A. Rydberg) ; not uncommon in the Aspen- and Spruce-zones from Silverplume to Steven's Mine, alt. 9,500–10,300 ft., and on Gray's Peak, alt. 13,000 ft. (the author).

C. festiva Dew. var. *Haydeniana* (Olney) W. Boott. Cameron Pass (C. S. Crandall); Marshall Pass, Gunnison Watershed, alt. 10,000 ft. (C. F. Baker); common on hillsides, mts. at Pagosa Peak, alt. 12,000 ft. (C. F. Baker); Silverplume (P. A. Rydberg); Mt. Kelso, alt. 12,000 ft., Thompson's Canyon on Long's Peak, alt. 10,500 ft., Mt. Massive, alt. 12,000 ft., Mt. Elbert, abundant in damp places, alt. 11,500 ft. (the author).

C. festiva Dew. var. *pachystachya* Bail. Bob Creek (Baker, Earle and Tracy); banks of streams, mts. near Pagosa Peak, alt. 9,500 ft. (C. F. Baker).

C. festiva Dew. var. *stricta* Bail. Walton Creek flats, Routt County (C. S. Crandall); common in meadows and along brooks, Georgetown and Silverplume (P. A. Rydberg).

C. festiva Dew. var. *decumbens* Holm. Mts. near Pagosa Peak, alt. 12,000 ft. (C. F. Baker); abundant on grassy slopes of Mt. Kelso near Steven's Mine, alt. 12,000 ft. (the author).

C. petasata Dew. 39°–41° (Hall and Harbour, C. C. Parry); Cameron Pass, at timber line (C. S. Crandall); La Plata River, alt. 10,000 ft. (Baker, Earle and Tracy); James Peak, alt. 13,000 ft., Mt. Massive, alt. 12,000 ft. and Mt. Kelso, alt. 12,000 ft. (the author).

C. pratensis Drej. Stove Basin, Laramie Co. (G. E. Osterhout); Howe's Gulch (C. S. Crandall); not uncommon on dry, grassy slopes near Long's Peak, alt. 8,600 ft. (the author).

C. siccata Dew. 39°–41° (Hall and Harbour, C. C. Parry); River-bank, Ft. Collins (C. S. Crandall); La Plata River, alt. 10,000 ft. (Baker, Earle and Tracy); Mt. Massive, alt. 11,000 ft., Mt. Kelso, alt. 12,000 ft. and on Lamb's Ranch near Long's Peak, alt. 8,600 ft. (the author).

C. Liddonii Boott. Campton's Ranch (C. S. Crandall).

C. Bonplandii Kunth var. *minor* Olney. 39°–41° (Hall and Harbour, C. C. Parry); near the snowbanks, headwaters of Clear Creek, alt. 12,000 ft. (the author).

Pterocarpæ Holm.

C. straminiformis Bail. West Mancos Canyon, alt. 9,500 ft. (Baker, Earle and Tracy).

Sphærostachyæ Holm.

C. incurva Lightf. Alpine ridge near Middle Park (C. C. Parry); Gray's Peak (Patterson); Silverplume (P. A. Rydberg).

Carices genuinæ

Melananthæ Drej.

C. alpina Sw. 39°–41° (Hall and Harbour, C. C. Parry); Headwaters of Beaver Creek, 50 miles south of Ft. Collins, alt. 10,000 ft. (C. S. Crandall); South Park (J. Wolfe); Upper La Plata River, alt. 10,000 ft. (Baker, Earle and Tracy); Idaho Springs (P. A. Rydberg); Georgetown (Patterson).

C. alpina Sw. var. *Stevenii* Holm. Not uncommon in the Aspen zone: Middle Park (Beardslee); Georgetown (P. A. Rydberg); Silverplume, alt. 9,500 ft.; swamps on Lamb's Ranch near Long's Peak, alt. 8,600 ft.; abundant in the Spruce zone: between Graymont and Steven's Mine, very seldom alpine: Gray's Peak, alt. 12,000 ft, associated with *Juncus triglumis* and *Carex misandra* (the author).

C. melanocephala Turcz. 39°–41° (Hall and Harbour, C. C. Parry); Upper La Plata, alt. 10,000 ft. (Baker, Earle and Tracy); Chamber's Lake (C. S. Crandall); Silverplume (P. A. Rydberg); mts. about Ouray (C. S. Crandall); very abundant in thickets of *Salix* on Mt. Elbert, alt. 11,500 ft.; on Mt. Kelso at 11,500 ft. and headwaters of Clear Creek, alt. 11,000 ft. (the author).

C. atrata L. 39°–41° (Hall and Harbour, C. C. Parry); Long's Peak, alt. 12,500 ft. and Gray's Peak, alt. 12,500 ft. (the author).

C. chalciolepis Holm. Little Kate Mine, La Plata Mts., alt. 11,000 ft. and Mt. Hesperus, alt. 11,500 ft. (Baker, Earle and Tracy); along brooks at Silverplume (P. A. Rydberg); Cameron Pass, timber line (C. S. Crandall); mts. near Pagosa Peak, on hillsides, alt. 12,000 ft. (C. F. Baker); James' Peak, alt. 13,000 ft., Mt. Massive, alt. 12,000 ft., Mt. Elbert, alt. 12,000 ft., Mt. Kelso, alt. 12,000 ft., Long's Peak, alt. 12,000 ft., Thompson's Canyon on Long's Peak, alt. 10,500 ft. and Gray's Peak, alt. 12,000 ft. (the author).

C. bella Bail. 39°–41° (Hall and Harbour, C. C. Parry); Mt. Hesperus, near Bob Creek and Upper La Plata, alt. 10,000 ft. (Baker, Earle and Tracy).

C. Parryana Dew. 39°–41° (Hall and Harbour, C. C. Parry); swamps at Twin Lakes, alt. 9,265 ft. (the author).

C. Buxbaumii Wahl. 39°–41° (Hall and Harbour, C. C. Parry).

Microrhynchæ Drej.

C. vulgaris Fr.; in moist ground, associated with *Platanthera* and *Pyrola* in the Aspen zone near Silverplume, alt. 9,500 ft. (the author).

C. rigida Good. near the snowbanks, headwaters of Clear Creek, alt. 11,500 ft. (the author).

C. scopulorum Holm. Marshall Pass, alt. 12,000 ft., abundant in wet places, covering extensive areas (C. F. Baker); mts. of Estes Park (G. E. Osterhout). Silverplume (P. A. Rydberg); abundant in swamps in the Spruce zone, Mt. Massive, alt. 11,000 ft., headwaters of Clear Creek, alt. 11,000 ft., common in swamps from Steven's Mine to Mt. Kelso and Gray's Peak, alt. 12,000 ft. (the author).

C. chimaphila Holm. Along brooks, associated with *Juncus biglumis*, *J. triglumis* and *J. castaneus* on Long's Peak, alt. 12,000 ft. (the author).

C. variabilis Bail. 39°–41° (Hall and Harbour, C. C. Parry); Twin Lakes (J. Wolfe); Leadville, Ute Pass (W. Trelease); wet places near Empire and along Clear Creek (Patterson); Cameron Pass (C. S. Crandall); Georgetown (P. A. Rydberg); swamps on Mt. Massive, alt. 11,000 ft., and Mt. Kelso (the author).

C. variabilis Bail. var. *sciaphila* Holm. Shaded places in the Spruce zone, Mt. Massive, alt. 11,000 ft. (the author).

C. acutina Bail. Silverplume and Georgetown (P. A. Rydberg); Graymont, in swamps on Lamb's Ranch, alt. 8,600 ft., and James' Peak, alt. 10,000 ft. (the author).

C. acutina Bail. var. *petrophila* Holm. On dry rocks near Graymont, alt. 9,500 ft. (the author).

C. Nebrascensis Dew. 39°–41° (Hall and Harbour, C. C. Parry); Oak Creek (T. S. Brandegee); Weston Pass and Twin Lakes (J. M. Coulter); Monument Park (T. C. Porter); swamp on the Plains near Ft. Collins and in ditch College Farm (C. S. Crandall).

C. rhomboidea Holm. Common in swamps on Lamb's Ranch near Long's Peak, alt. 8,600 ft., and Twin Lakes, alt. 9,265 ft. (the author).

Cenchrocarpæ Holm.

C. aurea Nutt. Mancos, alt. 7,000 ft. and West Mancos Canyon, alt. 9,000 ft. (Baker, Earle and Tracy); Los Pinos, in moist places, Piedra, along streamlets and near Gunnison (C. F. Baker); Mt. La Plata, alt. 11,000 ft. (J. M. Coulter); bank of Elk River, Routt County (C. S. Crandall); Clear Creek Canyon near Graymont, alt. 9,500 ft. (the author).

C. Torreyi Tuckm. On grassy slopes, in openings among *Pinus ponderosa* near Golden City (E. L. Greene).

Lejochlænæ Holm.

C. polytrichoides Muehl. 39°–41° (Hall and Harbour, C. C. Parry).

C. Geyerii Boott. 39°–41° (Hall and Harbour, C. C. Parry); Chamber's Lake (C. S. Crandall); Bob Creek, on dry ridges and meadows, alt. 10,500 ft. (Baker, Earle and Tracy).

Elynanthæ Holm.

C. filifolia Nutt. 39°–41° (Hall and Harbour, C. C. Parry); Ute Pass (T. C. Porter); Table Rock (G. F. Benninger); Silverplume (P. A. Rydberg).

C. elynoides Holm. On bare mountain tops near Pagosa Peak, alt. 12,000 ft. (C. F. Baker); Mt. Massive, alt. 12,000 ft., and Mt. Kelso, alt. 12,000 ft. (the author).

Lamprochlænæ Drej.

C. rupestris All. 39°–41° (Hall and Harbour, C. C. Parry); Gray's Peak (Patterson); Cumberland Mine, alt. 12,300 ft. (Baker, Earle and Tracy); very scarce on dry slopes of James' Peak, alt. 13,000 ft., Mt. Elbert, alt. 12,000 ft., Long's Peak, alt. 12,000 ft., and Gray's Peak, alt. 12,500 ft. (the author).

C. obtusata Liljebl. 39°–41° (Hall and Harbour, C. C. Parry); Georgetown (Patterson); South Park (J. Wolfe); Chicken Creek, alt. 9,500 ft. (Baker, Earle and Tracy); common in dry, sandy soil near Long's Peak, alt. 8,600 ft. (the author).

Athrochlænæ Holm.

C. nigricans C. A. Mey. 39°–41° (Hall and Harbour, C. C. Parry); Black Lake in Thompson's Canyon on Long's Peak, alt. 10,300 ft. and common along brooks, headwaters of Clear Creek, alt. 11,000 ft. (the author).

C. pyrenaica Wahl. 39°–41° (Hall and Harbour, C. C. Parry); mountains west of Cameron Pass (C. S. Crandall); mountains near Pagosa Peak, alt. 12,000 ft. (C. F. Baker); Long's Peak, alt. 12,000 ft., on dry rocks, and Gray's Peak, alt. 13,000 ft. (the author).

Stenocarpæ Holm.

C. misandra R. Br. Along brooks on Gray's Peak, alt. 12,000 ft. (Patterson and the author).

Sphæridiophoræ Drej.

C. scirpoidea Michx. 39°–41° (Hall and Harbour, C. C. Parry); South Park (T. C. Porter).

C. oreocharis Holm. Common near Golden City (E. L. Greene); on dry rocks in the Aspen zone at Lamb's Ranch near Long's Peak, alt. 8,600 ft. (the author).

C. Pennsylvanica Lam. Trail Creek and Riot Canyon (C. S. Crandall); Ute Pass (T. C. Porter); mountains near Central City, alt. 8,500 ft. (the author).

C. Rossii Boott. 39°–41° (Hall and Harbour, C. C. Parry); headwaters of Beaver Creek, 50 miles W. of Ft. Collins and Chamber's Lake (C. S. Crandall); common on moist mountain slopes, Silverplume (P. A. Rydberg and C. L. Shear); Little Kate Mine, alt. 11,500 ft. (Baker, Earle and Tracy); in the Spruce zone on mountains near Pagosa Peak, alt. 11,500 ft. (C. F. Baker); under Spruce on Mt. Massive, alt. 11,000 ft. and headwaters of Clear Creek, alt. 11,000 ft. (the author).

C. umbellata Schk. var. *brevirostris* Boott. Near Golden City (E. L. Greene).

Spirostachyæ Drej.

C. viridula Michx. Hamor's Lake (Baker, Earle and Tracy).

Trichocarpæ Holm.

C. lanuginosa Michx. South Park (W. M. Canby); Ute Pass (T. C. Porter); Canyon City (T. S. Brandegee); Campton's Ranch (C. S. Crandall); Durango, alt. 6,500 ft. (Baker, Earle and Tracy); Pagosa spring and wet places, Gunnison (C. F. Baker); along creeks in Estes Park (the author).

C. aristata R. Br. River-bank near Ft. Collins, alt. 5,000 ft. (C. S. Crandall).

Hymenochlænæ Drej.

C. capillaris L. 39°–41° (Hall and Harbour, C. C. Parry); Devil's Causeway (C. S. Crandall); West Mancos Canyon (Baker, Earle and Tracy); Bear Lake in Thompson's Canyon on Long's Peak, alt. 10,700 ft., in swamps at Twin Lakes, alt. 9,265 ft., and at a spring in the Aspen zone near Silverplume, alt. 10,000 ft. (the author).
C. Backii Boott. 39°–41° (Hall and Harbour, C. C. Parry).
C. longirostris Torr. var. *minor* Boott. 39°–41° (Hall and Harbour, C. C. Parry).

Echinostachyæ Drej.

C. microglochin Wahl. 39°–41° (Hall and Harbour).

Physocarpæ Drej.

C. Engelmannii Bail. Upper Clear Creek region, alt. 12,000 ft. (G. Engelmann); high mountains near Silverplume (P. A. Rydberg).
C. utriculata Boott var. *minor* Boott. 39°–41° (Hall and Harbour, C. C. Parry); Middle Park and Trapper's Lake (C. S. Crandall); Bob Creek, alt. 10,000 ft. (Baker, Earle and Tracy); mountains near Pagosa Peak, alt. 10,000 ft. and common in wet bottom, Gunnison (C. F. Baker).
C. pulla Good. Deep Creek Lake (C. S. Crandall).
C. monile Tuckm. Hamor's Lake, alt. 9,000 ft. (Baker, Earle and Tracy).
C. rostrata Stokes. Hamor's Lake, alt. 9,000 ft. (Baker, Earle and Tracy).

Rhynchophoræ Holm.

C. lupulina Muehl. Durango, alt. 6,500 ft. (Baker, Earle and Tracy).

B. *Notes on new or little known species from Colorado.*

Carex nardina Fr.

The plant which we collected upon Mt. Elbert shows a peculiar deviation from the type by being tristigmatic, besides that the utricle is very prominently slit on the outer or convex face. We have not, however, felt justified in regarding this as a distinct species, inasmuch as the number of stigmas is not a constant character within the genus *Carex*, even if the species in question be one of the *Vigneæ*. It is, also, to be pointed out that we were unable to detect any divergence whatsoever in the anatomical structure of the vegetative organs which we compared with those of typical individuals from Greenland, Norway, Alaska and British Columbia. Similar specimens with three stigmata were also observed in the copious material presented to the writer through the kindness of Mr. James M. Macoun, which was collected "on mountain summits, alt. 7,400 ft., at the headwaters of Fraser River in British Columbia."

Carex occidentalis Bailey.

Rhizome short, creeping, forming dense mats, with persisting, dark-brown sheaths; leaves glaucous, shorter than the culm, narrow, but flat, scabrous along the margins; culms numerous, from 20 to 60^{cm} in height, slender, triangular, scabrous, phyllopodic; spikes 3 to 8, androgynous, small and few-flowered, roundish, sessile, contiguous or the lower ones remote, the bracts scale-like or filiform, but much shorter than the inflorescence; scales ovate, acuminate and often mucronate, reddish-brown with green midrib and broad, hyaline margins, about as long as the utricles; utricle shortly stipitate, spreading at maturity, elliptical, plano-convex, wingless, spongious at the base, two-ribbed (the marginal), light brown, scabrous along the upper margins and along the short, but distinct, bidentate beak; stigmata 2.

Carex festiva Dew.

Certain points regarding the supposed identity of our plant with *C. Macloviana* d'Urv. make it necessary to reproduce some of the diagnoses already published. Dewey, the author of the species, described the utricle as follows: "fructibus ovatis oblongis rostratis in apice serrulatis bifidis convexo-planis, squama ovata acutiuscula longioribus," and his specimens came from Bear Lake and the Rocky Mountains. This description was by Boott,* somewhat modified, "perigyniis ovato-ellipticis attenuato-rostratis, ore albo-hyalino oblique antice secto demum bidentato, utrinque leviter nervatis"; thus the beak of the utricle at first described as bifid, became by Boott corrected to "obliquely slit on the dorsal face, finally bidentate." The Scandinavian plant is, in accordance with Hartman,† described as possessing a membranaceous, bidentate beak, and the figure given by Andersson‡ shows a similar, bidentate apex of the utricle. Blytt§ attributes a "membranaceously-lobed, truncate beak" to the utricle; thus it seems as if the North American and Scandinavian plants exhibit the same structure in this particular respect, i. e. the beak of the utricle. The Greenland plant of *C. festiva* is by Drejer ‖ described as follows: "perigyniis ovato-ellipticis plano-convexis nervosis mar-

* Ill. genus Carex, vol. i, p. 26.
† Skandinaviens Flora 1879, p. 475.
‡ Skandinaviens Cyperaceer 1849, fig. 27.
§ Norges Flora, vol. i, p. 197, 1861.
‖ Revisio crit. Caric. bor., p. 23, 1841.

gine serrulatis rostratis ore hyalino-lobato abscisso." However, in a subsequent paragraph (l. c., p. 24) Drejer calls attention to the fact, that "in *C. festiva* et affinibus os rostri quidem bidentatum est, sed dentes membrana hyalina diaphana conjunguntur, quæ stylo adhuc restante obscuratur ita ut os integrum videatur; stylo autem remoto membrana diaphana facile prætervidetur, quo fit, ut dentes, qui liberi vere non sunt, mere distincti et acutati videantur." Hence that the beak is really not bidentate, but entire on the ventral face by the presence of a transparent membrane. This very structure of the beak being only "apparently bidentate" we have noticed in all the specimens we have examined from Greenland, Scandinavia, Alaska, Vancouver Island and Rocky Mountains from Colorado northward through Canada, and we see no reason for separating these plants from one another. Nevertheless, a recent author, Rev. G. Kükenthal, has reached the conclusion that the Greenland and Scandinavian plants are distinct from the North-American *C. festiva* Dew, but identical with the South-American *C. Macloviana* d'Urv. We have seen no specimen of the latter, which the author, Rev. G. Kükenthal, has described as possessing a "rostrum profunde bidentatum," but this character surely does not apply to the European or Greenland specimens. Mr. C. B. Clarke of Kew has, however, informed us that he prefers to place them all, the South and North-American and European representatives, under *C. Macloviana*, which is an older name than *C. festiva*.

Olney described *Carex Haydeniana** as distinct from *C. festiva* by the long beak of the utricle, a character which is very striking, but hardly sufficient for separating the plant as a species, unless additional characters be observed.

We have proposed a new variety "*decumbens*" which is especially characteristic by the decumbent habit of the plant, somewhat suggestive of *Carex incurva*, besides that the utricle is much larger than in typical specimens of *C. festiva*. This variety *decumbens* has only been observed in the alpine region.

Carex straminiformis Bailey.

Rhizome loosely cæspitose with light brown, persisting sheaths; leaves relatively broad, flat, scabrous along the margins, shorter than the culm; culm erect, from 25 to 37^{cm} in height, quite stout, trigonous, nearly glabrous, leafy at the base, phyllopodic; spikes 3 to 4, gynæcandrous, dense flowered, ovoid, sessile, contiguous, forming a compact head about 2^{cm} in length and $1{\cdot}5^{cm}$ in width; scales oblong, acute, light brown with green midrib (of 3 veins) and broad, hyaline margins,

* Clarence King: Report Geol. Explor. 40th Paral. 1871, p. 366.

much narrower and shorter than the utricle; utricle almost sessile, erect, compressed, broadly ovate with very conspicuous, denticulate wings and 4 nerves, of which the marginal ones are very prominent on the ventral face, light green, tapering into a rather long, bidentate, scabrous beak; stigmata 2.

Carex alpina Sw. var. *Stevenii* Holm.

This differs from the type especially by its narrower spikes, which are less contiguous and often somewhat remote and peduncled; the utricle is at maturity dark, reddish brown with an emarginate beak, scabrous along the margins and early deciduous; the scales are brownish to almost black, with narrow, hyaline margins; in specimens from dry rocks the culms are seldom more than from 6–12^{cm} in height, but in specimens from swamps the culms attain a height of 55^{cm} and are much more slender than in the type.

Carex melanocephala Turcz.

C. nigra Olney Exsicc., fasc. 5, 24, 1871.
C. atrata L. var. *nigra* Am. auth.
C. nova Bailey.*

Turczaninow described this species in his work Flora Baicalensi-Dahurica with the following diagnosis: "Spicis 3 dense congestis sessilibus, adjecta rarius quarta subremota breviterque pedunculata, terminali androgyna basi mascula, reliquis fœmineis, utriculis glabris ellipticis dorso convexis subtrigonis, rostro longiusculo bidentato terminatis; radice stolonifera. In alpibus Baicalensibus Urgudei, Schibet, ad fl. Tessa et cæt. Floret Junio, Julio." Boott has, also, described *C. melanocephala*, but as a variety "*parviflora*" of *C. alpina:* "perigyniis majoribus ellipticis, bifidis, enerviis, fusco-purpureis, basi pallidis, squama ovata fusco-purpurea nervo concolori rarius extra apicem producto longioribus." The species has for many years been collected in this country, but has been confounded with *C. nigra* All. and with *C. alpina* Sw., while Professor Bailey segregated it as an independent species *C. nova*. The diagnosis of *C. nova* is, however, very incomplete, and since we have had the opportunity of studying an abundance of specimens at various elevations, we have thought it worth while to append a diagnosis of this interesting species, which Mr. C. B. Clarke has kindly identified for us as identical with Turczaninow's *C. melanocephala:* Rhizome loosely cæspitose with ascending shoots, the leaf-sheaths persisting, reddish brown; leaves shorter than the culm, relatively narrow, but flat, scabrous along the margins and lower face, the ligule

*Jour. Botany London, 1888, vol. 26, p. 322 and Mem. Torr. Bot. Club, vol. 1, 1889, p. 10.

very distinct; culm erect, stout, triangular, scabrous especially above, from 9 to 68^{cm} in height (the smallest specimens having been collected on Long's Peak, Mt. Elbert and Gray's Peak at 12,000 ft. alt.), leafy at the base, phyllopodic; spikes 2 to 4, but mostly 3, roundish and sessile, forming a dense, oval or roundish head, very seldom the lowest remote; the bracts very short, scale-like or the lowest one extended into a short bristle, much shorter than the spike; the terminal spike gynæcandrous, the lateral purely pistillate; scales ovate, acute to acuminate, dark purple with pale midrib, shorter than the utricle; utricle sessile, plano-convex, varying from broadly elliptical to roundish, granulated, glabrous or minutely denticulate along the upper margins, two-nerved (the marginal), spreading at maturity, yellowish and purplish spotted to almost black when mature, terminated by a beak of variable length, emarginate to bidentate; stigmata 3, seldom 2.

In high alpine specimens the utricle becomes wholly glabrous and the beak longer, and it was in such plants that the number of stigmata was observed to be, sometimes, only two.

Carex chalciolepis sp. n. (figs. 1–5).

Rhizome cæspitose, the leaf-sheaths persisting, purplish or brown; leaves shorter than the culm, relatively narrow, but flat, erect, scabrous along the margins; culm slender and weak, often reclining, triangular, scabrous or nearly glabrous, leafy at the base, from 17 to 75^{cm} in height, (the tallest being those from Pagosa Peak), phyllopodic; spikes 3 to 4, dense-flowered and thick, from 1 to $1{\cdot}5^{cm}$ in length and 1^{cm} in thickness, shining brown, "copper-colored," contiguous, sessile or the lowest very shortly peduncled and subtended by a short, filiform bract, the other bracts merely scale-like; an empty, sheathing and foliaceous bract is nearly always observable in some distance, varying from 2 to 6^{cm} below the inflorescence; scales of staminate flowers varying from lanceolate and acute (fig. 1) to elliptical; scales of pistillate flowers ovate and acuminate (fig. 2) or elliptical oblong to lanceolate (fig. 4), narrower, but longer than the utricle, dark purplish or reddish brown with the apex and margins more or less hyaline, but with the midrib seldom visible; utricle sessile, erect, ovoid (fig. 3) or almost orbicular (fig. 5), slightly plano-convex, granulated, two-nerved (the marginal), minutely scabrous along the upper margins, yellowish green with purplish spots or uniformly dark-colored, terminated by a short, emarginate to bidentate beak; stigmata 3.

The accompanying figures illustrate the scales and utricles of *C. chalciolepis* from Pagosa Peak (figs. 1–3), and Mt. Kelso (figs. 4–5), while fig. 6 represents the utricle with the scale of

Fig. 1. *Carex chalciolepis* from Pagosa Peak, scale of staminate spike; fig. 2, scale of pistillate spike; fig. 3, utricle; fig. 4, scale of pistillate spike, and fig. 5, utricle of the same species from Mt. Kelso. Figs. 6 and 7, utricle and scale of *C. atrata* from Long's Peak and Norway. Fig. 8, *C. rhomboidea* natural size; figs. 9 and 10, scale and utricle of same.

C. atrata L. from Long's Peak, and fig. 7 the utricle and scale of *C. atrata* from Norway.

Having proposed *C. chalciolepis* as a species distinct from *Carex atrata* L., and having studied a large collection of representatives of the latter and its nearest allies in North America, we feel induced to present some data concerning their characteristics.

As indicated in the synopsis of the species, *C. atrata*, the typical plant, occurs on some of the high mountains of Colorado, but seems, however, to be rare. In speaking of the "typical plant" we might state at once, that this is very seldom recognized in this country, and is excluded altogether in Professor Macoun's Catalogue of Canadian plants, where the variety "*ovata*" (Rudge) Boott is the only one that is enumerated as occurring between the Atlantic coast and the Rocky Mountains. A like disposal is suggested in Gray's Manual (1890), where the variety *ovata* is credited to the White Mountains, New Hampshire, Vermont and northward, with no mention of the typical plant. It is very likely that Rudge's *C. ovata* is the predominant form in the northeastern parts of this continent, but it is not the only one in the north, since the type has been collected in southern Greenland, on mountains at "Kicking Horse Lake" and on "Sheep Mountain" in the British provinces, besides in Wyoming, Montana and Utah.—Linnæus is the author of *C. atrata*, and he described it from Lapland specimens, the diagnosis, brief as it may seem, being nevertheless sufficient for distinguishing the species from the others in his Flora Lapponica: "*Carex* spicis ad apicem culmi pendulis androgynis"; by "androgynis" is naturally meant "gynæcandrous," since the spikes bear the pistillate flowers at the apex, the staminate ones at the base. But, strange to say, very few authors have since described the species in the same way "spicis androgynis," while they have referred the androgynous character only to the terminal spike, and this deviation from the original diagnosis is noticeable in the works of Wahlenberg, Andersson, Blytt, Hartman, Treviranus and Koch; on the other hand, Lightfoot, Schkuhr, Kunth, Gaudin and Boott have described the species in accordance with Linnæus as possessing "several gynæcandrous spikes." Otherwise the European authors seem to agree in respect to the general characterization of the species, the shape of the spikes, the scales, utricle, etc., and we might point out some of these characteristics for further comparison with its European and American allies. The spikes are mostly all gynæcandrous, and the terminal is oval, the lateral more or less oblong; they are borne on rather stout peduncles, which are almost glabrous; the scales are ovate, acute to obtuse, blackish-brown with very narrow, hyaline margins, and a little shorter than the utricle; this organ is ovate, compressed trigonous, granulated, two-nerved (the marginal), and abruptly terminated by a short, emarginate to bidentate beak; the color of the utricle is light green, but changes often to brownish and purple-spotted at maturity. A variety "*spadicea*," with the scales and utricles grayish-brown, is described by Beurling from the mountains of Norway.*

Among the nearest allies of *C. atrata* in Europe may be mentioned *C. nigra* All. and *C. aterrima* Hppe., both of which seem confined to the Pyrenees, the "Alps" of Switzerland and Austria. In the former of these the spikes are nearly sessile and ovate, the utricle is reddish-brown, when young, becoming dark purplish at maturity, and is prominently scabrous along the upper margins; while in *C. atrata* the granulation is only represented by roundish projections; *C. aterrima*, which looks more like *C. atrata*, is quite robust, with the spikes oblong—cylindrical, peduncled, and the utricle is merely granulated, but purplish-black with greenish base and margins. Of these the former is by most authors considered distinct from *C. atrata*, while *C. aterrima* is frequently enumerated as a mere variety of this from higher elevations and with a later time of flowering. But even if *C. aterrima* be a good species, *C. atrata* does, nevertheless, occur in Europe, with narrow, cylindrical spikes of variable color, from almost black to reddish-brown. This variation in color and shape of spikes may sometimes be so pronounced that the European *atrata* seems to pass over into the American *C. ovata* Rudge.

As already stated, typical *C. atrata* occurs in this country, but judging from the collections which we have studied, it does not seem to be as frequent as the so-called *C. ovata* Rudge. The principal characteristics of this plant are in accordance with Rudge, the gynæcandrous spikes being ovate and pendulous, the ovate, acute scales of a fuscous color. A number of Canadian specimens demonstrate a habit somewhat different from that of *C. atrata vera*, not only by the larger and narrower spikes of a dark, reddish color, but also by the long peduncles, which are very slender and prominently scabrous. *C. ovata* is altogether a much more graceful plant than *C. atrata*, and may, perhaps, represent a species distinct from *C. atrata*. But *C. ovata*, *C. nigra* and *C. aterrima* were with Boott only varieties of *C. atrata* L.

In comparing these plants with our *C. chalciolepis* it is readily seen that this is at once distinguished by its dense, cæspitose growth, the very slender, glabrous culms, which are more or less reclining, and by its usually sessile, contiguous,

* Caricum Scandinaviæ conspectus. (Bot. Notiser 1853, p. 36.)

Fig. 11, *Carex chimaphila*, natural size; figs. 12 and 13, utricle and scale of same. Fig. 14, *C. acutina* var. *petrophila*, natural size.

dense-flowered spikes with shining, copper-colored scales and utricles. The larger size of the scales in proportion to the utricles is very characteristic. It is a plant not easily confounded with typical *C. atrata* or *ovata*, and we do not feel inclined to merge it with the others as a mere form or variety of *C. atrata*.

Besides *C. ovata* and *chalciolepis* there is still a third plant in the Rocky Mountains, which also exhibits a close affinity to *C. atrata*, the so-called *C. bella* Bailey. This plant possesses much narrower spikes than any of the preceding; the peduncles, especially of the lower spikes, are very long and slender, prominently scabrous, and the scales are dark purplish with broad, light green midrib and very broad, hyaline margins, and are a little shorter than the membranaceous, somewhat inflated, pale green utricle, of which the two marginal nerves are quite thick and conspicuous. In this species the utricle exhibits only a minute granulation and lacks the scabrous margins, a structure which in many respects is suggestive of that of *C. Mertensii* Prescott. We have, thus, before us another type of the *Carex atrata* alliance which shows transition to one of the most evolute forms of the *Melananthæ: C. Mertensii*, and it appears as if the typical *C. atrata* may be considered as constituting the fundamental species of a series of types, some characteristic of Europe alone: *C. nigra* and *aterrima*, and others of this continent: *C. ovata*, *chalciolepis*, *bella* and *Mertensii*.

Carex Parryana Dew.

The distribution of the sexes seems very variable in this species and we have observed diœcism in several individuals. The terminal spike is very often gynæcandrous, while the lateral, when such are developed, are purely pistillate; in monostachyous specimens the spike is mostly gynæcandrous or in a few cases pistillate only. Mono- and di-stachyous culms frequently occur on the same individual.

Carex chimaphila sp. n. (figs. 11–13).

Rhizome loosely cæspitose with short, ascending stolons, the leaf-sheaths persisting, purplish or dark brown; leaves relatively broad, flat, a little scabrous along the margins, shorter than the culm; culm erect, slender, triangular, scabrous, from 12 to 30^{cm} in height, phyllopodic; spikes 3 to 4, mostly 3, contiguous or the lowest one remote, subtended by black, scale-like bracts without sheaths, the lowest sometimes with a blade, shorter than the inflorescence; terminal spike staminate, short and clavate, peduncled, the scales spatulate, brown to almost black with pale midrib; lateral spikes pistillate, from 1 to $1{\cdot}5^{cm}$

in length, dense-flowered, all, especially the lowest, peduncled, erect; scales (fig. 12) lanceolate, acuminate, spreading, blackish purple with hyaline apex and very short and inconspicuous midrib, the scale narrower, but longer than the utricle; utricle (fig. 13) sessile or minutely stipitate, spreading, roundish, compressed, granulated, two-nerved, sparingly scabrous along the upper margins, dark green with purplish spots especially above, terminated by a short, entire or subemarginate beak; stigmata 2; style exserted, but short.

This species, to a certain extent, has the aspect of some members of the *Aeorastachyæ*, *C. cryptocarpa* for instance, but seems, nevertheless, to be more naturally allied to the *Microrhynchæ*, and its place may be defined as near *C. hyperborea* Drej., but diverging from this by the long and spreading scales.

Carex variabilis Bailey.

Rhizome stoloniferous with persisting, light-brown to purplish sheaths; leaves flat, relatively broad; scabrous along the margins, as long as the culm or longer; culm erect, stiff, triangular, scabrous especially below the inflorescence, from 10 to 45^{cm} in height, phyllopodic; spikes from 3 to 6, contiguous or the lowest one remote, the terminal and uppermost lateral ones staminate, the others pistillate or, sometimes, androgynous, erect, sessile or the lowest peduncled; a pistillate spike is often developed from the axil of one of the basal leaves, borne on a very slender peduncle to the length of 12^{cm} in length; bracts of the inflorescence leaf-like about as long as the inflorescence or the uppermost ones shorter, but without sheaths; staminate spike broadly linear; the pistillate, cylindrical, obtuse, dense-flowered except towards the base (from 2 to 5·5^{cm} in length); scale of staminate flower spatulate oblong and obtuse, light purplish with hyaline apex and midrib; scale of pistillate flower ovate to elliptical, acute, dark purplish to almost black with green, not excurrent midrib, shorter and narrower than the utricle; utricle sessile, light green, granulated, two-nerved (the marginal), obovate to broadly elliptical, compressed, terminated by a short, entire, purplish or green beak; stigmata 2.

var. *sciaphila* nob.

Culms from 25 to 42^{cm} in height, very slender and reclining; spikes very short and mostly remote, otherwise as the type.

Carex acutina Bailey.

Rhizome cæspitose with persisting, purplish or brownish sheaths; leaves quite broad and flát, scabrous along the margins, as long as the culms or longer; culm erect, stiff, triangular, scabrous, from 50 to 75cm in height, phyllopodic; spikes 4 to 6, contiguous or the lowest one remote, erect or sometimes spreading, the upper ones sessile, the lower ones short-peduncled; the terminal and uppermost lateral spikes staminate, the others pistillate or androgynous, subtended by sheathless foliaceous bracts, of which the lowest exceeds the inflorescence, the others being shorter; staminate spike linear, the scales oblong-lanceolate, reddish-brown with pale, not excurrent midrib; pistillate spike from 3 to 4cm in length, quite thick, cylindrical, obtuse, the scales ovate-lanceolate and acuminate, dark brown to almost black with the midrib obsolete, longer, but narrower than the utricle; utricle stipitate, oval to elliptical, compressed, granulated light green, two-nerved, the beak short, entire, purplish around the orifice; stigmata 2.

var. *petrophila* nob. (fig. 14).

Culms very low, from 7 to 15cm in height; spikes until 6cm in length, very narrow, but dense-flowered, attenuated at the base, contiguous, the lower ones often very long-peduncled; utricle stipitate, almost roundish in outline with a short, entire beak.

Carex rhomboidea sp. n. (fig. 8–10).

Rhizome loosely cæspitose, the sheaths persisting, light purplish; leaves rather narrow, but flat, scabrous along the margins, a little shorter that the culm; culm 30 to 40cm in height, erect, slender, triangular, scabrous, phyllopodic; spikes 3 to 5, the terminal and, sometimes, the uppermost lateral staminate, the others pistillate, or the uppermost lateral androgynous, erect, sessile or the lowest one short-peduncled, mostly contiguous, subtended by foliaceous, sheathless bracts with blades as long as the inflorescence or shorter; staminate spike linear, the scales spatulate oblong, obtuse, light reddish-brown with pale midrib and hyaline margins; pistillate spikes very dense-flowered, cylindrical, attenuated at the base, from 1·5 to 4cm in length, the scales (fig. 9) dark purplish with white, broad midrib, oblong, obtuse, narrower, but longer than the utricle; utricle sessile, elliptical, rhomboid (fig. 10) granulated, light green, two-nerved, compressed, entirely beakless; stigmata 2.

Carex variabilis, *C. acutina* and *C. rhomboidea* constitute a small group of *Microrhynchæ* of which the two first show some approach to the old world types of the *aquatilis* group, though very distinct from this; *C. rhomboidea* stands somewhat isolated among the other *Microrhynchæ*, but belongs undoubtedly to this section, and perhaps to the group, the center of which is Boott's *C. angustata*.

Carex Rossii Boott.

It is strange to see how often vegetative characters are overlooked by systematic writers. The structure of the rhizome for instance is very seldom studied, and by looking at the plant descriptions in the last edition of Gray's manual, in the Synoptical Flora and other more recently published works, it is too evident that this part of the plant might have been considered and studied much more carefully. Even in such inconspicuous and uniform looking plants as our *Carices* does the structure of the rhizome, of the leaves and the culms afford good characters for distinguishing closely allied species, and sometimes easier than the structure of the utricle, or the scales. And the fact that the vegetative characters have been left out altogether in descriptive works upon *Carex* has resulted in mistakes, that could easily have been avoided.

One writer* has for instance stated that the European *Carex pilulifera* is identical with the North American *C. communis* (*C. varia* of many authors), by presenting an elaborate table of measurements of spikes, of the distance between these, of the length of the utricle, of the beak, etc., etc., but overlooking the fact that *C. pilulifera* is phyllo-, *C. communis* aphyllo-podic, not speaking of the extremely different habit possessed by these species, when studied "in the field." A similar disposal has been made† of Horneman's *C. deflexa* and Boott's *C. Rossii*, in this way that *C. deflexa* is enumerated as the type of a species with four varieties, *Deanei*, *media*, *Rossii* and *Boottii*. Of these *C. Rossii* is the only one which occurs in Colorado, and a study of this plant has led us to the belief that it is specifically distinct from the Greenland *C. deflexa*, as Boott himself considered it to be. The latter species we have had the opportunity to observe in a living state in Greenland, and it never appeared to us, when we found the former, *C. Rossii*, in Colorado, that they should represent the same species. There is, among other characters, exactly the same and very conspicuous distinction noticeable in *C. Rossii*, when compared with *C. deflexa*, as we have described above between *C. pilulifera* and *C. communis*: *C. Rossii* is aphyllo-, *C. deflexa* phyllo-podic.

To fully emphasize the importance of this character, it is, of course, necessary to study a number of specimens collected at different seasons, and to compare the different shoots, floral and vegetative, and their leaves. But besides this distinction derived from the shoots, the structure of the rhizome itself deserves, also, some attention. Thus is the rhizome of *C.*

* M. L. Fernald in Contrib. Gray Herb., vol. xxii, p. 503, 1902.
† L. H. Bailey in Mem. Torrey Bot. Club., vol. i, p. 43, 1889.

deflexa very slender, horizontally creeping and stoloniferous, but producing a number of shoots every year as if it were really cæspitose; each shoot develops only leaves during the first year, succeeded by a terminal, flower-bearing culm the year following. In *C. Rossii* there is, also, a number of shoots from each rhizome, but the shoots are either purely floral or vegetative; moreover the rhizome is much more robust, relatively shorter and ascending, not horizontal, and not stoloniferous in the stricter sense of the word. In considering the other parts of the plants, we might mention that the utricle in *C. deflexa* is very shortly beaked, and the beak bifid, while this organ in *C. Rossii* is extended into a very prominent, bidentate beak; the diagnosis as reproduced (l. c.) is, altogether, not very correct.

C. The Geographical Distribution of the Carices of Colorado.

In the accompanying table the species which are marked by an asterisk prefixed are exclusively confined to the bare exposures above the timber-line and are, thus, truly alpine; they number fifteen, and to these may be added the variety *decumbens* of *C. festiva.* Several of the others are, also, to some extent alpine, but have occasionally been observed below the timber-line on some of the mountains; among these, are, for instance: *C. melanocephala*, *C. scopulorum* and *C. capillaris.* Of these the two former are most abundant just at timber-line, while *C. capillaris* is more frequent at lower elevations, where it reaches a more luxuriant growth than higher upward.

Besides this distribution shown in the table given below, the following species have been reported from

China: *C. stellulata, stenophylla, incurva, atrata, vulgaris, rigida, rupestris* and *microglochin.*
Japan: *C. canescens, siccata, Buxbaumii, vulgaris* and *pyrenaica.*
South America: *C. canescens* (Argentina–Tierra del Fuego), *marcida* (Patagonia), *festiva* (Argent.–T. del. Fuego), *incurva* (Peru–T. del. Fuego) and *vulgaris* (Chile).
Sandwich Islands: *C. festiva.*
New Zealand: *C. stellulata, teretiuscula, vulgaris* and *pyrenaica.*
Spitzbergen: *C. incurva, nardina, misandra, rupestris* and *pulla.*

And if we examine the highest altitude reached by some of these arctic-alpine species in the Himalayan Mountains, the following may be recorded: *C. microglochin* from 11,000 to 15,000 ft., *canescens* until 12,000 ft., *rigida* 13,000 ft., *alpina* 15,000 ft., *incurva* 15,500 ft. and *atrata* 17,000 ft.

Species of *Carex* in Colorado.	North America.					Europe.				Asia.				
	Rocky Mts. of Canada.	Coast of Alaska.	Arctic region.	Atlantic slope.	Greenland.	North Europe.	Alps and Pyrenees.	Ural.	Caucasus.	Arctic Siberia.	Altai Mts.	Bajkal Mts.	Himalaya.	Kamtschatka and Sachalin.
canescens	+	+	+	+	+	+	+	+	+	+	+	+	+	+
tenella	+	--	--	+	--	+	--	--	--	--	--	--	--	+
**nardina*	+	+	+	--	+	+	--	--	--	--	--	--	--	--
Deweyana	+	--	--	+	--	--	--	--	--	--	--	--	--	--
gynocrates	+	+	+	+	+	?	--	--	--	--	--	--	--	+
stellulata	+	+	--	+	--	+	+	+	+	--	+	--	--	--
occidentalis	-	--	--	--	--	--	--	--	--	--	--	--	--	--
Hookeriana	+	--	--	--	--	--	--	--	--	--	--	--	--	--
Hoodii	+	--	--	--	--	--	--	--	--	--	--	--	--	+
marcida	+	--	--	--	--	--	--	--	--	--	--		--	--
Sartwellii	+	--	--	+	--	--	--	--	--	--	--	--	--	--
Douglasii	+	--	--	--	--	--	--	--	--	--	--	--	--	--
teretiuscula	+	--	--	+	--	+	+	--	--	--	--	--	+	--
fœtida	--	--	--	--	--	--	+	--	--	--	--	--	--	--
stenophylla	+	--	--	--	--	--	+	--	+	--	+	+	+	--
athrostachya	+	--	--	--	--	--	--	--	--	--	--	--	--	--
festiva	+	+	+	--	+	+	--	--	--	--	--	--	--	+
**petasata*	+	+	--	--	--	--	--	--	--	--	--	--	--	--
pratensis	+	--	--	+	+	--	--	--	--	--	--	--	--	--
siccata	+	--	--	+	--	--	--	--	--	--	--	+	--	+
Liddonii	+	--	--	--	--	--	--	--	--	--	--	--	--	--
**Bonplandii*	+	--	--	--	--	--	--	--	--	--	--	--	--	--
straminiformis	--	--	--	--	--	--	--	--	--	--	--	--	--	--
**incurva*	+	+	+	--	+	+	+	--	+	+	--	--	+	--
alpina	+	+	+	--	+	+	+	+	--	--	+	+	+	--
melanocephala	--	--	--	--	--	--	--	--	+	--	+	+	--	--
**atrata*	+	--	--	--	+	+	+	+	+	--	+	+	+	--
**chalciolepis*	--	--	--	--	--	--	--	--	--	--	--	--	--	--
bella	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Parryana	+	--	--	--	--	--	--	--	--	--	--	--	--	--
Buxbaumii	+	+	--	+	+	+	+	+	--	--	+	+	--	+
vulgaris	+	+	--	+	+	+	+	--	+	--	--	--	+	--
**rigida*	+	+	+	+	+	+	+	+	+	+	+	+	+	+
scopulorum	--	--	--	--	--	--	--	--	--	--	--	--	--	--
**chimaphila*	--	--	--	--	--	--	--	--	--	--	--	--	--	--
variabilis	+	--	--	--	--	--	--	--	--	--	--	--	--	--
acutina	+	--	--	--	--	--	--	--	--	--	--	--	--	--
Nebrascensis	+	--	--	--	--	--	--	--	--	--	--	--	--	--
rhomboidea	--	--	--	--	--	--	--	--	--	--	--	--	--	--
aurea	+	--	--	+	--	--	--	--	--	--	--	--	--	--
Torreyi	+	--	--	+	--	--	--	--	--	--	--	--	--	--
polytrichoides	+	+	--	+	--	--	--	--		--	--	--	--	--
Geyerii	+	--	--	--	--	--	--	--	--	--	--	--	--	--
**filifolia*	+	--	--	--	--	--	--	--	--	--	--	--	--	--
**elynoides*	--	--	--	--	--	--	--	--	--	--	--	--	--	--
**rupestris*	+	--	+	--	+	+	+	+	+	+	--	--	--	--
obtusata	+	--	--	--	--	+	+	+	+	--	+	+	--	--
nigricans	+	+	--	--	--	--	--	--	--	--	--	--	--	--
**pyrenaica*	+	+	--	--	--	--	+	--	+	--	--	--	--	--
**misandra*	+	+	+	--	+	+	+	+	--	+	--	--	--	+
scirpoidea	+	+	+	+	+	+	--	--	--	--	--	--	--	+

TABLE (continued).

Species of *Carex* in Colorado.	North America. Rocky Mts. of Canada.	Coast of Alaska.	Arctic region.	Atlantic slope.	Greenland.	Europe. North Europe.	Alps and Pyrenees.	Ural.	Caucasus.	Asia. Arctic Siberia.	Altai Mts.	Bajkal Mts.	Himalaya.	Kamtschatka and Sachalin.
oreocharis	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pennsylvanica	+	--	--	+	--	--	--	--	--	--	--	--	--	--
Rossii	+	--	--	--	--	--	--	--	--	--	--	--	--	--
umbellata var. *brevirostris*	+	--	--	--	--	--	--	--	--	--	--	--	--	--
viridula	+	--	--	--	--	--	--	--	--	--	--	--	--	--
lanuginosa	+	--	--	+	--	--	--	--	--	--	--	--	--	--
aristata	+	--	--	--	--	--	--	--	--	--	--	--	--	--
Backii	+	--	--	+	--	--	--	--	--	--	--	--	--	--
capillaris	+	+	--	+	+	+	+	--	+	--	+	+	--	+
longirostris	+	--	--	--	--	--	--	--	--	--	--	--	--	--
microglochin	+	+	+	--	+	+	+	--	+	--	+	--	+	+
**Engelmannii*	--	--	--	--	--	--	--	--	--	--	--	--	--	--
utriculata	+	+	--	+	--	+	--	--	--	--	--	--	--	+
**pulla*	?	+	+	--	+	+	--	+	--	+	--	+	--	+
monile	--	--	--	+	--	--	--	--	--	--	--	--	--	--
rostrata	+	--	--	--	--	--	--	--	--	--	--	--	+	+
lupulina	--	--	--	+	--	--	--	--	--	--	--	--	--	--

The *Carices* of Colorado may, from a geographical viewpoint, be classified in two sections : Northern and Southern.

I. *Northern Species.*

a. Circumpolar types.

C. canescens, incurva, rigida, rupestris, misandra and *pulla.*

b. Arctic, but not circumpolar.

C. nardina, gynocrates, festiva, alpina, atrata, Buxbaumii, scirpoidea, capillaris and *microglochin.*

c. Northern but not arctic types.

C. tenella, stellulata, teretiuscula, pratensis, siccata, Hoodii, vulgaris, obtusata, utriculata and *rostrata.*

d. Northern types, endemic to North America.

C. Deweyana, Hookeriana, marcida, Sartwellii, Douglasii, athrostachya, petasata, Liddonii, Bonplandii, Parryana, variabilis, acutina, Nebrascensis, aurea, Torreyi, polytrichoides, Geyerii, filifolia, nigricans, Pennsylvanica, Rossii, Backii, umbellata, longirostris and *lanuginosa.*

II. *Southern Species.*

e. Species common to both worlds.

C. fœtida, stenophylla, pyrenaica and *melanocephala.*

f. Species endemic to North America.

C. occidentalis, straminiformis, chalciolepis, bella, scopulorum, chimaphila, rhomboidea, elynoides, oreocharis, Engelmannii, monile and *lupulina.*

When comparing the geographical distribution of these *Carices*, the arctic-alpine are of a special interest, because they prove that there are species common to these mountain-peaks and to the polar regions, a fact that may point towards the place where these species originated, or let us say "developed."

And the most natural explanation seems to be, that they are remnants of a glacial flora which were left on these mountains, while the others migrated back to their northern homes, when the ice receded. Their center of distribution would, thus, be the arctic region. This explanation might be plausible in respect to the circumpolar species, but less so concerning the others. For in regard to the latter there is some, and indeed no small, possibility for supposing that these had originally developed in the South, but that they accompanied their arctic brethren on their return to the North. The latter explanation might be applicable especially to such species which are not strictly alpine, but which, nevertheless, are known to occur in the arctic region.

When, thus, the geographical distribution fails to give us any exact information about the center of development of such species which are arctic, but not alpine, some other data may be taken into consideration. We suggest the association with allied species as perhaps giving some clue to the solution of this problem.* Would it not be natural to suppose that where some species is found associated with a group of types which appear to be closely allied to this, that "there" may be sought the center of its distribution, if not of its development? We might illustrate this suggestion by an example, taken from *Carex festiva.* This species is arctic, but neither circumpolar or strictly alpine; it is relatively rare in the polar-regions and occurs there only as what may be termed the "typical" plant. But much farther South and especially in the subalpine zone of the Rocky Mountains is a herd of this same species, accompanied by several aberrant forms, besides by species that are apparently distinct, but among its closest allies: *C. athrostachya, petasata, pratensis,* etc. Judging from our present knowledge

* Compare R. v. Wettstein: Grundzüge d. geogr.-morphol. Methode d. Pflanzensystematik, 1898, p. 35, etc.

of the distribution of this species, *C. festiva*, its geographical center and, also, its center of development seems to have been in the South, in the Rocky Mountains, where it is, thus, typically developed, accompanied by allies and most abundant. And its occurrence in the arctic region may be explained in this way, that individuals of this species were among those that migrated northward with the arctic plants. This instance of an arctic plant having evidently originated in the South may easily be supplemented with others, and there is even among the circumpolar *Carices* from Colorado a species which seems to illustrate the same case: *C. canescens.* This species is also rather rare in the extreme North, while it abounds farther South, associated with more or less deviating forms, besides by close allies. Moreover this species is especially frequent in the lowlands of North and Middle Europe, Central Asia and of the temperate zones of this continent, extending throughout the southern portions of South America to Tierra del Fuego. But it is, of course, impossible to define the original center of a species with such wide distribution as *C. canescens*, with any closer proximity than that the center was evidently in the temperate zone. The remarkable predominance of varieties of *C. canescens* on this continent in contrast to Europe and Asia, might point towards its center as being looked for here, inasmuch as it is here surrounded by such species which we, for morphological reasons, consider as close allies, e. g., *C. vitilis, trisperma, tenuiflora, loliacea* and *tenella*, of which only the first, *C. vitilis*, has reached beyond the arctic circle.

These examples might be sufficient for illustrating the probable southern origin of certain plants that are, also, known as "arctic." But in regard to the other circumpolar *Carices* from Colorado, we are unable to locate the original center of these but in the polar regions. *C. rigida, misandra* and *pulla* appear as a matter of fact not only to have their greatest distribution within these regions, but they exhibit, besides, a much more pronounced tendency to develop varieties than they do farther south, where they are relatively very rare. The mono- and homo-stachyous *C. rupestris* and *incurva* lack the plasticity of the hetero-stachyous species and occur only as typically developed, wherever they are found; but their prevalence in the North make us suppose that they originated there. We may for similar reasons attribute a northern and arctic center of distribution to *C. nardina* and *C. microglochin.* But in regard to the other members of the category, "Arctic, but not circumpolar types," we believe that all of these came from stations south of the arctic region. Let us, for instance, consider *C. atrata* and *alpina.* The former is only known as arctic in a few stations of the European continent, while the other has been collected in arctic Russia, Finmark, Greenland

and North America, but is much more frequent farther South. We have called attention to the occurrence of *C. melanocephala* in the mountains of Colorado, where *C. alpina* also occurs, and we have mentioned the presence of two types, which we consider as allies of *C. atrata*: *C. bella* and *C. chalciolepis*, as inhabiting these same mountains together with *C. atrata*. Furthermore that a third ally of *C. atrata*, *C. ovata*, abounds in the northeastern parts of this continent, thus illustrating the occurrence of allied types associated with each other, which we believe might indicate the location of the center of distribution as being in the Rocky Mountains, as far as concerns the American representatives of *C. atrata* and *alpina*. We have stated, moreover, that *C. atrata* is in Europe, to some extent, accompanied by two plants *C. nigra* and *aterrima*, both of which may be looked upon as immediate allies of this species. And if we extend our comparison of these species with those that occur in the Himalayas, we find there not only typical *C. atrata* and *alpina*, but also some aberrant forms, and some distinct species, among which *C. Lehmannii*, *obscura*, *Duthiei*, *nivalis*, and *psychrophila*, which appear to represent immediate allies of these two species. If thus the association with allies in connection with frequent occurrence and tendency to vary may throw any light upon the question as to their center of distribution or even of development, we believe we are justified in supposing that as far as we know *C. atrata* and *C. alpina* in this particular respect, these species had probably more than one center, and very likely one in the Rocky Mountains, another in the European Alps and a third one in the Himalayas.

The third and fourth category of Northern types emphasize such species as are not arctic; only a very few of these are alpine; *C. petasata*, *Bonplandii* and *filifolia*, and these are, furthermore, endemic to the Rocky Mountains. The remaining species of these same categories are either common to both worlds or endemic to North America and some to the Rocky Mountains alone. *Carex stellulata* is widely distributed throughout the northern hemisphere in the lowlands of the temperate zone; besides that, it occurs in New Zealand. It reaches its highest development on this continent, where it exhibits a vast number of forms, some of which have been segregated as distinct species and is, in the northern provinces, frequently associated with an ally, *C. gynocrates*, which we consider as representing a *forma hebetata* of the section *Astrostachyæ*. *C. gynocrates* does not seem to occur in Siberia, but its homologue, *C. Redowskyana*, has been reported from several stations of that country, where, however, *C. stellulata* is absent, at least in the northern parts. The European *C. stellulata* shows no tendency to vary, but the fact that it is associated with such species as *C. diœca* and *Davalliana*, both of which appear to represent lower types of the section (*Astrostachyæ*), makes us believe that there is both an American and an European center of its distribution and development. *Carex tenella* shows a similar wide distribution on this continent from the Atlantic slope to Alaska, associated with such near allies as *C. canescens*, *loliacea*, *tenuiflora*, etc., all of which are, also, known from Scandinavia; hence we might conclude that they originated from two centers, one in Scandinavia and another one in the northern Rocky Mountains.

Among the species of this category, which we suppose were developed in the Rocky Mountains, but which took part in the migration northward with the arctic plants on their return, may be mentioned *C. pratensis*, of which the very isolated occurrence in South Greenland does not seem explainable in any other way. The almost cosmopolitan *C. vulgaris* is difficult to locate, inasmuch as it is generally accompanied by several allied types, wherever it occurs in the mountains or lowlands. We can only say that it does not belong to the arctic region, and that the diversity of types into which it has developed, for instance in the Himalayan Mountains, in Scandinavia and in the northwestern parts of this continent, indicates several local centers.

In regard to the other types, the majority of these are endemic to North America and several to the Rocky Mountains, where they have, naturally, developed.

The second category, "Southern types," contains a few species common to both worlds, among which *C. pyrenaica* shows a remarkable wide distribution: from Colorado to the British provinces, Alaska, the Pyrenees and Alps of Switzerland, Caucasus, Japan and New Zealand, while its nearest ally *C. nigricans* is confined to the Rocky Mountains and Alaska and *C. macrostyla* to Spain and the Azores. *C. fœtida* is only known from Colorado, California and the Alps of Switzerland. *C. stenophylla* follows the Rocky Mountains throughout Canada, and is known also from Southern Europe, Caucasus, Altai, Bajkal, Himalayas and China. The geographical center of *C. nigricans* may, beyond doubt, be sought in the Rocky Mountains, while it seems impossible to locate that of *C. pyrenaica*, unless there may have been at least two centers, one in the Rocky Mountains and another in the old world, Europe or Asia; its occurrence in New Zealand can not be accounted for with any satisfaction. In regard to *C. fœtida* we feel unable to explain its distribution in any other way than by admitting two centers, the Rocky Mountains and Switzerland Alps. And if we consider *C. stenophylla*, there seems no possibility of defining its center with any proximity neither in this country or in the old world.

Among the southern types that are endemic to this continent are some alpine species: *C. elynoides*, *Engelmanni*, *chalciolepis*, *chimaphila*, *scopulorum* and *bella*. We have already discussed the distribution of *C. chalciolepis* and *bella*, both of which show affinities to *C. atrata*. In regard to *C. scopulorum* this is undoubtedly a southern type, but has, however, spread farther North to Wyoming and Montana, but is not reported as being frequent. *C. elynoides* is hardly to be considered as a rare species, since its great resemblance to *Elyna spicata* may have caused it to be confounded with this, besides that relatively few species of *Carex* are represented in the herbaria from the higher alpine regions of these mountains.

There is thus quite a number of Carices in Colorado endemic to this country, and although these are not of so much interest from a geographical viewpoint as the northern, common to both worlds, they will, no doubt, prove valuable to the study of homologues, such as many of these actually are, of old world species.

Considering the arctic species, which are, also, occurring in Colorado, we have demonstrated the possibility of some of these having originated in the arctic region: *C. incurva*, *rigida*, *rupestris*, *misandra*, *pulla*, *nardina* and *microglochin*. Not less than five of these are, also, circumpolar and it seems as if the existence of these, together with *C. nardina* and *microglochin*, indicate that the Rocky Mountains harbor a certain element of that flora, which we call the arctic, which was reared in the polar-regions, but forced south during one of the greatest revolutions in the history of the earth, known as the glacial epoch. Some of the other *Carices* which we have enumerated from Colorado are, also, arctic, but neither circumpolar or having originated in the extreme North, as far as we know, for instance *C. atrata*, *alpina*, *festiva*, *scirpoidea* and *gynocrates*, and these illustrate a flora partly of American, partly also of old world origin. Most of the others are truly American types, and evidently young types.

If it had been within the scope of the present paper to consider other genera than *Carex*, as represented in Colorado and in the arctic region, we would have been able to offer further evidence of the existence of a glacial flora in the Rocky Mountains, easily illustrated by a number of other types, such as *Dryas octopetala*, *Silene acaulis*, *Campanula uniflora*, *Saxifraga nivalis*, *cernua* and *flagellaris*, *Lloydia serotina* and many others. But when we undertook the task of discussing the geographical distribution of the genus *Carex* in Colorado and quite especially that of the alpine types, it was simply the writer's intention to make an attempt to show, that even a single genus of plants might offer some tangible proof of the foundation of the theory relating to the history of arctic plants, as demonstrated in the writings of the Swedish naturalist A. G. Nathorst.

Brookland, D. C., December, 1902.

ART. IV.—*Chrysocolla: A Remarkable Case of Hydration;* by CHARLES M. PALMER.

SOMEWHAT over a year ago a quantity of medium grade oxidized copper ore from Pinal County, Arizona, came into the writer's hands, with the information that it was representative of the class of ore that was being shipped to the smelters, and that as the latter were claiming the presence of surprisingly large quantities of moisture, sometimes as high as 16 or 17 per cent, it seemed to be a matter for investigation. The ore consisted mostly of bluish or greenish chrysocolla impregnating or filling seams in a siliceous matrix, and occasionally as an incrustation; sometimes, however, being associated with a black variety containing considerable manganese.

Water determinations were made on several lots which gave results varying from about 17 to 20 per cent, which, for an air-dried ore carrying but 12 or 14 per cent of copper, was somewhat unexpected and remarkable. Then several large pieces of enamel-like turquoise blue chrysocolla were picked out, which seemed to be comparatively pure, and these were powdered preparatory to analysis (sample No. 1) with the view of getting more light on the character of the mineral. One gram was weighed out on a watch glass one evening and placed in a dessicator over concentrated sulphuric acid. The next day upon weighing for determining the loss under these conditions and finding it, according to my weights, to be over 12 per cent, I thought I had simply made one of those unaccountable mistakes in my weights that will sometimes happen, and therefore promptly weighed out another portion, which gave practically the same result. The material gave the following upon analysis:

Silica (insoluble)	38·64%
Cupric oxide	25·22
Alumina	11·76
Ferric oxide	trace
Water (over H_2SO_4)	12·36
Water (additional loss at red heat)	12·22
	100·20

An effort was made to obtain a purer specimen, and from a lot of ore from another locality in Arizona, another sample (sample No. 2) of deep blue chrysocolla, apparently pure and perfectly homogenous in appearance, was carefully picked out. It lost 18·24 per cent after 22 hours in a dessicator over sulphuric acid, which loss was increased only to 18·96 per cent after 33 days more, and to 19·60 per cent after 24 hours at 100° C. After this, the platinum dish containing the substance was allowed to sit in the balance case for 48 hours, during which time it not only regained all its previous loss but 0·68 per cent in addition, and all this, too, without a perceptible change in color or general appearance.

The total loss by heating at a low red heat to constant weight was 27·28 per cent. Analysis of the sample gave the following results:

Silica	35·84%
Cupric oxide	31·50
Alumina	3·74
Ferric oxide	trace
Manganese oxide	"
Calcium oxide	1·76
Magnesium oxide	0·16
Water (over H_2SO_4)	18·96
Water (at low red heat)	8·32
	100·28

Another sample (No. 3) of dark green material from the Pinal ore was found, which occurred as an incrustation about one-eighth of an inch thick, and which appeared no less pure and even richer in copper than the last. It lost 15·60 per cent over sulphuric acid in 24 hours, this being increased after 11 days to 20·54 per cent. The dish containing the substance was then placed in a dessicator over water. In 21 hours it had made up all its former loss and 2·64 per cent besides, and after four and one-half days more under the same conditions, this increase amounted to 5·14 per cent, making a variation of 25·68 per cent in the amount of water at ordinary temperature with no change whatever in appearance. The loss at 100° C. was 20·72 per cent, being but very little higher than the loss over sulphuric acid, and the total loss at a red heat was 29·14 per cent. The analysis of this material, of which only about 1·5 grams were obtainable, is as follows (calcium and magnesium being present but not determined quantitatively):

Silica	33·28%
Cupric oxide	30·76
Alumina	4·60
Ferric oxide	trace
Manganese oxide	trace
Calcium oxide	not det.
Magnesium oxide	not det.
Water (over H_2SO_4)	20·54
Water (at low red heat)	8·60
	97·78

These samples began to change color at the temperature of the sand bath and at red heat turned black. Treatment of this black residue with acids, and even prolonged and repeated fusion with potassium bisulphate, failed to bring all the copper in solution. Sodium carbonate fusion was not tried.

The most remarkable feature of the whole affair is that a mineral or chemical compound should occur in nature with such a large amount of water so loosely attached to its molecular structure. Chrysocolla not being a crystalline mineral, the loss of water of crystallization is not indicated by the loss of crystalline form, and neither is there a change of color upon the loss of the very portion that would ordinarily be regarded as water of crystallization. Diligent search of the literature of hydrous minerals in general, and chrysocolla in particular, accessible to the writer, failed to indicate that any such unusual behavior has been previously noticed. Heretofore, a loss of 2 or 3 per cent over sulphuric acid has been regarded as probably the limit to be expected, even in special cases, from the minerals containing water most loosely combined, as in the zeolites and others.

It seems almost superfluous to mention, in this connection, the importance of including in the results the so-called hygroscopic moisture in the analysis of minerals. Indeed, upon comparing the results given above (only the last two analyses are referred to for comparison, as the first is too obviously a mixture) with the published analyses of chrysocolla given in the table below (from Rammelberg's "Mineralchemie," 1860, page 551), one is inclined to suspect that possibly considerable "hygroscopic" water was overlooked in some of the latter, or else there is something inherently different in the two classes. It will be noticed that while the amounts of silica are similar, the cupric oxide in No. 2 and No. 3 is about one-fourth less and the amount of water is about one-half as much more than the other analyses show. The loss of No. 2 and No. 3 over sulphuric acid closely approximates two-thirds of the total water present.

			3			
	1	2	*a*	*b*	4	5
SiO_2	37·25	40·00	35·00	36·54	35·14	32·55
CuO	45·17	42·60	39·90	40·00	43 07	42·32
Fe_2O_3	----	1·40	3·00	1·00	1·09*	1·63
CaO	----	----	----	----	----	1·76
MgO	----	----	----	----	----	1·06
H_2O	17·00	16·00	21·00	20·20	20·36	20·68
Gangue	----	----	1·10	2·10	----	----
	99·42	100·00	100·00	99·84	99·66	100·00

* With Al_2O_3, CaO, K_2O.

As to any formula being deduced from the analyses given, the case seems hopeless without resorting to assumptions that are, to say the least, questionable.

The duties of a commercial laboratory afford scant opportunity for purely scientific investigation, however interesting, and it was only after many interruptions that the above work was accomplished, but it is offered as food for speculation and a stimulus for future investigation with the hope that some one with more time and ability may be able to grasp the significance of this remarkable behavior.

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St. Louis, Missouri.

ART. V.—*An Inquiry into the Cause of the Nebulosity around Nova Persei;* by FRANK W. VERY.

THE processes by which the nebular illumination around the great nova of 1901 has been produced may conceivably be explained under some one of the following heads:

First hypothesis: The nebular radiation is emitted from myriads of small gaseous masses, either heated or electrified, which have been evolved in the collision of meteorites, belonging to antagonistic and mutually interpenetrating meteor swarms whose motions through space, under the action of gravitation, has brought them together.

Second hypothesis: Radiation from the nova, perhaps of Hertzian waves, perhaps of ordinary luminous vibrations, or possibly of some especially potent ultra-violet rays, but at any rate proceeding in radial lines from the source, has been received upon quiescent matter already existing in the surrounding space, and has generated in this matter some chemical or physical process attended by radiation affecting a photographic plate, or else the material of space, by simple diffuse reflection, has turned the path of the original rays earthwards without altering their quality.

Third hypothesis: Powerful explosions from the nova, and the emission of great volumes of excessively hot gases, have been accompanied by violent electric disturbances which have produced extensive discharges of ions under magnetic control, moving with velocities possibly as great as those of electromagnetic waves, but along magnetic lines of force, instead of radially. The luminous phenomena of the nebula may be conceived either as due to phosphorescence of quiescent matter under impact of the flying ions, or as emanating from the ions themselves.

Either of these three heads may be subdivided into subordinate modes of origin, only a few of which are indicated.* Since any one of these processes may conceivably produce a luminous effect analogous to the nebula, we must decide between the proposed explanations by considering the objec-

* Dr. Max Wolf (Astronomische Nachrichten, No. 3752, Bd. 157, 144, Dec., 1901) suggests for the origin of the nebula the progression of an explosive wave in detonating gas ("Knallgas"), a term which is used to denote an explosive mixture of hydrogen and oxygen, such as is produced in our laboratories by the electrolysis of water. Mr. H. B. Dixon, however, has measured the velocity of the propagation of an explosion in a mixture of these gases, obtaining 2819 meters per second, or a quantity which bears no comparison to the nebular velocity (see Rep. British Assoc. for Adv. Sci., 1885, p. 905). The supposition of an explosion of a mixture of hydrogen and chlorine, which might be started by light from the nova, is open to the same objections as the other radiant hypotheses.

tions which can be urged against them, either from rational considerations, or on the ground of observational data, especially availing ourselves of every scrap of observation which can support either of the hypotheses.

(1) The first explanation, attributing the phenomenon to colliding meteor swarms, has been chiefly advocated by Sir Norman Lockyer. The certain existence of meteor swarms in free space, and the partial agreement between the spectra of some meteorites and nebulæ, are strong points in favor of the general theory. The fatal objections to the explanation in the present case are: (*a*) That the expansion of the nebula has proceeded at too rapid a rate. Let us suppose that two spherical swarms of equal diameter and equal velocities of 100 kilometers per second, are traveling in opposite directions along a common diameter, and that the circle of the intersecting surfaces moves outward with the velocity of light, which it must do if the nebular expansion has been produced in this way. In one year each body will have moved through 3156×10^6 km., and the line of intersection will have expanded through nine and one-half billion kilometers (English numeration). Allowing that the nova is in the center of its sphere, and measuring from this center, the angular aperture of the lenticular volume bounded by the intersecting swarm-surfaces, after one year, is less than 3°, and if the nova's parallax is 0″·05, the swarm will stretch two-thirds of the way to the sun! Even the broad celestial spaces are not wide enough to contain such monsters. (*b*) The fading of the nebula has been too rapid, for there is no reason to suppose that the meteoric particles are confined to a thin superficial shell and that the space within is relatively vacant. (*c*) As it would take over 100,000 years for the motion to pass from the circumference to the center of the sphere, any connection between the actual nova and the nebula would be impossible on this hypothesis. I showed in a previous paper* that the outburst of the nova itself cannot be due to colliding meteor swarms. It is, if anything, more completely demonstrable that the nebula has no such origin.

Sir Norman Lockyer explains the nebula around *Nova Persei* as "a nebula [previously too faint to be detected] invaded, not by one, but by many swarms [of meteors], under such conditions that the collision effects vary very greatly in intensity. . . . The most violent one . . . constitutes *Nova Persei.* The least violent ones occurring in other parts of the disturbed nebula, almost immeasurably removed, i. e., more than 700 solar distances away, we only learn of from the recent photographs."† The distances are here greatly underesti-

* This Journal (4), xiii, 114. † Nature, lxv, 134, Dec. 12, 1901.

mated, in fact the nebular velocities seem to be confounded with those spectroscopically observed. I have shown elsewhere* that the gaseous envelopes about the nova, whose existence we must infer from the spectroscopic observations, belong to an entirely different order of magnitude from the nebulous forms which have been discovered by photography. The latter probably extend to 100,000 solar distances. The general combination of the nebular details into nearly circular rings which have expanded in a continuous manner, requires that the aggregate of the swarms postulated shall be spherical.

(2) There are various hypotheses assigning the nebular phenomenon to the action of radiation from the nova on diffused quiescent matter already existing in surrounding space, for example: (*a*) The hypothesis of electro-magnetic waves, emitted by the nova at its maximum development, exciting luminosity in masses of rarified gas, after the manner of Tesla's disconnected tubes. (*b*) The hypothesis of dissociation of a compound gas by ultra-violet radiation proceeding from the nova at its maximum intensity, and the subsequent production of light by the recombination of the atoms. (*c*) The hypothesis that luminous radiation from the nova has been reflected by finely divided matter.

The following objections apply to all three of these hypotheses: 1. The duplicity, or possible triplicity of the nebulous ring, and the double ratio of the radii of the two principal rings, are not explained. 2. The expansion of the concentric rings should be uniform, since any supposition of cylindroid or conoidal nebulosities, directed earthwards, is improbable. But instead of uniform expansion in a radial direction, there has been retardation in the movement after a certain time. The deviation from radial direction of movement in special forms does not enter into the argument, which concerns rather the figure produced by the combination of details into an annulus whose outer boundary may be taken to limit the region through which a special process has progressed. 3. The deviation of both rings from the circular to an elliptical shape, and to the same extent, is not easy to explain by radiant hypotheses. Mr. Arthur R. Hinks, of Cambridge Observatory, England,† suggests reflection of light from inclined circular rings of nebulous material, concentric with the star; but this requires several years for the completion of each ellipse, whereas the ellipses are already very nearly complete through arcs far in advance of the arrow heads which are supposed to be describing these figures. 4. Finally, the reflection hypothesis in any

* Astronomische Nachrichten, No. 3771, clviii, 33, Feb., 1902.
† Astrophysical Journal, xvi, 198, 1902.

of its forms, whether as developed by Kapteyn* or by Seeliger† or by Hinks, presupposes an albedo which is quite impossible in nebulous material as it actually exists in extreme rarefacfaction. Professor H. H. Turner‡ has given the following rough but simple calculation in regard to Kapteyn's hypothesis: "Light takes 8 min. to reach the moon from the sun, 8 months to reach the nebula from *Nova Persei.* Taking the original flare up to be 5000 times the brightness of our sun, the illumination of the nebula should be to that of the moon as 5000 to $(30 \times 24 \times 60)^2$. The moon could be photographed with Mr. Ritchey's instrument in (say) $0^s{\cdot}003$. Hence the nebula, if of the same albedo as the moon [could be photographed] in $0^s{\cdot}003 \times (30 \times 24 \times 60)^2 \div 5000 = 20$ min. say. The actual exposures required," says Professor Turner, "thus seem reasonable on Kapteyn's hypothesis." Let us see what this "reasonable" conclusion implies. It will be noted that in forming his equation, Professor Turner has introduced the proviso of equal albedo in nebula and moon. The assumption remains in the final conclusion, and how far it is from the truth may be seen from the following considerations: In 1895, I measured the light from a small area of the moon in total eclipse,§ photometrically, and found it to be four one-thousand-millionths of the light from a corresponding fraction of the full moon. My range of vision embraces lights which are in the ratio of 1 to 1,000,000,000,000,000. Hence I could certainly see a small luminous surface considerably fainter than the fraction (less than 1 per cent) of the eclipsed moon, and as no one has been able to see the nebula, I conclude that its light must be less than one one-thousand-millionth of that from an equal area of the full moon. Professor Turner's calculation demands equal albedo, that is, equal intrinsic brightness from the same angular area in the two cases. We are not concerned with the albedo of the individual reflecting particles in the nebula. This may be exactly the same as the moon's albedo, but that is not the question. The albedo of the nebula is the effective albedo of a surface, apparently continuous, but in reality undoubtedly composed of excessively minute particles separated by large vacant spaces. With the actual effective nebulous albedo of 10^{-9} (moon = unity), we see from Professor Turner's own figures that the conclusion which he draws is not warranted, and that no reflection from nebulous material at the vast distance of these nebulous forms from the central illuminating body can affect the photographic plate,

* Astronomische Nachrichten, No. 3756, clvii, 201, Dec., 1901.
† Astrophysical Journal, xvi, 187, 1902.
‡ The Observatory, Feb., 1902.
§ "Photometry of a Lunar Eclipse," Astrophysical Journal, ii, 293, 1895.

even though the exposure were to be prolonged many thousand fold.

(3) The supposition that the observed motions are actually those of some form of matter, either itself luminous, or producing luminosity in widely distributed material with which the moving substances react, demands so large an expenditure of force in sustaining the prolonged movement to enormous distances, that some hesitation in adopting it is pardonable. Yet, considering the stupendous scale of operations in the nova, the objections on this score do not seem insuperable. Comet's tails have been seen to develop through millions of miles in a few hours,* perhaps by electric repulsion, perhaps by the pressure of light on small masses, but at any rate without demanding greater force than the sun is competent to produce. High velocities have been measured in vacuum tubes for the cathode rays, and yet higher ones for the luminous column from the positive pole, even approaching, if not equaling that of light. These facts at once suggest a movement of Thomsonian corpuscles, or negative ions, under a magneto-electric impulse, as a solution of the problem.

Professor C. D. Perrine, however, has urged what appear to him to be further objections to the hypothesis of a real translation of matter. He says:† "The motions observed are not radial. Nearly all of them have large tangential components. It is difficult to account for these tangential components. A consideration of the conditions probably existing in the nebula, upon the assumption of an actual translation of matter, would lead us to expect a very rapid loss of light. The inner ring has decreased in brightness, and some of its features have become too faint to record themselves on the photographs. Several masses, all in the outer ring, have been recorded only on the later photographs, and have grown both in brightness and size, a condition difficult to explain on the above hypothesis. It is perhaps not inconceivable that the two rings represent different phenomena." If these difficulties urged by Professor Perrine can be removed, nay more, if the facts con-

* Miss Agnes M. Clerke, in her "History of Astronomy during the Nineteenth Century" (4th ed., p. 100), says of the comet of 1811, that Olbers "calculated that the particles expelled from the head traveled to the remote extremity of the tail in eleven minutes, indicating by this enormous rapidity of movement (comparable to that of the transmission of light) the action of a force much more powerful than the opposing one of gravity." By reference to Olbers' original communication in Zach's Monatliche Correspondenz (xxv, pp. 3–22, 1812) it will be seen that the extreme length of the tail of this comet, on October 13, 1811, was taken at 0·6391 astronomical units, or about 96,000,000 kilometers; and the time consumed by the vapors in attaining this distance, computed according to Newton's method, was stated to be *eleven days*, instead of eleven minutes.

† Astrophysical Journal, xvi, 260, 1902.

sidered to be objections to a theory of real motion can be shown to be demanded by a special form of the theory, they constitute a strong argument in favor of this explanation. I believe that such a modified explanation is indicated.

The difficulties urged by Perrine in regard to the sudden appearance and brightening of local spots on the outer ring, and the tangential motion which prevails in many features, appear to him contrary to what should be expected if the phenomenon is due to actual motion. Evidently the only actual motion considered is a radial one. These difficulties which form the most serious objection to such theories of actual motion as have been hitherto published, become, on the contrary, a strong argument in favor of a different theory of real movement.

(4) The theory which I would propose is that of the actual movement of diamagnetic ions under the control of magneto-electric impulses emanating from the star and following the lines of magnetic force. We may compare such a stream of moving ions to the beam of light from a parabolic mirror. The rays are directed and do not at once expand to fill the entire sphere. Diamagnetic ions may be expected to follow lines of magnetic force to regions of least potential in the magnetic equatorial plane, and with only slight expansion of the tubes of force through a limited range of the magnetic sphere. Hence the luminosity, as in the distinct phenomenon of a comet's tail, may extend to a great distance before becoming too faint for observation, although of course the light must eventually fade, unless perpetually renewed. This seems to answer the objection on account of the long continuance of the phenomenon.

In the next place, if the structure observed in the nebula is to be compared with that of a magnetic phantom, a strong tangential component must enter into lines emanating from the nova after these have extended to a certain distance. The magnetic phantom, whether exhibited by iron filings or by dust of bismuth, extends in sweeping curves from pole to pole of the magnet—the only difference being that magnetic particles move towards the poles, and diamagnetic away from them, but that both follow the lines of force. The observed trajectories of nebulous material around the nova are in fair, perhaps I should say in nearly perfect, agreement with the projection of a system of lines of magnetic force.

If the brightening or sudden appearance of new bright spots on the outer ring can also be explained on this hypothesis, I think it must be admitted that the facts decidedly favor, if they do not demonstrate, the proposed explanation.

Two cases may be distinguished: *(a)* The light is produced by phosphorescence of dark matter, previously existing in the surrounding space, and made luminous by colliding ions. *(b)* The moving ions are themselves luminous.

On either hypothesis, the luminous shape is a species of magnetic phantom, where only those portions of the general magnetic figure are visible which happen to be infilled with matter capable of becoming luminous under the given conditions.

Two distinct processes can be inferred from the succession of phenomena exhibited by *Nova Persei.* First, there were violent eruptions of hydrogen, helium, etc., with velocities up to 2000 km. per sec., and the formation of concentric shells of glowing gas, reaching distances comparable with those of the planetary orbits; and, second, there was a profound electrical disturbance accompanying this turmoil of the elements, producing a complex and excessively attenuated appendage, thrown off with velocities possibly 150 times as great as those of the gaseous eruptions, and reaching far out into stellar space. It is this second appendage with which we are now concerned. We see this object on the photographic plate in projection, and must infer its shape from such details as are visible. A strong condensation on the S.S.W. side reminds one of the jets from a cometary nucleus on the side towards the sun, and to this extent favors some such theory as that of Professor T. C. Chamberlin, who has suggested* the tidal disruption of a star upon the near approach of a massive dark body. The condensation in question, called *m* by Ritchey and D by Perrine, bears an even stronger resemblance to the polar coronal filaments of the eclipsed sun, which curve away on either side of the coronal axis, but with the difference that it appears at only one pole.

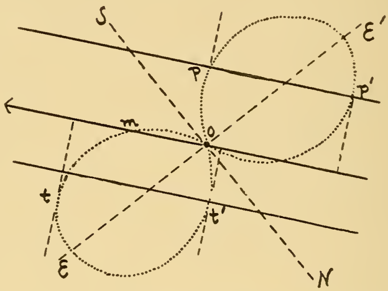
Let us assume that there has been an ionic discharge following the lines of magnetic force around a highly magnetized sphere. The general form of an envelope, consisting of a series of such discharges, will be that of an oblate spheroid with polar depressions (i. e., a species of lemniscoid); and if the nebula about *Nova Persei* is to be thus interpreted, its southern pole is directed towards us, the axis forming an angle of 40° with the line of sight.

Consider a magnetic line of force lying in a plane including the line of sight from the star to the earth (whose direction is indicated by the arrow from the nova *o* in fig. 1). Particles emitted from *o* and passing to *m* will be moving almost end-on, and the line of sight will encounter many such particles. The prominence *m* is therefore brilliant and changes its position slowly. Particles moving along the curve to *p* reach a part of

* Astrophysical Journal, xiv, 17, 1901.

their trajectory where they begin to recede from us with increasing velocity. If the actual velocity is that of light, the component of motion in the line of sight will soon reach a high value—let us say 100,000 km. per sec.—when, even if the original ionic radiation were rich in violet and ultra-violet light, the waves of ether must be so lengthened by the motion of recession that they no longer impress the photographic plate. Consequently, at this radial distance from the star, and in like manner on the opposite side at t, the nebula fades out; but at nearly the same radial distance, particles which have passed undetected on account of their recession along lines from the star's north pole, reach, at t' and p', positions where the motion of recession changes to one of approach. Violet light begins to emanate from these regions. Soon the motion

1



of approach becomes so vigorous that even red or infra-red rays, if they exist, will have their wave-lengths so shortened that they can be photographed. On the supposition that the nebula is a gigantic corona with symmetrical sheaves of filaments around both poles, diverging under angles of something over 60°—one capable of being photographed, the other not—the puzzling phenomena of appearance and disappearance at the outer ring are explained. They are demanded by the theory, instead of being anomalies. The spectroscope alone can decide whether these hypothetical changes of wave-length are real; and as yet this evidence is wanting. If the spectroscope should decide against the change, the supposition of direct ionic luminosity would have to be given up, but not necessarily the ionic theory, since there remains the hypothesis of phosphorescence of quiescent matter under ionic impact.

Perrine's observation of March 29, 1901, indicates the existence, at that date, of two nebulous rings, with radii in the ratio of 1 : 2, and an arc on the N.E. side, which perhaps is the sole record of a third and wider ring. The three radii having approximately the ratio 1 : 2 : 4, may correspond to ions having masses in the ratio of 4 : 2 : 1, and, if so, bear witness to the existence of at least three sorts of ions out of which, in varying proportions, we may conceive the atoms to be made.

An alternative hypothesis assumes that there are as many kinds of ions as of atoms, and that the difference between a corpuscle and an atom of the same substance is principally one of size. If so, since the atomic weights of hydrogen and helium are as 1 to 4, if the masses of their corpuscles have the same ratio, the outer arc might be composed of hydrogen corpuscles, the inner ring of helium corpuscles, and the central member of the series, that is, what we call the "outer ring," would consist of corpuscles belonging to an unknown substance with atomic weight of two. A single good spectroscopic observation, such as might possibly be obtained with an objective prism of large size, would be of inestimable value in deciding this and other questions raised by this extraordinary object, whose like may not be seen again for many years.*

A selection between these hypotheses will be a matter of opinion. Seeing that the chemical elements exhibit many properties analogous to those of homologous series in hydrocarbons, I am inclined to favor the supposition that the atoms are formed by various arrangements of numerous ions of perhaps only three species. Even when their motions are confined and limited in the ionic aggregate (the atom), three fundamental sorts of ionic motions are distinguishable in principal, first subordinate, and second subordinate series of spectral lines, whose pressure shifts, according to Dr. W. J. Humphreys,† are in the ratio 1 : 2 : 4. The same sequence appears again in

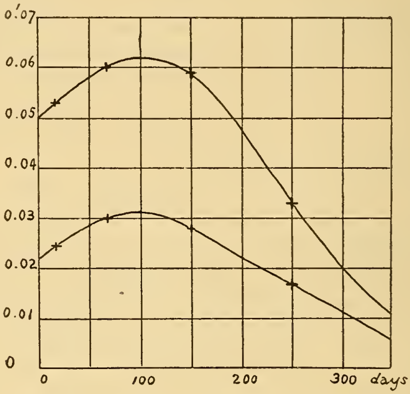
* Note added April, 1903.—Since this paper was read at the annual meeting of the Astronomical and Astrophysical Society of America, in Washington, December, 1902, Professor Perrine has published the following measurement, made with a slit-spectrograph of special construction, provided with a quartz prism and quartz lenses: "The slit of the spectrograph was placed across the brightest portion of condensation D. The resulting negative showed a very faint spectrum, which, after careful consideration and some experiments was deemed to be that of the nebulosity. So far as can be told from such small dispersion and intensity, the spectrum is continuous, with the greater portion of the light condensed in a band between $H\beta$ and $H\gamma$. This band is strongest just above $H\beta$ and from this point fades gradually until it is entirely lost in the H and K calcium region. Beyond this point, up to the ultra-violet region, there is a very slight increase of strength again. It is suspected that in one or two cases there may be traces of bright lines, but the whole spectrum is so faint as to preclude any definite deduction on this point. The above observation shows that the spectrum of this mass of nebulosity is not the ordinary bright-line spectrum of the nebulæ." (Publications of the Astronomical Society of the Pacific, XV, No. 88, p. 26, 1903.) This observation is not inconsistent with the supposition that a spectrum, normally composed of bright lines, has been extended and diffused by excessive motion of the radiating particles through a considerable range of velocities, according to Doppler's principle, until the resulting spectrum is one of ill-defined, superposed, hazy bands.

† Astrophysical Journal, vi, 219, 1897.

the differences between the vibration-numbers of the components of the triplets in the spectra of many of the elements, for example, ratio of intervals: zinc 2·07, magnesium (b line) 2·03, oxygen 1·78 to 2·0, calcium 2·02, etc.

An examination of the rate of expansion of the nebula shows that, since the hundredth day from the outburst of the nova, there has been a retardation, and probably an increasing retardation, in the motion of the nebulous rings. I assume that the nebula consists, in a general way, of two or more lemniscoidal

2



shells involving minor details of structure which find their limit in the elliptical projection of equatorial circles of the lemniscoids. Since the minor details are of vague shape and difficult to locate with precision, I prefer to estimate the positions of the elliptical rings, and taking the mean of major and minor semi-axes as varying with the successive loci of the motion which traces the lemniscoidal figure, I obtain for the rate of nebular expansion the values contained in the following table:

	Time interval.	Mean radius.	Expansion—Mean daily rate.
	0–36 days	1′·85	0′·0514
Outer	36–100 "	5 ·7	0 ·0602
shell	100–200 "	11 ·6	0 ·0590
	200–300 "	14 ·9	0 ·0330
	0–36 "	0 ·88	0 ·0244
Inner	36–100 "	2 ·8	0 ·0300
shell	100–200 "	5 ·7	0 ·0280
	200–300 "	7 ·4	0 ·0170

The curves of the rates of expansion (fig. 2) differ totally from that of matter moving outward under the retardation of the attraction of a central mass (namely, velocity diminishing with the inverse square root of the distance); but the motion is in agreement with that to be expected under the influence of gravity and magnetic repulsion combined, and is thus a strong argument in favor of the theory.

Assuming the radius of the nova to be 10,000,000 km., I find the magnetic repulsion upon the ions at the surface of the star must be about 100,000 times as great as the attraction exerted upon them by the star's mass. At a distance (for the outer ring) of about a billion kilometers, however, gravitation becomes the more powerful, and the velocity of recession begins to diminish. The distance of course depends upon the dimensions of the excessively minute corpuscles.

In order to discover whether the forces required to communicate the observed motion are within the limits of possibility, and are able not only to separate and expel but also to guide the ions, I have taken the dimensions given for the corpuscles by Professor J. J. Thomson, and have combined them with my computation of the mass of the nova.* I find that the computed magnetic repulsion (in excess of gravity) could generate a velocity of nearly 100,000 km. per sec. in the first second, if it were able to exert its full power. Hence it does not seem improbable that velocities as great as this, or even three times as great (i. e., having the velocity of light) could be started by electric oscillatory discharges in the huge masses of intensely heated gases erupted from the nova, ionizing them, and preparing material for dissipation and control by the powerful magneto-electric impulses started at the same time.

I suppose the corpuscles or negative ions to be ethereal vortices, and consequently must make the further assumption that they are diamagnetic, in order to account for their being repelled magnetically.

At this point it is possible to descend from the sky to the earth. A laboratory experiment by Goldstein,† which has never been fully explained, furnishes a connecting link in favor of my last assumption. This experimenter subjected a vacuum-tube in which diamagnetic sodium and magnetic nitrogen glowed together under the electric discharge, to the action of a powerful magnetic field, with the result that only the nitrogen glowed, the diamagnetic substance having been entirely cleared away by repulsion. Free diamagnetic substances must tend to accumulate in regions of least magnetic potential, and the diamagnetic hydrogen of the gaseous nebulae possibly maps out such regions.

I will now allude very briefly to the difficulties encountered by the hypothesis. The attraction or repulsion on a magnetic body is a differential one, and in a uniform field increases with

* Astronomische Nachrichten, No. 3771, clviii, 33, 1902.
† Wied. Ann., xii, 261, 1881.

the distance between the poles of the body. The ions are so minute that the differential repulsion on opposite poles of a corpuscle is very small. Morever, if an ion consists of a circulation of electricity, everywhere at right angles to a circular axis, the corpuscle has no free magnetic poles. It is conceivable that an instantaneous variation in the magnetic field may produce within a limited space a gradient of magnetic force which is steep relatively to the dimensions of an ion, and that the corpuscle is carried along at the rate of motion of the magnetic impulse. Unless there is some such process, it is difficult to find a sufficient cause for the deviation of the motion from a radial direction by a magnetic field as feeble as that at the extreme nebular distances. Something remains to be discovered in regard to the way in which magnetic forces of considerable strength are exhibited far from their sources. The volcanic explosion of Mt. Pelée produced an instantaneous magnetic impulse recognizable all over the earth. Rapid changes in large sun-spots are often accompanied by magnetic storms upon the earth, especially if the earth is near a solar radius through the spot, or the tangent plane at the spot's position. A continuous outpouring of magnetic energy in these cases, and to the immensely greater distances of the *Nova Persei* nebula, would dissipate energy at a startling rate; but a series of instantaneous impulses, separated by relatively large intervals of time, while entirely competent to guide the ionic movements, would also economize energy. Besides this, there is a further economy in the magneto-electric impulse which is not shared by the electromagnetic wave, for the former travels along the magnetic lines of force from pole to pole, and is part of a regenerative system, while the electromagnetic waves pass away in ever expanding spheres and are dissipated. The ionic hypothesis of the origin of the nebula is attended by difficulties, but at least it offers the possibility of a complete explanation.

In conclusion, I think that we may summarize the evidence in regard to the cause of the nebulosity around *Nova Persei* as follows:

Lockyer's hypothesis does not fit the facts. The first two radiation hypotheses are ruled out by the continued visibility of the rings in spite of the gradual cessation of motion. The reflection hypothesis of Kapteyn and Seeliger and its modification by Hinks are further discredited by the impossibility of an adequate albedo in a widely dispersed or nebulous material. Of the two ionic hypotheses, that of luminous diamagnetic corpuscles under magnetic control, and moving with velocities of the same order as that of light, is favored by the appearances and disappearances at the outer ring, but only spectroscopic observation can decide between them authoritatively.

Arcturus, Virginia.

Art. VI. — *The Heat of a Change in Connection with Changes in Dielectric Constants and in Volumes;* by C. L. Speyers.

When carbon and oxygen react to form carbon dioxide many of us say that chemical energy brings this about; that carbon and oxygen containing more chemical energy than the quantity of carbon dioxide produced, the difference escapes as heat and light. But when asked to define chemical energy we become extremely perplexed. We can measure heat energy as such in water units but we cannot measure chemical energy *as such* in any units. We can measure heat energy as such by the increase in volume produced by it, but we do not know of any effect by which we can measure chemical energy *as such.* Invariably do these attempts result in producing heat energy, or light energy, or electric energy, or mechanical energy, or some other energy. But because we do not find these energies previously in the reacting system, we say they come from the chemical energy, which must have been previously in the system. How account otherwise for the energy evolved?

That is, many of us say this, not all of us. Yet all of us agree that water does not contain chemical energy although it gives out heat and changes into ice when placed in an atmosphere below 0°. We all of us agree to this because we agree to call this change into ice a physical change and not a chemical one. No other real reason. On careful investigation and thought we come to the conclusion that the term "chemical" is one for convenience only, that we cannot distinguish chemical changes from physical ones by any definition that can be experimentally sustained at all points. So if we wish to express things as they are, all we can say is that the term chemical energy is an abbreviation for the statement that some energy is involved in chemical change, *but not that there is such an energy as chemical energy.* Abbreviations are very good and necessary, but unless extremely simple and clear, their proper meaning is likely to be forgotten, and this is what has happened with the term chemical energy. It has come to mean a real thing in the minds of writers. A real thing in an elementary text-book* as well as in the last work by Ostwald, a philosophic work too.† Still Ostwald writes in another place‡ "Jeder, der die Beseitigung einer unhaltbar gewordenen allgemeinen Auffassung und ihren Ersatz durch eine neue sich

* Remsen; Inorganic Chemistry, p. 38 (1889).
† Vorlesungen u. Naturphilosophie, p. 232 (1901).
‡ Ib., p. 166.

zur Lebensaufgabe gemacht hat, muss an irgend einer Stelle seiner Vergangenheit den Tribut zahlen."

The barrenness of the notion of chemical energy shows how useless to seek an explanation of chemical action inside the reacting system. How very productive was Faraday's treatment of electricity and magnetism! Outside the charged sphere, the wire, and the magnet, are the energies.

Just so in chemical reactions, let us say, for example, those involving heat, outside the material part of the system is where we are to find the source of the heat.

Consider an infinite uniform electric field whose dielectric constant is K_0, whose electric intensity is E_0, and whose dielectric displacement is D_0. Then the energy W_0 in a volume v_0 is

$$W_0 = \tfrac{1}{2}E_0D_0v_0$$

or, since in a uniform field

$$D_0 = \frac{K_0E_0}{4\pi},$$

we have

$$W_0 = \frac{K_0E_0^2}{8\pi}v_0. \qquad (1)$$

Now introduce into the infinite field a sphere of radius b and of volume v_1 and whose dielectric constant is K_1. Since the field is infinite, we consider that no change is made in the total energy of the field outside the sphere, for there is nothing to maintain a change in the intensity of the field if it is not directed, and if it is directed any change produced on one side of the sphere is balanced by an equal opposite change on the other side. Inside the sphere, the electric force is changed to E_1* such that

$$E_1 = \frac{3K_0E_0}{K_1+2K_0}, \qquad (2)$$

the moment M of the imaginary doublet representing the sphere being

$$M = \frac{E_0(K_1-K_0)}{K_1+2K_0}b^3.$$

Substituting 2 in 1, we have for the electric energy W_1 in the sphere

$$W_1 = \frac{9K_0^3E_0^2}{8\pi(K_1+2K_0)^2}v_1. \qquad (3)$$

* Elements of Elect. and Mag., J. J. Thomson, chap. v. (1895).

We shall call the quantities represented by 1 and 3, the *dielectric energies.*

The change in dielectric energy when the sphere is placed in the field is

$$W_1 - W_0 = \frac{K_0 E_0^2}{8\pi}\left(\frac{9K_0^2}{(K_1 + 2K_0)^2} - 1\right)v_1.$$

For a second sphere of dielectric constant K_2 and volume v_2 we have

$$W_2 - W_0 = \frac{K_0 E_0^2}{8\pi}\left(\frac{9K_0^2}{(K_2 + 2K_0)^2} - 1\right)v_2.$$

Consequently the dielectric energy involved in changing the first sphere into the second, if we put $K_0 = 1$, is

$$W_2 - W_1 = \frac{E_0^2}{8\pi}\left[\left(\frac{9}{(K_2 + 2)^2} - 1\right)v_2 - \left(\frac{9}{(K_1 + 2)^2} - 1\right)v_1\right]. \qquad (4)$$

Now imagine that we are living in surroundings corresponding to an electric field and that the energy in the space occupied by a particular body is measured by 3. Then as we produce one set of bodies from another set we can expect such change in the energy of the system as is represented by 4, in which the indices refer to the two sets of bodies respectively. This change should be measured by a corresponding quantity of some other form of energy rejected by the changing system or absorbed by it; for instance, measured by the heat of the change. Whether the change from state 1 into state 2 causes a rejection or absorption of heat is not predicted; the only assumption made is that the dielectric constant measures the effect the body has upon the energy of the field according to the laws of electric action, when placed in that field.

Equation 4 was deduced for spheres, but since such very slight changes are produced in the properties of a system by moderate subdivision, we claim the same relation for all shapes.

Let us apply 4 to vaporization, for there are enough data in Landolt and Börnstein's Tabellen and elsewhere for three liquids, sulphur dioxide, ammonia, and water. In this case $W_2 - W_1 = Q$ and if $8\pi/E_0^2 = A$, we have

$$\left(1 - \frac{9}{(K_2 + 2)^2}\right)v_2 - \left(1 - \frac{9}{(K_1 + 2)^2}\right)v_1 = AQ \qquad (5)$$

where v_2 is the volume in c.c. of saturated vapor produced from v_1 in c.c. of liquid and K_2 and K_1 are the respective dielectric constants of vapor and liquid.

It will be convenient to put $v_1 = 1^{cc}$, in which case Q is the heat of vaporization of 1^{cc} of liquid.

The data for carbon dioxide cannot be used without extreme extrapolation.

In the following table, t^0 is the temperature of vaporization, p is the pressure in atmospheres, d_1 is the weight in grams of 1^{cc} of liquid at t^0 and under p pressure, d_2 is the weight in grams of 1^{cc} of saturated vapor at t^0, v_2 is the volume of saturated vapor at t_0 produced from 1^{cc} of liquid at t^0, K_2 is the dielectric constant of the saturated vapor and K_1 that of the liquid, both at t^0 and under p pressure.

	t^0	p	d_1	d_2	v_2	K_2	K_1	Q	A10⁴
SO_2	23°	3·60[1]	1·37[1]	0·0107[1]	128	1·031[1]	14·8[3]	114[2]	140
NH_3	18°	7·89[1]	0·612[1]	0·0055[5]	111	1·058[4]	20[6]	181[2]	175
H_2O	140°	3·57[1]	0·95[7]	0·0020[7]	475	1·027[4]	40	481[7]	154

[1] Tabellen; L. and B.
[2] Tabellen; by interpolation and computing for 1^{cc}.
[3] Linde; Wied. Ann. lvi, 563 (1895).
[4] Bädeker; Zeitsch. phys. Chem. xxxvi, 305 (1901). By interpolation and calculating to p by Boltzmann's rule.
[5] Calculated by Boyle-Avogadro law.
[6] Franklin and Kraus; Am. Chem. Journ. xxi, 14 (1899).
[7] From Tabellen dp/dT between 135° to 145° = 77·2^{mm} Hg. Taking 0·95 as the density of liquid water at 140°, we have $v_2 = 475$ and

$$Q = \frac{413(475-1)7.72 \cdot 13.6}{42750} = 481 \text{ cals.}$$

Substituting these values in 5, we get for A the values given in the last column. They were considered close enough to warrant further research, particularly as the uncertainties in the tabulated data are unknown and a slight change in K makes a large difference in A. For instance, putting 1·030 instead of 1·027 for the dielectric constant of water vapor gives 0·0173 for A instead of 0·0154.

In continuation of this line of work, a simple investigation seemed to be one into the heats of solution. Carbon compounds in carbon solvents were chosen to avoid complications which might arise from the presence of a metallic component and because a considerable quantity of necessary data had already been accumulated.

The dielectric constants were measured by the method of Drude.* It seemed advantageous to put a layer of sheet rubber on the secondary coil of the Tesla transformer and to wind the three turns of the primary on that instead of on a

* Wied. Ann., lxi, 466 (1897). Drude's Ann., viii, 336 (1902).

wood cylinder. Perhaps in view of the recent research by Drude* that was not a good plan, but these determinations were finished before this last work of Drude came to my notice. The use of mercury for the inside coating of the Leyden jar was a great convenience, for then the capacity could be adjusted with great nicety. The vacuum tube for the detector was on the Nernst† plan.

The length of the induced wave in air was 71·5^{cm} and this was the second wave from the exciter, not the one taking in the brass tubes. The stationary bridge was always grounded.

The acetone for standardizing came from Eimer and Amend. No mark. It was changed into the acid sodium sulphite compound and this decomposed by chemically pure normal sodium carbonate. The liquid was dried over calcium chloride for twenty-four hours and distilled from fresh calcium chloride. Its boiling point was 56·8° to 57·8° cor., barometer = 763^{mm} at 22°.

The benzene for standardizing came from Kahlbaum. Marked "Crystall." Tested for thiophene but none found. Not otherwise examined or purified since an accuracy greater than 5 per cent. could not be obtained when the dielectric constants were so low as that of benzene.

The average room temperature was 22°, ranging from 19° to 25°.

Two sets of three double observations each of the wave lengths were measured, the two sets being made at different times, though with the same solutions. The mean of these two sets was subtracted from the zero point, that is, from the position of the slide when the condenser was replaced by a metallic bridge, and the dielectric constant read off from the calibration curve. The zero point was determined every day and was the average of three observations. Two independent series of observations were made for the calibration curve, one at the commencement of the measurements of the dielectric constant and one at the end of all the measurements. These two series were plotted and form the calibration curve. Each series consisted of two sets of three double observations, the two sets being made at different times but with the same solutions. So the curve is the result of 12 observations at each point of plotting. Notwithstanding much care, the curve was not all that could be desired, for at times an observation or a number of them would slip far away from neighboring ones.

The solvents and solutes have already been described in preceding papers. The solutions were made by placing the solutions, saturated at a higher temperature, in running city

* Drude's Ann., ix, 293, 590 (1902). † Wied. Ann., lx, 303 (1897).

water and letting them stand over night. That gave plenty of time for proper separation and the temperature of the running city water was very constant, ranging from 22·0° to 22·8° cor. An ordinary thermostat could not have been used below 30° on account of the hot summer weather, and then would have come the trouble with crystallization when the solutions were cooled to the room temperature to go into the condenser.

The dielectric constants for the solid solutes were obtained by melting and letting them solidify in the condenser. When the series of measurements with the solid solutes was finished, the condenser was filled with pure acetone and the dielectric constant measured again. No change in value could be detected, showing no change in the position of the condenser plates.

The conductivity of the solutions was found to be so low that there was no danger of interference from that source. The highest conductivity was that of acetamid in water = 0·0018 coulombs per sec. through 1^{cc} at 1 volt *p. d.*, while the lowest was $< 0{\cdot}0_6 2$ coulombs per sec. through 1^{cc} at 1 volt p. d. and this was a solution in toluene.

The dielectric constants are given in the large table together with their estimated uncertainties. Also the function $1-9/(K+2)^2$ with its "mean uncertainty." This "mean uncertainty" is found by computing the function when the estimated uncertainty is added to K and when it is subtracted from K, which two values will be quite unequally distant from $1-9(K+2)^2$ when K is small, and taking the mean of these differences from the function when the experimentally observed value of K is used. When K is greater than 16, the value of the function is about the same whether the uncertainty in K is added to K or subtracted from it.

The densities of the solutes, solvents, and solutions are needed to find their volumes. The densities of the last two have already been determined,* but not the densities of all the solutes. Landolt and Börnstein quote some data from Schroeder and others, but the trouble which Schroeder had with air bubbles made his results a little questionable and a redetermination of them seemed desirable, while at the same time the necessary new data could be obtained.

The densities were found by weighing in saturated solutions of kerosene or of amyl alcohol, according to the nature of the solid. Kerosene was excellent; only naphthalene, acenaphthene, and phenanthrene were too soluble in it; for these, amyl alcohol was used. The air bubbles with kerosene were insignificant, but with amyl alcohol they were sometimes quite annoying and could not be altogether removed, but those left are not believed to have influenced the second decimal place at

* This Journal, xiv, 293 (1902).

all; the data are to be considered correct in all cases to and including the second decimal place. Boiling the amyl alcohol under reduced pressure diminished the air bubbles somewhat. The best way to remove them seemed to be to roll the specific gravity flame round and round after displacing some of the liquid with the proper quantity of solid. In this way a large number of air bubbles were loosened and rose to the surface, but not all; for after the weighings were completed, another rolling would show a few more air bubbles. In the worst case, those remaining had a volume of perhaps $(2^{mm})^3$, hardly more, so in this worst case the error due to air bubbles fell within the uncertainty due to variation in the temperature of the thermostat.

The solutes were purified carefully as in the earlier investigations.

The process consisted in saturating the kerosene or amyl-alcohol with the solid whose density was to be determined, finding the density of this saturated liquid in a specific flask holding 25^{cc}, and displacing some of the liquid by a known weight of the solid as powder or small crystals. From 4 to 11 grams of solid were used.

The weighings were not reduced to vacuo because the temperature of the thermostat varied through a range of 0·2°.

Two altogether independent determinations were made. The temperature of the thermostat was 22·2°±0·1 uncor. The experiments were simple and need no detailed description.

The data are given in the table below, the mean values being used in the large table further on. L. and B. signify Landolt and Börnstein's Tabellen.

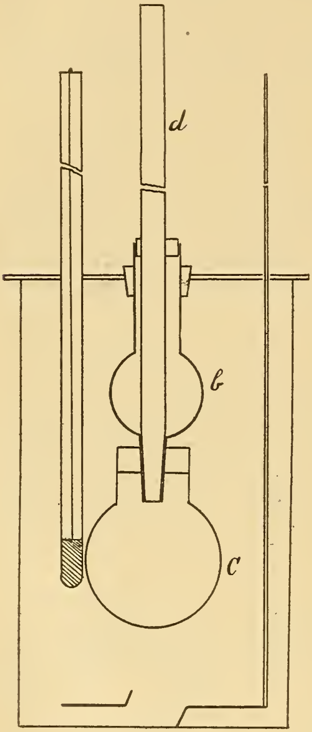
WEIGHT IN GRAMS OF 1^{cc}.

Urea	1·322	1·315	Mean=	1·318	L. and B.	1·33
Urethane	1·133	1·139	"	1·136		
Chloral hydrate	1·900	1·894	"	1·897	"	1·86
Succinimid($C_4H_5O_2N$)	1·408	1·406	"	1·407		
Acetamid	1·127*	1·129†	"	1·128	"	1·159
Resorcinol	1·274	1·272	"	1·273	"	1·283
Mannitol	1·486	1·480	"	1·483	"	1·488
Benzamid	1·267	1·275	"	1·271	"	1·341
p-Toluidin	1·122	1·124	"	1·123	"	1·046
Acetanilid	1·204	1·207	"	1·205	"	1·211
Naphthalene	1·169	1·176	"	1·172	"	1·145
Acenaphthene	1·205	1·201	"	1·203‡		
Phenanthrene	1·179	1·181	"	1·180		

* Some crystals contained large bubbles.
† Fused and powdered.
‡ Bubbles = $(2^{mm})^3$.

The benzamid used came from Kahlbaum and had a melting point of 126·5° cor. which did not change on one recrystallization from ethyl alcohol, so the large difference between these values and the one quoted by L. and B. is unexplained. In the case of *p*-toluidin, the difference may be due air bubbles with Schroeder.

The next thing to be determined was the heat of formation of the saturated solution from solute and solvent.



The calorimeter used is figured here. The large glass beaker held 500^{cc} water comfortably. The spherical portion of *c* held 25^{cc}. In this was the solute, small crystals or coarse powder. From 7 to 22 grams of it. The vessel *b* held about 4^{cc} and contained the solvent in such quantity that when run into *c*, a fairly thick paste was formed and there was no reasonable doubt that the solvent became saturated before the end of the experiment. It was run in at the proper time by raising the long ground glass stopper *d*. From 0·7 to 6·7 grams of solvent. The vessel *b* was securely fastened by a cork into the cover of the calorimeter and supported *c* by a water-tight rubber stopper. The vessel *c* was weighed with solute in it before submersion in the calorimeter and afterwards when the observation of the thermometer was finished. The increase in weight gave the quantity run in from *b*. The solubilities being known,* the composition of the solution formed could be calculated. The thermometer and platinum stirrer were those used in an earlier investigation into the heat of formation of highly dilute solutions.† The calorimeter stood in a bright tin vessel which in turn stood in another bright tin vessel submerged to the rim in a thermostat at 22·3°±0·1, the space between being packed with cotton.

An experiment was made to see if the large excess of solute

* This Journal, xiv, 293 (1902).
† Journ. Am. Chem. Soc. xviii, 146 (1896).

would absorb enough saturated solution on its surface to affect the temperature. Propyl alcohol saturated with acenaphthene, which dissolves very slightly in it, as liquid was used and acenaphthene as solid. The quantities were 3·1 grms. of saturated solution and 5·6 grms. of acenaphthene. After 5 mins. the mercury had risen 0·001° while the regular rise per minute before running in the liquid was 0·0001°. This lay within the uncertainty of reading and the conclusion was drawn that the surface action was too slight to be noticed.

The thermometer was read by a telescope and under favorable circumstances 0·001° could be estimated, but in general this was not possible and so the thermometer readings are to be considered uncertain to ±0·001°.

The correction for radiation was deduced on the assumption that the change in temperature of a body is proportional to the difference between its temperature and that of its surroundings. Let T be the total change in temperature of the calorimeter from the time of running in the solvent to the time it is saturated, t_1 be the change in temperature at the end of the first minute after running the solvent in, Δt_1 be the average change per minute of the calorimeter for 10 mins. before running in the solvent, and Δt_2 be the average change per minute for 10 mins. after the solvent is saturated. The change T is always a drop, always $-$. So for the first minute the correction is

$$-\left[\frac{\mathrm{T}-t_1}{\mathrm{T}}\Delta t_1+\frac{t_1}{\mathrm{T}}\Delta t_2\right] .$$

and for the second minute

$$-\left[\frac{\mathrm{T}-t_2}{\mathrm{T}}\Delta t_1+\frac{t_2}{\mathrm{T}}\Delta t_2\right]$$

and for the n^{th} minute

$$-\frac{n\mathrm{T}\Delta t_1+(t_1+t_2+\ .\ .\ .\ .\ t_n)(\Delta t_2-\Delta t_1)}{\mathrm{T}},$$

n being the number of minutes needed for the solvent to get saturated, beginning from the time the solvent was run into c. This was shown by the mercury beginning to rise after its fall or by Δt_2 being less than Δt_1 if Δt_1 was negative. Sometimes the external temperature would change during an experiment in such way that Δt_2 and Δt_1 got opposite signs, and sometimes when T was small $\Delta t_2=\Delta t_1$, and it became very difficult to fix on a proper value for n. In general, n was less than 40 mins., but once it rose to 102 mins. and once fell to 8 mins.

The water equivalent of the calorimeter and fittings contained an uncertainty of less than 0·2 per cent. In calculating the water equivalent of the solution, 0·5 was taken as the specific heat of the solute and that value given in L. and B.'s Tabellen as the specific heat of the solvent, and the sum of these as the specific heat of the solution. The quantity of solution was small in comparison with the 500^{cc} of water and so this introduces an uncertainty of likewise less the 0·2 per cent. of the total water equivalent.

Let q be the total water equivalent, then the heat of solution is $(T \pm 0{\cdot}001)\,(q \pm 0{\cdot}001q)$. Let n be the number of grammolecules of solute in 100 grammolecules of saturated solution, m the molecular weight of the solute and M that of the solvent, w be the weight of solvent run into c and d the weight of 1^{cc} of solute, that is, its density. Then letting Q refer to 1^{cc} of solute we have

$$(T \pm 0{\cdot}001)\,(q \pm 0{\cdot}001q)\,\frac{100-(n \pm \Delta n)}{n \pm \Delta n}\,\frac{M}{m}\,\frac{d}{w} = Q \pm \Delta Q.$$

The expressions Δn and ΔQ represent the uncertainties in the respective quantities; Δn, the uncertainty in reading n from curve; ΔQ, the uncertainty due to the uncertainties on the left. These uncertainties on the left were combined to make a maximum effect and a minimum effect and the mean of these two values was taken as Q, the variation of this mean value from either of the extreme values giving ΔQ.

The quantities M, m, w and d were taken without any uncertainty; the molecular weight, because M and m contain about the same elements, and being in the form of a quotient the uncertainties have a small effect upon Q; w and d, because their uncertainties lie in the third decimal place. The atomic weights used are C = 12, H = 1, O = 16, N = 14, Cl = 35·4. The uncertainty in reading from the solubility curve was never more than 0·4 grammolecules and usually not more than 0·2 grammolecules; that is (Δn was never $> 0{\cdot}2$ and usually $\Delta n = 0{\cdot}1$).

The heats of solution are given in the large table following.

The densities of solvents and solutions were taken from plots of published data and will be found in the large table with their uncertainties.

In applying equation 5 to the present system, we must remember that the initial state involves two bodies, solvent and solute, while the final state involves only one, the solution. Putting the volume of the solute for convenience equal to 1^{cc}, we have from 4 or from 5

$$\frac{\left(\frac{9}{(K_1''+2)^2}-1\right)v_1''-\left[\left(\frac{9}{(K_0''+2)^2}-1\right)v_0''+\frac{9}{(K_0'''+2)^2}-1\right]}{Q}=A. \quad (6)$$

Here K_1'' is the dielectric constant of the saturated solution and v_1'' is the volume of the saturated solution produced from 1^{cc} of the solute, K_0'' is the dielectric constant of the solvent and v_0'' the volume of the solvent needed to make a saturated solution with 1^{cc} of the solute, K_0''' is the dielectric constant of the solute, Q is the heat of solution in small calories of 1^{cc} of solute in the necessary quantity of solvent to make a saturated solution at t°, the temperature of solution.

These quantities, together with those needed to get them, are given in the following table, in which the additional symbols are used of $_0'''$ for pure solute, of $_0''$ for pure solvent, of $_1''$ for solution :—

d_0''' = density of solute
d_0'' = " solvent
d_1'' = " solution
n = per cent. grammolecules of solute
$N = 100 - n$
w_0'' = weight of solvent = $(NM/nm)d_0'''$
v_0'' = volume of solvent $= w_0''/d_0''$
v_1'' = " solution $= (w_0''+d_0''')d_1''$
$f_0''' = 1-9/(K_0'''+2)^2$
$f_0'' = 1-9/(K_0''+2)^2$
$f_1'' = 1-9/(K_1''+2)^2$
e = the numerator of 6.

An absence of a ± quantity implies a corresponding absence of uncertainty.

	t_0 cor.	d_0'''	d_0''	d_1''	n	w_0''	v_0''	v_1''	K_0'''	K_0''	K_1''	f_0'''	f_0''	f_1''	e	Q	$\Lambda 10^4$
H_2O																	
Urea	22·1°	1·32	1·00	1·15	24·5 ± 0·1	1·22	1·22	2·21	3·5 ± 0·2	77	90 ± 5	0·70 ± 0·02	0·999	0·999	0·29 ± 0.02	65·3 ± 0·9	44·4 ± 3·6
Urethane	21·7°	1·14	"	1·07	35·5 ± 0·2	0·416	0·416	1·46	4·0 ± 0·2	"	32 ± 1	0·75 ± 0·02	"	0·992	0·28 ± 0·02	55·9 ± 0·7	50·1 ± 4·2
Chloral hyd.	21·8°	1·90	"	1·56	40·8 ± 0·2	0·352	0·352	1·44	3·4 ± 0·2	"	33·5 ± 1	0·69 ± 0·02	"	0·993	0·39 ± 0·02	31·3 ± 0·4	125 ± 8
Succinimid $C_4H_5O_2N$	22·3°	1·41	"	1·07	5·2 ± 0·1	4·65 ± 0·09	4·65 ± 0·09	5·66 ± 0·08	2·9 ± 0·2	"	58 ± 1	0·62 ± 0·03	"	0·997	0·36 ± 0·20	75·9 ± 2·5	48·3 ± 27·9
Acetamid	21·7°	1·13	"	1·04	40·7 ± 0·1	0·499	0·499	1·57	7·2 ± 0·2	"	90 ± 5	0·89	"	0·999	0·18	49·5 ± 0·5	36·3 ± 0·3
Resorcinol	21·8°	1·27	"	1·13	17·8 ± 0·1	0·965	0·965	1·98	3·2 ± 0·2	"	47·5 ± 1	0·67 ± 0·02	"	0·996	0·34 ± 0·02	41·6 ± 0·5	82 ± 6
Mannitol	22·0°	1·48	"	1·06	1·8 ± 0·1	8·09 ± 0·46	8·09 ± 0·46	9·03 ± 0·43	3·0 ± 0·2	"	77 ± 2	0·64 ± 0·03	"	0·999	0·30 ± 0·92	50·3 ± 4·5	76 ± 190
CH_3OH																	
Urea	22·1°	1·32	0·79	0·87	10·4 ± 0·2	6·05 ± 0·10	7·66 ± 0·13	8·46 ± 0·10	3·5 ± 0·2	31 ± 1	44 ± 1	0·70 ± 0·02	0·991	0·996	0·14 ± 0·25	52·8 ± 2·1	28 ± 48
Urethane	21·6°	1·14	"	1·00	55·5 ± 0·1	0·327	0·413	1·47	4·0 ± 0·2	"	18·0 ± 0·5	0·75 ± 0·02	"	0·997	0·28 ± 0·02	46·5 ± 0·3	60 ± 4
Acetanilid	22·2°	1·20	"	0·88	10·5 ± 0·1	2·44 ± 0·02	3·08 ± 0·02	4·12 ± 0·02	3·0 ± 0·2	"	37 ± 1	0·64 ± 0·03	"	0·994	0·41 ± 0·07	36·1 ± 0·9	114 ± 22
Naphthalene	22·1°	1·17	"	0·81	1·8 ± 0·1	16·02 ± 0·92	20·23 ± 1·16	21·27 ± 1·14	2·7 ± 0·2	"	30 ± 1	0·59 ± 0·35	"	0·991	0·43 ± 2·63	48·1 ± 5·1	145 ± 559
C_2H_5OH																	
Urea	22·0°	1·32	0·79	0·81	4·0 ± 0·1	24·30 ± 0·63	30·71 ± 0·80	31·59 ± 0·78	3·5 ± 0·2	21·5 ± 0·5	25·0 ± 0·5	0·70 ± 0·02	0·984	0·988	0·29 ± 1·29	62·7 ± 5·2	64 ± 211
Urethane	21·6°	1·14	"	0·97	52·0 ± 0·1	0·544	0·688	1·73	4·0 ± 0·2	"	16·0 ± 0·5	0·75 ± 0·02	"	0·972	0·25 ± 0·02	48·4 ± 0·4	52 ± 4
Chloral hyd.	21·5°	1·90	"	1·39	51·3 0·2	0·502 ± 0·004	0·635 ± 0·005	1·73	3·4 ± 0·2	"	13·0 ± 0·2	0·69 ± 0·02	"	0·960	0·35 ± 0·02	51·7 ± 0·9	67 ± 2
Succinimid $C_4H_5O_2N$	21·8°	1·41	"	0·81	2·3 ± 0·1	27·88 ± 1·24	35·25 ± 1·57	36·34 ± 1·54	2·9 ± 0·2	"	23·0 ± 0·5	0·62 ± 0·03	"	0·986	0·53 ± 3·09	105 ± 6	67 ± 299
Acetamid	22·0°	1·13	"	0·88	35·6 ± 0·1	1·59	2·02	3·09	7·2 ± 0·2	"	45·0 ± 1	0·89	"	0·996	0·20	53·3 ± 0·6	36 ± 1
Resorcinol	22·0°	1·27	"	1·04	40·3 ± 0·1	0·786 ± 0·003	0·995 ± 0·005	1·98	3·2 ± 0·2	"	11·5 ± 0·5	0·67 ± 0·02	"	0·950 ± 0·004	0·24 ± 0·02	24·9 ± 0·3	96 ± 9
p-Toluidin	21·7°	1·12	"	0·93	50·0 ± 0·1	0·481	0·608	1·72	3·0 ± 0·2	"	10·0 ± 0·5	0·61 ± 0·03	"	0·937 ± 0·005	0·38 ± 0·03	38·0 ± 0·3	100 ± 9
Acetanilid	21·8°	1·20	"	0·85	9·4 ± 0·1	3·94 ± 0·04	4·98 ± 0·05	6·02 ± 0·06	3·0 ± 0·2	"	29·0 ± 0·5	0·64 ± 0·03	"	0·991	0·42 ± 0·14	46·2 ± 1·1	105 ± 37
Naphthalene	21·5°	1·17	"	0·81	3·3 ± 0·1	12·33 ± 0·39	15·58 ± 0·50	16·47 ± 0·29	2·7 ± 0·2	"	22·0 ± 0·5	0·59 ± 0·03	"	0·984	0·22 ± 0·82	53·8 ± 3·5	51 ± 156

	t_0	d_0'''	d_0''	d_1''	n	w_0''	v_0''	v_1''	K_0'''	K_0''	K_1''	f_0'''	f_0''	f_1''	e	Q	$A10^4$
C_3H_7OH																	
Urethane	20·9°	1·14	0·81	0·95	52·5 ±0·1	0·695	0·863	1·94	4·0 ±0·2	18·0 ±0·5	15·51 ±0·5	0·75±0·02	0·978	0·97	0·29 ±0·01	43·0 ±0·3	67±3
Naphthalene	22·0°	1·17	0·80	0·82	3·8 ±0·1	13·90 ±0·38	17·28 ±0·48	18·36 ±0·46	2·7 ±0.2	"	18·0 ±0·5	0·59±0·03	"	0·98	0·45 ±0·94	56·7 ±3·5	98±163
$CHCl_3$																	
Urethane	21·2°	1·14	1·49	1·27	54·8 ±0·1	1·26 ±0·01	0·846	1·89 ±0 01	4·0 ±0·2	4·0 ±0·2	10·5 ±0·3	0·75±0·02	0·750 ±0·017	0·942	0·40 ±0·03	40·9 ±0·4	97±9
Chloral hyd.	21 6°	1·90	"	1·52	19·3 ±0·1	5·73 ±0·03	3·85 ±0·02	5·02 ±0·02	3·4 ±0·2	"	6·2 ±0·3	0·69±0·02	"	0·866±0·010	0·76 ±0·17	38·0 ±0·9	98±8
Acetanilid	21·3°	1·20	"	1·44	11·3 ±0·1	8·29 ±0·11	5·56 ±0·07	6·59 ±0·08	3·0 ±0·2	"	9·8 ±0·3	0·64±0·03	"	0·935	1·34 ±0·28	32·4 ±1·2	202±49
Naphthalene	21·5°	1·17	"	1·30	30·2 ±0·1	2·52 ±0·01	1·69	2·84	2·7 ±0·2	"	3·3 ±0·2	0·59±0·03	"	0·679±0·004	0·08 ±0·06	36·2 ±0·4	22±17
Acenaphthene	21·4°	1·20	"	1·36	21·2 ±0·1	3·45 ±0·02	2·31 ±0·01	3·42	3·0 ±0·2	"	3·7 ±0·2	0·64±0·03	"	0·723±0·019	0·10 ±0·14	30·3 ±0·5	34±46
C_7H_8																	
Urethane	21·7°	1·14	0·863	0·897	19·2 ±0·1	4·96 ±0·03	5·74 ±0·03	6·80 ±0·03	−4·0 ±0·2	2·3 ±0·2	3·0 ±0·2	0·75±0·02	0·513 ±0·045	0·640±0·029	0·66 ±0·49	21·5 ±0·8	315±240
Chloral hyd.	21·9°	1·90	"	0·979	13·1 ±0·1	7·01 ±0·07	8·12 ±0·08	9·10 ±0·08	3·4 ±0·2	"	3·0 ±0·2	0·69±0·02	"	0·640±0·029	1·23 ±0·48	40·0 ±1·4	312±131
Naphthalene	22·6°	1·17	"	0·912	22·5 ±0·1	2·89 ±0·02	3·35 ±0·02	4·45 ±0·02	2·7 ±0·2	"	2·8 ±0·2	0·59±0·03	"	0·609±0·033	0·40 ±0·35	49·0 ±0·8	83±73
Acenaphthene	22·0°	1·20	"	0·915	15·4 ±0·1	3·94 ±0·03	4·57 ±0·03	5·62 ±0·03	3·0 ±0·2	"	2·8 ±0·2	0·64±0·03	"	0·609±0·033	0·44 ±0·46	32·1 ±0·9	141±147
Phenanthrene	21·7°	1·18	"	0·931	21·0 ±0·1	2·29 ±0·01	2·65 ±0·01	3·73 ±0·01	2·9 ±0·2	"	2·3 ±0·2	0·62±0·03	"	0·513±0·045	−0·6 ±0·32	21·3 ±0·5	−24±150

Collecting for discussion, including the vaporization data, we have

		Δ	Δ^2	
140		+ 44	1936	140 − 72 = 68
175		+ 79	6240	175 − 72 = 103
154		+ 58	3364	154 − 72 = 82
44	± 4	− 52	2704	44 + 72 = 116
50	± 4	− 46	2116	50 + 72 = 122
125	± 8	+ 29	841	125 − 72 = 53
48	± 28	− 48	2304	48 + 72 = 120
36	± 0	− 60	3600	36 + 72 = 108
82	± 6	− 14	196	82 + 72 = 154
76	± 190	− 20	400	76 + 72 = 148
28	± 48	− 68	4624	28 + 72 = 100
60	± 4	− 36	1296	60 + 72 = 132
114	± 22	+ 18	324	114 − 72 = 42
145	± 559	+ 49	2401	145 − 72 = 73
64	± 211	− 32	1024	64 + 72 = 136
52	± 4	− 44	1936	52 + 72 = 124
67	± 2	− 29	841	67 + 72 = 139
67	± 299	− 29	841	67 + 72 = 139
36	± 1	− 60	3600	36 + 72 = 108
96	± 9	± 0	0	96 = 96
100	± 9	+ 4	16	100 − 72 = 28
105	± 37	+ 9	81	105 − 72 = 33
51	± 156	− 45	2025	51 + 72 = 123
67	± 3	− 29	841	67 + 72 = 139
98	± 163	+ 2	4	98 − 72 = 26
97	± 9	+ 1	1	97 − 72 = 25
98	± 8	+ 2	4	98 − 72 = 26
202	± 49	+ 106	11204	202 − 72 = 130
22	± 17	− 74	5475	22 + 72 = 94
34	± 46	− 62	3844	34 + 72 = 106
315	± 240	+ 219	47950	315 − 72 = 243
312	± 131	+ 216	46660	312 − 72 = 240
83	± 73	− 13	169	83 + 72 = 155
141	± 147	+ 45	2025	141 + 72 = 69
−24	± 150	− 120	14400	−24 + 72 = 48
96 = Mean			174287 = $\Sigma\Delta^2$.	

The mean error of a single determination is therefore

$$\sqrt{\frac{174287}{34}} = \sqrt{5126} = \pm 72$$

and the mean error of the mean, 96, is

$$\frac{72}{\sqrt{35}} = 12.$$

The probable errors for single determinations and for the mean determination are respectively

$$\tfrac{2}{3}72 = 48 \text{ and } \tfrac{2}{3}12 = 8.$$

At first inspection these figures are discouraging, but when we find the mean error of a single determination to be 72 and then find that this mean error will more than bring 29 out of the 35 determinations into the mean of the whole, namely 96, and that 5 of the 6 exceptions have experimental errors of their own more than sufficient to bring them also into the mean, and that the other one has an unknown experimental error, the final result is not so bad and there is nothing to disprove the correctness of equation 4 and the constancy of the quotient e/Q. In other words, that the heat of a change comes from a change in the field surrounding us and that this change is measured by the dielectric constants of the components of the system, is an assumption in agreement with the foregoing experiments.

Rutgers College, New Brunswick, N. J.
February, 1903.

Art. VII.—*Some Notes on the Genus Baptanodon, with a Description of a New Species;* by Wilbur C. Knight.

It was many years ago that Marsh described Baptanodon (Sauranodon*), and with the exception of a very short paper† by the same author in which he describes a new species, nothing has been written to give us a better understanding of the peculiar American Ichthyosaur until Charles Gilmore published some additional and valuable information very recently in Science.

Yet we do not know very much about this peculiar swimmer, and a great deal of information is desirable before it will be possible to say with any certainty, whether there is any great difference between Baptanodon and Opthalmosaurus or not. Several paleontologists have already expressed themselves in the belief that these genera are identical. For a number of years specimens have been accumulating in the collection of the University of Wyoming, and from these some valuable points have been secured. From what I know of Baptanodon I am in favor of retaining the name. In the following notes will be found some argument favoring this generic name and showing how that Baptanodon differs from Opthalmosaurus.

Front Limb of Baptanodon.—Humerus about one-third the length of the limb, with a stout twisted shaft that is greatly compressed near the distal end. Planes passed through the articulate ends of the humerus stand at an angle of 50°. The head is slightly rounded and is almost identical with Ichthyosaurus. There are three distal facets; but they are not of equal size. The facet for the ulna is the largest, the one for the radius next in size, and the one opposite the pisiform is rudimentary, for that bone was held in cartilage and did not articulate with the humerus. These facets are elliptical in form, and those opposite the ulna and radius elongated in the plane of articulation in place of being vertical to it, as they are in Opthalmosaurus. The radius is a subangular bone, with the exterior margin reduced to a thin edge that is nearly straight. It is also larger than the ulna, which is slightly hexagonal in shape. The pisiform is subcircular in form and is the smallest bone of the second segment of the limb. The next segment is composed of four subcircular bones as noted by Marsh, but the succeeding row is composed of only three bones. The largest appears to have been formed by the consolidation of three elements. This might have been considered as an indi-

* This Journal, xvii, 85.

† Ibid., xix, 169, 491.

vidual characteristic had I not found it in at least three animals. The limb that I have been studying and have figured differs from the one published by Marsh, inasmuch as the abnormal number of digits do not appear until the phalanges are reached, and then by a division of the third digit. This information has been secured from a specimen in the matrix and is absolutely reliable. The carpals, metacarpals and phalanges are compressed grooved cylinders, the most of which have slightly concave surfaces. The grooves are ornamented with tuberosities for muscular attachment. Along the margins of the limb the cylinders have their exterior borders reduced to quite thin edges. Any one finding the limb of a Baptanodon for the first time scattered about in the field would surely

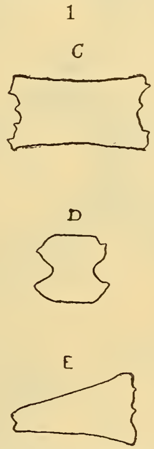


FIGURE 1. C.—Transverse section of an interior carpal; D.—Terminal carpal; E.—Marginal carpal. All reduced one-half.

try to fit the ventral and dorsal surfaces of the metacarpals together in trying to construct a digit.

In comparing the limbs of Opthalmosaurus and Baptanodon one should consider the following points: In Baptanodon the humerus is about one-third the length of the arm; it has a twisted shaft which is greatly compressed. The distal facets are all unequal in size and one of them is merely rudimentary, besides they are elliptical in the plane of articulation. There is also an abnormal number of digits, and the arm is much more powerful and larger than found in Opthalmosaurus of equal size. The indications are that Baptanodon was a remarkable swimmer.

Hind Limb.—The hind limbs in the collection are too fragmentary to admit of accurate determinations. The femora examined all have two facets only. I was not satisfied with

2

FIGURE 2.—Right pectoral limb, dorsal aspect, reduced about 2½ times.

the material in hand and wrote Dr. Beecher concerning the material at Yale University, and he informed me that the ones examined by him in the Yale collection had but two facets, and that the humerii had three but one was very small. The fact that Baptanodon so far as known has but two elements articulating with the femora is worthy of special consideration.

Vertebral Column.—The specimen S in the Wyoming collection contains 41 precaudal vertebræ. These are consecutive and represent the series from the head backwards. The atlas and axis are so completely fused that there is not the slightest trace of their union. Anteriorly the first vertebra (atlas and axis) is only slightly excavated; but upon this elongated vertebra there are two normal or almost normal processes. The first vertebra (atlas and axis) is 41^{mm} in length, and the second is only 31^{mm} long. There is no intercentra between these (the second and third) vertebræ. It is also questionable whether there is any between the atlas and axis and the axis and the basiocipital. If they are present they are so perfectly anchylosed to the centra as to make it impossible to distinguish them. I have only examined a single specimen, and while I think it possible that all of the intercentra have disappeared, it will be desirable to make further examinations before this point can be passed upon. In specimen S the vertebræ gradually increase in length and width from the atlas and axis to No. 19; the third vertebra being 31^{mm} long and 80^{mm} wide and the nineteenth 41^{mm} long and 90^{mm} wide. These are separated by intercentra measuring from 10 to 15^{mm}. From No. 19 backwards to the end of the series the vertebræ decrease slightly in length and width. In specimen T in the same collection there are 46 consecutive caudal vertebræ. These are of the usual ichthyosaurian type, and represent an animal that had an extremely long and slender tail. The reduction in the size of the vertebræ occurs very near the body and within a distance of a few inches the vertebræ decrease in diameter over one-half. The vertebræ in the area of reduction have reduced margins, in fact in two of them the articulations nearly meet upon the side of the centrum. This signifies that the tail was extremely flexible near the body, which would make it of great value in swimming, and without question this animal could lash its sides with its tail. I have not noted anything of this kind in the genus Ichthyosaurus. Although caudal vertebræ from at least a half dozen different animals have been examined, no trace of chevrons has been observed, and the vertebræ lack chevron facets.

Pectoral Girdle.—The coracoids are broadly elliptical bones, anteriorly deeply and broadly notched; posteriorly circular. They thicken rapidly from the center to the interior margin of the anterior half into a large elliptical facet with a rugose surface. A facet measured 81 by 123mm. These facets unite on the median symphysis, which must have made the girdle very ridged during life. There was no evidence of an inter-

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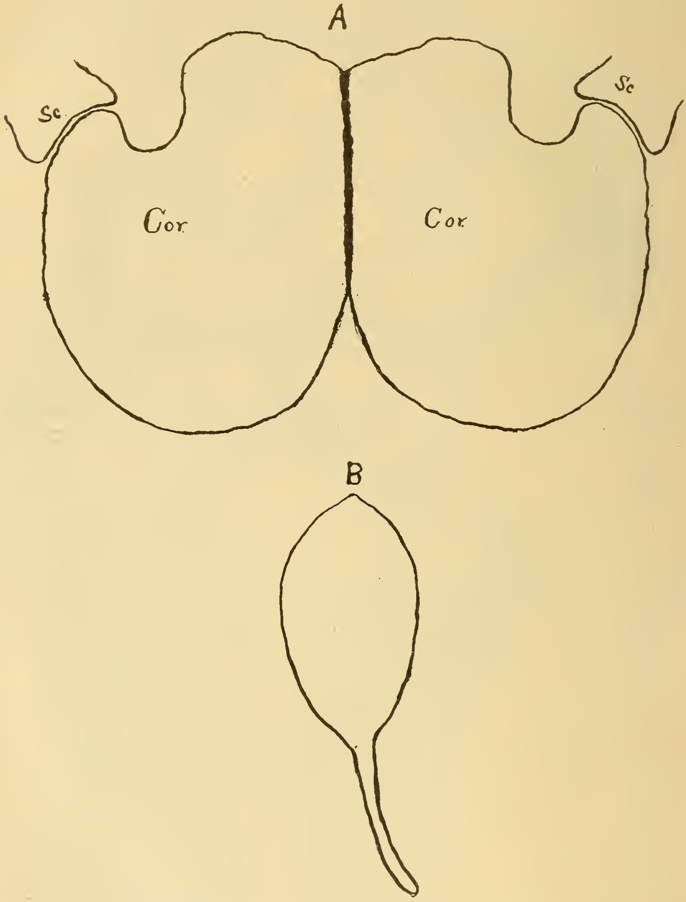

FIGURE 3. A.—Pectoral girdle incomplete, about $\frac{1}{5}$ natural size; B.—Outline of the interior margin of coracoid, about $\frac{1}{5}$ natural size.

clavicle, and the peculiar union of the coracoids precludes an interclavicle of the regular Ichthyosaurian type. In consequence the interclavicle in Baptanodon must be considered rudimentary or wanting. The scapulæ are rather heavy bones, with broad notched proximal ends, that fit the projection of the coracoids between the anterior notch and the glenoid cavity. Clavicles are unknown to me.

The most of the above information has been taken from the S skeleton of the Wyoming collection, and I have found it impossible to include this in the species already described and for that reason propose the name of *Baptanodon Marshi*, in honor of Prof. O. C. Marsh, who originated the generic name Baptanodon. The accompanying figure of a front limb can be considered as typical for this species.

Some Measurements for Baptanodon Marshi.

	M.
Humerus.	
Length	·190
Prox. width	·127
Prox. thickness	·080
Distal width	·130 +
Distal thickness	·050
Facet for ulna, length	·080
Facet for radius, length	·050
Facet for pisiform, length	·010 ?
Ulna,	
Width	·069
Length	·054
Radius,	
Width	·065
Length	·046
Pisiform,	
Width	·036
Length	·054
Coracoid,	
Length	
Width	
Median facet,	
Length	·123
Width	·081

In comparing Baptanodon with Opthalmosaurus it will be well to consider that in Baptanodon the interclavicle is either rudimentary or wanting, the absence of the intercentra between the second and third vertebræ, the development of the large facets upon the interior margins of the coracoids, the striking differences in the development of the limbs, causing Baptanodon to have been a much more powerful swimmer than its European ally.

Geological Laboratory, University of Wyoming.

Art. VIII.—*The Characters of Pteranodon;* by G. F. Eaton. (With Plates VI and VII.)

A careful preparation of Pterodactyl material from the Niobrara Cretaceous of western Kansas has been commenced at the Yale University Museum, for the purpose of adding an example of one of the gigantic species of the genus *Pteranodon* Marsh, to the series of restorations of fossil vertebrates recently attempted with success. Preparatory to this work, a critical examination both of the fossils themselves and of the literature based upon them has been made, and an excellent opportunity has been thus afforded to extend our knowledge of the skeleton of *Pteranodon*, in regard to several important points of structure. This, in turn, may be of great value in determining the true position of the genus among the Pterodactyls.

The large collection of these reptiles made by Prof. Marsh and his assistants in the field, during a period including the years 1870 to 1894, and representing, according to Prof. Marsh, the fossil remains of more than six hundred individuals, was never completely examined and described by him. His series of papers upon this unique order, which appeared in this Journal, 1871 to 1882, were, at the time of publication, considered by him as little more than preliminary notices. No detailed work on the American Pterodactyls ever issued from his hands, as his attention was constantly diverted by the acquisition of other and not less valuable vertebrate fossils.

His researches both in field and in laboratory having awakened the interest of the scientific world in the Kansas Pterodactyls, it is not surprising to find other collectors and authors engaged in similar investigations. While part of Prof. Marsh's earlier work on this group was performed in a somewhat hurried manner, the accuracy with which he seized upon important osteological characters is amazing. In one instance, at least, his opinion, after having been disputed almost to the point of ridicule, proves to be much more correct than that advanced by his critic. Considering his great talent and the abundance of material at his command, it is to be regretted that Prof. Marsh did not pursue the study further before laying it aside. Had he done so, he would have prevented the misconceptions which have lately gained credence.

The Sagittal Crest.

The most important correction to the prevailing idea of *Pteranodon* is to be made in regard to the sagittal crest. Prof. Marsh in describing the skull makes use of the following words (this Journal, vol. xxvii, May, 1884): "an enormous sagittal crest extends far backward, and somewhat upward." The accuracy of this statement is denied by Prof. S. W. Williston (Kansas Univ. Quarterly, vol. i, No. 1, July, 1892), whose views have been accepted largely because of the fact that he collected the head of Marsh's type of *Pteranodon*. Material in the Yale Museum now shows that, contrary to Williston's opinion, the elongation of the crest, as figured by Marsh, was too conservative. Reference to Plate VI, figure 1, will show its true form, taken from an actual specimen, which is indicated by the continuous line. Marsh's incomplete restoration is shown by the dotted line, while Williston's figure of the skull, shorn of its crest, is reproduced carefully in figure 2. Prof. Marsh laid emphasis on this character, and it is of great importance that this error be corrected at once. Following Williston's lead, Dr. S. P. Langley and Mr. F. A. Lucas, both of the Smithsonian Institution, have perpetuated the error in their respective papers in the Annual Report of that Institution for 1901.

In justice to Williston, it is perhaps only fair to quote him verbatim (loc. cit.): "As stated by me in the American Naturalist, the type specimen of *Pteranodon*, also collected by myself, was incomplete, and the figures of it, as given by Marsh, are faulty." This statement can not be gainsaid. The type suffered through the rough methods of collecting employed in those days; but the following clause has been shown above to be incorrect: "The sagittal crest is large, but not nearly so large as it is figured by Marsh, the outline of whose figure is undoubtedly wrong."

To assign the cause of mistake on the part of another writer may be considered a work of supererogation, yet I am tempted to offer here a possible explanation of Williston's misinterpretation of the sagittal crest of this reptile. At the present time of writing, an incomplete Pterodactyl skull is being worked out at the Yale Museum, which will in all probability prove to be that of *Nyctodactylus* Marsh. The crest, which is apparently entire, is of small size compared with that of *Pteranodon*, the measurement from occipital condyle to tip of crest being only 49^{mm}, while the length from occipital condyle to tip of beak was approximately 47^{cm}. In general, the skull compares favorably with that shown in Williston's restoration of *Nyctodactylus* given in the American Journal of Anatomy, vol. i, No. 3, May 26, 1902, where he states that the outline is taken in part from a specimen of *Pteranodon* Marsh, or *Ornithostoma* Seeley, as the genus was then called. It is therefore fair to infer that the apparent similarity of the two genera led Williston to draw unintentionally upon the characters of *Nyctodactylus* when making his restoration of *Pteranodon.*

The Suspensorium.

Another remarkable character of the skull of *Pteranodon*, which belongs apparently to *Nyctodactylus* also, is the articulation of the mandibles with the quadrates. The distal end of each quadrate has the form of a spiral groove, left-handed in the right quadrate and right-handed in the left. The articular elements of the mandibles have a reciprocal form. So perfect is the mutual adjustment of these parts that, unless actual dislocation took place, the act of opening the mouth must have resulted either in a considerable widening of the lower jaws posteriorly or in the forcing together of the quadrates. Apparently the pterygoids and palatines serve as a rigid and immovable support to the quadrates, a condition which would render movement of the latter impossible. In such case an expansion of the lower jaws is, in my judgment, the only way by which the lateral motion caused by the spiral articulation could be taken up mechanically; and this in the face of the seemingly inflexible mandibular symphysis and the thorough union of the mandibular elements.

The existing vertebrate offering the closest parallel in this respect to *Pteranodon* is the Pelican. A careful inspection of the suspensorium of this peculiar bird reveals a similar spiral articulation between quadrates and mandibles, and it is recorded that in the Pelican the act of opening the mouth results also in the widening of the jaws posteriorly. There has been some speculation in regard to the habits of the American Pterodactyls, but no definite conclusions have yet been reached. Possibly the mechanical similarity between the mandibular suspensorium of the Pelican and that of *Pteranodon* is to be received as evidence of the possession of a gular pouch by this Pterdactyl as well as by the bird.

Mr. Lucas has apparently arrived at the same conclusion along another line of evidence. He says (loc. cit.): "In the peculiar shape of the lower, back portion of the beak there is a suggestion of the former presence of a small pouch, like that found in cormorants, and this would be in accord with the supposed fish-eating habits of *Ornithostoma*" (*Pteranodon* Marsh).

The Pelvis.

A nearly perfect pelvis, recently worked out at the Yale Museum, throws much light on the discussion of the characters of this important part of the skeleton of *Pteranodon*, which has not been thoroughly understood and described by paleontologists. Three diagrams of this specimen are here given, showing the side, top, and bottom views (Plate VII, figures 1, 2, and 3, respectively). It is not my intention at this time to enter into a detailed description of the pelvic characters. Indeed, at present, it is necessary to publish little more than the diagrams, which may prevent any further serious misinterpretation of the pelvis.

Ten vertebræ firmly anchylosed together form the sacral series, using this term in its broader sense. The upper ends of the neural spines of all these vertebræ are united in a continuous ridge about 9^{mm} wide and about 6^{mm} in vertical depth (Plate VII, figure 1). The general form of the transverse processes of the three anterior vertebræ in this series, and their union with the ilia, are sufficiently well shown in the accompanying diagrams (Plate VII, figures 2 and 3). The first vertebra bears anterior zygapophyses for articulation with the last free dorsal; and the transverse processes of the first three vertebræ have on their lower surfaces small facets for the support of ribs. One of these posterior ribs still lies upon the third vertebra, with little displacement from its original position. The transverse processes of vertebræ 4, 5, 6, and 7, depart widely from the foregoing simple arrangement. They are likewise separated by large foramina, but they unite again laterally and form a continuous support for the ilia. The lower ends of the transverse processes of vertebra 4 extend downward and backward, as stout buttresses, finally becoming confluent with the inferior margins of the ilia. The three remaining vertebræ, numbers 8, 9, and 10 of this series, bear short transverse processes, separate at their distal ends, upon which the ilia rest posteriorly.

The ilia extend forward as broad, thin blades, supported, at their inner margins, by the transverse processes of the anterior sacral vertebræ. Posteriorly they unite over the neural spines of the last three sacrals, and are anchylosed to them as well as to the transverse processes. The united pubes and ischia are directed downward and backward, and meet below in a long median symphysis. The obturator foramina lie just beneath the imperforate acetabula. They are circular in form, of about half the diameter of the acetabula, and may be considered as marking the theoretical line of fusion between the true pubic and ischial elements. On the anterior border of these ischiopubic expansions are small facets, which undoubtedly served for the attachment of prepubes. In no specimen in the Yale Collection has a prepubis yet been found in place.

Paleontologists will perhaps disagree on the number and position of true sacrals in *Pteranodon*. It will be remembered that Huxley, when confronted with a similar problem in the avian sacrum, chose the intervertebral foramina as the best criteria for distinguishing true sacrals from sacro-dorsals and uro-sacrals. In the present fossil specimen there are, of course, no nerves to serve as guides, but I hope to show in a subsequent paper that vertebræ 5, 6, and 7, which clearly form a natural division, are the true sacrals. Vertebra 4 may prove to be the homologue of the last lumbar vertebra in the sacrum of recent birds. In closing I should like to state, with due apologies to Prof. Lydekker, that the "parallel" between the sacrum of *Pteranodon* and that of recent birds is striking, though I have no desire to postulate "converging lines" of structure and descent.

Paleontological Laboratory, Yale University Museum,
June 8, 1903.

EXPLANATION OF PLATES.

Plate VI.

Figure 1.—Restoration of skull of *Pteranodon.*
True outline of sagittal crest is shown by continuous line. Marsh's restoration of sagittal crest is shown by dotted line. One-sixth natural size.

Figure 2.—Enlargement of Williston's diagram of skull of *Pteranodon.* Approximately one-quarter natural size.

Plate VII.

Figure 1.—Pelvis of *Pteranodon* ; side view.
Figure 2.— " " ; top view.
Figure 3.— " " ; bottom view.
All three figures are one-half natural size.

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SKULL OF PTERANODON.

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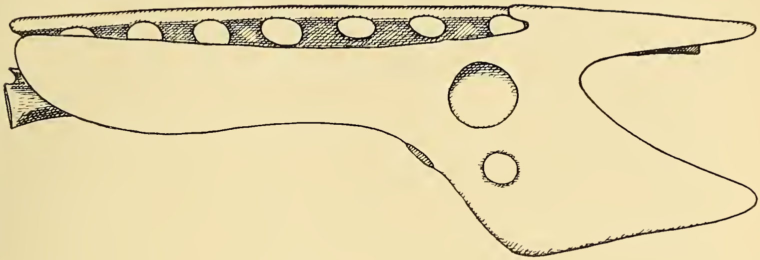

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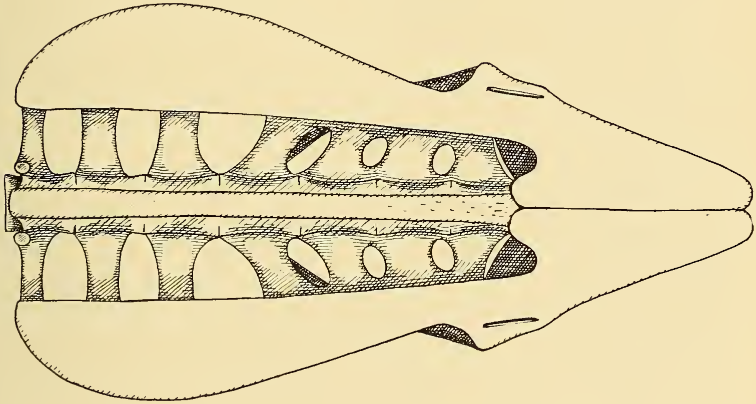

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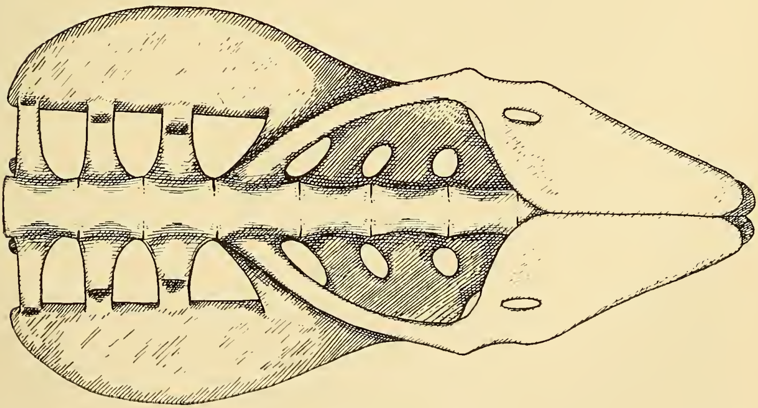
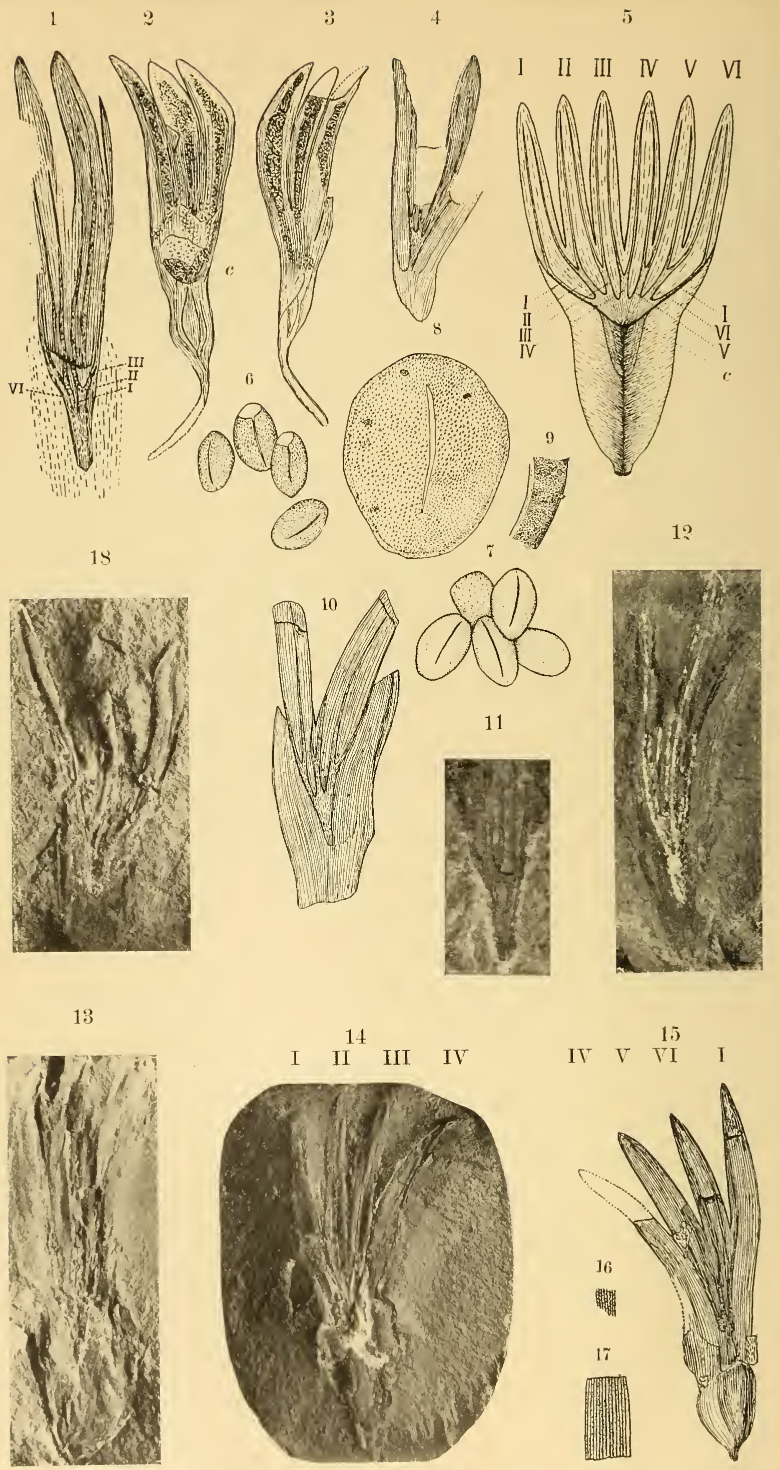


Pelvis of Pteranodon.



Codonotheca, a New Type of Spore-bearing Organ.

ART. IX. — *Codonotheca, a New Type of Spore-Bearing Organ from the Coal Measures;** by E. H. SELLARDS. (With Plate VIII.)

THE iron-stone nodules of Mazon Creek, Illinois, which have preserved so many interesting fossils, contain not infrequently an isolated, but unique, and as yet undescribed type of fructification. The conditions of preservation in these nodules are such that by careful developing it is possible to make out many of the details of structure of the fossils contained in them. In the present case, the abundance of material at hand, and the unusual organization of the reproductive organ give an especial interest to the study. It is the purpose of the present paper to describe the structure of this peculiar type, in so far as the material at hand will permit, in the hope that a description of the fructification will lead to its recognition in collections from other localities in this and foreign countries, and to the determination of the plant to which it belongs. The collections from the Mazon Creek locality in museums, especially of this country, are generally quite extensive and some of these may be found to contain specimens throwing new light on the relation of this fructification.

The spore-bearing organ is a symmetrical cup- or bell-shaped body, made up of a circle of six equidistant, lamina-like, spore-bearing divisions, arising at a common level, united laterally at the base, free at the tips, thus surrounding a central cavity; each division is traversed on the inner or spore-bearing side by two strong bundles supplied by the dichotomy of six main strands; the union of the laminæ and bundles below forms a cylindrical base, while the whole organ is borne on a slender petiole. The base, which seems to have consisted for the most part of an external envelope of non-resistant fleshy tissue, is usually more or less completely flattened in the fossil condition. It is traversed by lines, often wavy and irregular, lying near the surface and extending along the dorsal side of the spore-bearing divisions, probably representing subepidermal bands of strengthening tissue. The fusion of the six main vascular strands forms a cone-shaped area of resistant tissue at the center of the base, large at the top where it breaks up into strands, pointed below where it is replaced by less resistant tissue. This area occasionally retains its cylindrical shape (figs. 1 and 11, Pl. VIII). The six strands originating at a common level from this central area diverge and dichotomize also at approximately the same level. The twelve bundles formed by this dichotomy pass into the six spore-bearing divisions, which

* Abstracted from a thesis submitted to the Graduate Faculty of Yale University, May, 1903, for the degree of Doctor of Philosophy.

for convenience will be spoken of in this paper as spore-bearing segments, or simple segments. The distribution of the bundles to the segments is characteristic. Each individual segment is supplied not by the two bundles resulting from the dichotomy of a single main strand, but receives one bundle from each of two adjacent strands (compare figs. 1, 4, 11, 15, and the plan of structure, fig. 5, Pl. VIII). This peculiarity in the arrangement of the bundle system can be verified from numerous specimens, and is one of the prominent structural features of the organ of fructification. The free tips of the segments occasionally stand open, thus retaining in part their original shape, owing probably to their having been quickly buried in sediment. By carefully removing the matrix which fills the cone-shaped cavity enclosed by the segments, it is possible to examine the six parts in place. The two figures, 14 and 15, illustrate a specimen worked out in this way, as seen from the two sides. The matrix filling the cavity formed by the expanded segments was removed intact and has the shape of a cone flattened laterally, on which is preserved the impressions of the six spore-bearing segments. On refitting the two parts of the nodule together, there results an elliptical cavity, large at one end corresponding to the top of the organ, and becoming smaller and disappearing toward the crushed base. The shape of the organ is thus partly preserved in this nodule, being simply compressed laterally. On looking into the cavity a very satisfactory idea of the shape and arrangement of the parts, and of the whole organ as it appeared in life is obtained. The outline restoration of this fructification given in the accompanying text figure is based on this and similar specimens. The plan of structure of the organ (fig. 5, Pl. VIII) represents the hollow top as unrolled and the solid base as cut through the center and laid open. The section is made to pass between segments I and VI, hence directly through strand number I. The letter *c* marks the bottom of the cavity enclosed by the segments.

Codonotheca; restoration of the spore-bearing organ. Natural size.

Considerable variation in size is evident in the series of specimens. Those of an average size measure 3 to 5^{cm} from the base to the tips. The width at the top is about $1\frac{1}{3}$^{cm}. The segments above the point where they become free are $1\frac{1}{2}$ to 2^{cm} long and $2\frac{1}{2}$ to 3^{mm} wide. The petiole is incomplete, the longest observed being a little over 1^{cm}. When well preserved the petiole shows a netlike structure made by strong longitudinal striæ and weaker cross lines, suggesting the structure occasionally seen on the leaves of some *Cordaites* (fig. 16, Pl. VIII).

Spores.—Much interest is attached to the presence of the spores and the position in which they lie. In the best-preserved specimens the spores lie over the segments from the tip to the base, and seem to be confined to a more or less well-marked depression occupying one-half or two-thirds the width of the segment. In such spore-bearing segments as are crushed laterally, at the side of the fossil, the spores are pushed to the inner side, indicating that they were contained in sporangia or chambers near the inner surface, and apparently were not, as might otherwise have been thought possible, held loosely in a central cavity of the segment after the manner of moss sporogonia ; in the latter case the spores would appear along the center line of the segment, however crushed. There is no grouping of the spores or other indications of the location of sporangia, which were doubtless more or less completely immersed in the tissue. In order to contain even a few of these large spores the sporangia would necessarily be of large size and if external in position would probably have left definite impressions in the stone, as do the sporangia of most other plants in these nodules. The spores seem to have been scattered somewhat, owing probably to the disappearance of the walls of the sporangia at maturity, so that in the fossil they run together and entirely fill the depression in which they lie.

From the position of the spores, the sporangia appear to have been located along the vascular bundles. Inasmuch as they have not been seen, no attempt is made to represent them in the restoration. The spores are large, elongate-elliptical, 0·29 to $0{\cdot}31^{mm}$ long and 0·18 to $0{\cdot}20^{mm}$ wide. They are brown in color, somewhat flexible, and section readily on the microtome.* The spore wall consists of an inner, compact layer, and an outer much thicker layer which appears granular in microtome sections seen under a high power. A slit is usually present in the side of the spore, apparently indicating bilateral division from the spore mother-cell. The spores occasionally contain small round grains with dark centers, doubtless representing a part of the original food supply. In size and shape, the spores rather closely resemble those of *Dolerophyllum*, except that there is but a single slit in the side, instead of two furrows as described for that genus. The spores (pollen grains) of *Dol-*

* The spores may be imbedded by the ordinary methods ; less time, however, is necessary for dehydrating, and the paraffin bath may be brought to any desired temperature.

erophyllum are contained in a boxlike excavation in the fleshy tissue of the reduced leaf.* There is apparently nothing in the structure of the spore itself, as preserved, to determine whether the plant was homosporous or heterosporous. From their large size the spores might be taken for megaspores. Bilateral megaspores, however, although seemingly occurring rarely, are exceptional among vascular cryptogams. A careful search has been made through all the available material, amounting to about seventy-five specimens (with in most cases their counterparts), many of which have the spores preserved, but no evidence of two kinds of spores has been found. This negative evidence, although hardly conclusive, is entitled to considerable weight. In view of the abundance of material, the chances are very great that if two kinds of spores existed both would be present. The conclusion that the plant was homosporous is, therefore, reasonably certain, unless the second kind of spore proves to have been borne by a differently constructed organ.

The generic name *Codonotheca* is proposed for this type of spore-bearing organ. The type species here described may be known as *Codonotheca caduca.*

Botanical Relations.—The botanical relations of this unusual fructification are as yet very uncertain. The spore-bearing organ seems to have been readily deciduous, and thus far has not been found in connection with the vegetative part of the plant. Two of the fossils lie side by side on one of the nodules in such a way as to indicate that both were probably attached by long petioles to a common stem. At one side and at a slightly lower level is seen a slender striated stem; but the actual connection is not preserved. Three other specimens lie near each other on the same nodule. It has been assumed in the above description that the six parts of the organ are sporangia-bearing divisions. A second hypothesis may perhaps suggest itself, namely, that the parts are themselves enormous sporangia united at the base somewhat after the manner of such genera as *Botryopteris*, *Zygopteris*, and some of the small species referred to *Calymmatotheca.* Their great size and especially the presence of well-developed vascular strands running through them is, however, much against, if not fatal to, such a supposition. Even a slight development of vascular tissue within the walls of a sporangium is unusual, although such may occasionally occur, as shown in a recent paper by Prof. F. W. Oliver.† It seems hardly possible, therefore, that the spore-bearing segments can be individual sporangia, because of their large size and especially the prominence of the vascular

* Renault, Bassin houiller et Permien d'Autun et d'Epinac, p. 266, 1890.

† On a Vascular Sporangium from the Stephanian of Grand Croix, The New Phytologist, vol. i, p. 60, March, 1902.

strands running through them. On the contrary, the organ appears to be made up of six lamina-like fertile divisions, united in a circle at the base so as to enclose a central cavity, the sporangia being borne on the inner side and probably partly or entirely immersed in the fleshy tissue.

It seems wholly improbable that *Codonotheca* can have any direct or close connection with the mosses or other plants lower in the scale of development than the vascular cryptogams. It is true that a water-conducting tissue is rather well developed in the stem of some mosses, and to some extent in the sporogonia of a few genera, but a well-developed vascular system, such as this organ possesses, is at present entirely unknown in any plant below the Pteridophytes. On the other hand, the unusual structure of the reproductive organ makes it difficult to determine the systematic position of the genus among the vascular plants. The spore-bearing region of the known Paleozoic and recent Equisetales is typically a cone formed by the shortening of the internodes of the main axis, or of the axis of a branch. The cone is made up of several to many nodes and internodes. Each node may bear a whorl of fertile sporophylls, or fertile and sterile whorls may alternate or be variously modified according to the genus. In the extinct Sphenophyllales, the cone is also formed by a shortening of the internodes of the axis, and the fertile sporophylls are borne in whorls at the nodes. The sporangia of the Lycopodiales are borne at the base of the sporophylls, which usually form a cone. The ferns, although a more varied class, seem to include no type whose fundamental structure is comparable to that of *Codonotheca*. Some species of *Schizæa*, as *S. pennula*, have a cluster of similarly shaped sporangia-bearing divisions, but these have external dorsal sporangia with a ring of thick-walled cells at the top, and lack entirely the unusual cyclic arrangement and the fleshy petiolate base characteristic of *Codonotheca*. It is also evident that this new type can have no connection with such ferns as the Hymenophyllaceæ, in which the elongated receptacle, bearing the sporangia, is surrounded by an indusium-like outgrowth of the lamina. The extinct fernlike genera *Botryopteris* and *Zygopteris*, which have sporangia clustered at the ends of slender peduncles, do not seem to admit of comparison with *Codonotheca* except on the hypothesis, which appears to me untenable, that the six divisions of the organ are so many large sporangia.

For many years numerous plants have been known from the Paleozoic, having a stem structure resembling that of the ferns on the one hand, and the cycads on the other, but so different in many ways from both as to be with difficulty included in either. Since 1899* these plants have been united to form an

* Potonié, Lehrbuch der Pflanzenpalaeontologie, p. 160.

intermediate group, the Cycadofilices, the more generalized divisions of which are believed to form, to some extent at least, a connecting series between the ferns and cycads. The stem structure indicates considerable diversity among the several divisions of the group. Unfortunately hardly anything is known of the fructification. Certain sporangia of the *Calymmatotheca* type have been found so closely associated with one genus of the Cycadofilices, *Lyginodendron*, as to make their connection probable.* *Lyginodendron* has finely divided foliage, and is one of the more fernlike of its class. The small species of *Calymmatotheca* found in association with *Lyginodendron* have large sporangia grouped in a cluster at the end of a petiole, free at their tips, free or united at their bases, and borne on dimorphic fronds. A number of other plants of various structure have been referred to *Calymmatotheca*. The largest of these and also the first described species of the genus, *C. Schimperi* Stur, is an imperfectly known fossil. According to Stur† the plant consists of six parts, 18^{mm} long, united at the base by threes, and is apparently entirely different from many of the smaller species which have been referred to the genus.

Aphlebiocarpus Stur is another imperfectly understood genus of unknown affinity.‡ This remarkable fructification consists of about five foliar parts, more or less deeply lobed or fringed, arranged in an involucre-like whorl. According to Stur, the sporangia are small, solitary, and deep set, and are placed thickly over the upper or inner surface of the "involucre." The spores are not described, and the vegetative part of the plant, except for the branching axis, is unknown.

Codonotheca suggests at first sight a possible resemblance to the male flowers of some gymnosperms. *Tumboa (Welwitschia)* has microsporophylls united in a circle at the base. The microsporophylls of the Mesozoic Bennettitaceæ, also, as Wieland has shown, are fused in a circle at the base. But the relation to these genera is probably not close, since the Bennettitaceæ, as well as *Tumboa*, seem to have an abortive, seed-bearing cone at the center.§

While the genus may find its place as an aberrant type among one of the well-known classes of Pteridophytes or even gymnosperms of Cordaitalean affinity, it may on the other hand

*Scott, Studies in Fossil Botany, pp. 334–336; Benson, Ann. Bot., vol. xvi, pp. 575–576, 1902.

†Die Culm-Flora der Ostrauer und Waldenburger Schichten, Abhandl. der k. k. geol. Reichsanst. zu Wien, vol. viii, p. 149, 1877.

‡Ibid., p. 304, pl. 37, 1877; Die Carbon-Flora der Schatzlaren Schichten, ibid., vol. xi, Abth. I, p. 15, 1885.

§Wieland, A Study of Some American Fossil Cycads, pt. iv, This Journal, vol. xi, p. 424, 1901.

prove to fall within the comparatively varied but less well-known Cycadofilices, as representative of a specialized division at present included in that group and which has suffered extinction. The plants to which the *Codonotheca* type of fructification belongs, as far as the arrangement of their spore-bearing organs is concerned, seem to have reached a comparatively specialized condition as early as the Upper Carboniferous. There are present in the Coal Measures and at the Mazon Creek locality several genera or groups of plants, the fructification of which is either unknown or but imperfectly understood. Conspicuous among these, both from its large size and great abundance, is *Neuropteris*, especially the large species, *N. decipiens* Lesqx. Renault* and others have shown that the petiole of *Neuropteris* as well as that of *Alethopteris*, possesses the *Myeloxylon* type of stem structure. The Meduloseæ to which *Myeloxylon* belongs are regarded as a divergent branch of the Cycadofilices.† The only information regarding the fructification is that obtained by Kidston from a specimen of *N. heterophylla*, a species of the small-pinnuled division of the group.‡ Kidston's material was unfortunately poorly preserved, but served to indicate that the fronds were dimorphic, and that the spore-bearing organs were grouped in clusters at the ends of the slender petioles. There is reason for believing that the entire Neuropterid group was dimorphic. As a rule, those plants having the sporangia on the under side of the fronds, after the manner of ordinary ferns, not infrequently preserve impressions of the sporangia and sori. *Neuropteris* is abundant throughout the Coal Measures, and very large collections of Neuropterid fronds have been examined by various paleontologists without finding evidence of sporangia. The large fronds of *Neuropteris* would doubtless supply a considerable number of detached pinnules as compared with the number of fertile spore-bearing parts, however these may have been arranged. In the Yale University Museum collection, the proportion between *Codonotheca caduca* and *Neuropteris decipiens* is approximately one of the former to ten of the latter.§ Nevertheless, the fact should not be lost sight of that there are a number of other plants in the Coal Measures to any one of

*Renault, Affinités botaniques du genre *Neuropteris*, Comptes rendus, vol. lxxxiii, pp. 399–401, 1876.

†Scott, Studies in Fossil Botany, pp. 394–396. Compare also Solms-Laubach, Über *Medulosa Leuckarti*, Bot. Zeitung, Bd. lv, Heft x, pp. 175–202, 1897.

‡Trans. Roy. Soc. Edinburgh, vol. xxxiii, pt. i, p. 150, pl. viii, fig. 7, 1887.

§ The relative proportion, as here given, is based on the Yale collection from Mazon Creek, which contains 75 specimens of *Codonotheca* to some 1,200 of *Neuropteris*, 750–800 of which are *Neuropteris decipiens*.

which the fructification here described may belong, or that it may represent an entirely new plant.

My thanks are due Dr. Alexander W. Evans for references to recent botanical literature, and to Dr. David White and Dr. G. R. Wieland, as well as to Dr. Evans, for suggestions on the text and illustrations. Dr. E. R. Cumings has very kindly made most of the drawings. The material on which the study is based is contained in the fossil plant collection of Yale University Museum, made accessible to me through the kindness of Professor C. E. Beecher.

Paleontological Laboratory, Yale University Museum,
New Haven, Conn., April 2, 1902.

EXPLANATION OF PLATE.

Plate VIII.

Codonotheca caduca gen. et sp. nov.

Figure 1.—The fleshy covering has disappeared from this specimen by maceration, allowing the resistant area at the center, which still retains its cylindrical shape, to stand out prominently. Strands I to III and VI are visible, IV and V being hidden on the opposite side. Figure 11 is a photographic reproduction of a part of the same specimen with the covering removed, exposing strands IV and V. ×2.

Figures 2–3.—Obverse and reverse sides of a small specimen. The very numerous large spores lie in a depressed channel along the segments from the tip to the base. The cavity formed by the united bases of the segments ends at *c*. A part of the upper side of the covering is broken away near the bottom, allowing the spores to be seen within. The base of this specimen, as preserved, is comparatively slender and is traversed by wavy lines. A considerable part of the long slender petiole is preserved. Natural size.

Figure 4.—The two bundles supplying the segment, and their origin from two adjacent main strands below, are very well shown in this specimen. Natural size.

Figure 5.—Plan of structure of the spore-bearing organ. The top is represented as cut open and unrolled, the base as split down the center and laid open. The cut is represented as passing between segments I and VI, hence directly through strand number I. The end of the cavity is marked at *c*. The cylindrical area at the base first breaks up into six main strands (I to VI) which dichotomize and supply the twelve bundles to the spore-bearing divisions. Natural size.

Figure 6.—A group of spores imbedded in sphalerite, and having the surface ornamentation well preserved. ×28.

Figure 7.—Spores taken from the surface of the specimen illustrated in figure 2. ×28.

Figure 8.—A single spore; showing the slit in the side, indicating probably the bilateral division of the spore mother-cell. Several dark bodies, apparently representing stored food supply, are contained within the spore. ×85.

Figure 9.—Section through the spore wall; showing a thick granular outer, and a thin compact inner layer. ×200.

Figure 10.—The specimen illustrated by this figure has suffered lateral crushing, and the bundles are partly displaced. A few spores are still clinging to the surface. Natural size.

Figure 11.—Same specimen as figure 1. ×2.

FIGURE 12.—Photograph of a small specimen. The first segment on the right is seen from the dorsal surface, showing the parallel striæ. The next segment is seen from the ventral (inner) side. The two strong bundles traversing this segment can be traced in the photograph. The origin of these two strands from alternate strands below, which can be distinguished only by close scrutiny in the photograph, is very evident in the specimen. The outline of the resistant area formed by the union of the bundles below can be followed by its white micaceous coating such as often covers the fossils in these nodules. Natural size.

FIGURE 13.—The large base is here flattened. The striæ of the base are more or less disarranged and have a wavy course. Some of them seem to divide, and all converge to the point of attachment. The photograph also shows the cone-shaped resistant area at the center, which is large above where it breaks up into strands; pointed below. The first spore-bearing segment on the left is crushed, giving it an unnatural width. At the top of the next one is seen the dorsal surface marked by fine striæ. Farther down the segment is removed, leaving the impression of the ventral (inner) surface on which the two bundles supplying the segment are seen. At one point about half-way down, the break extends through to the opposite side of the organ and a few spores are seen in place on the opposite surface. Natural size.

FIGURES 14–15.—A specimen worked out so as to expose both sides of the organ. The base of this specimen is not entirely flattened, having partly retained its shape. The side illustrated in the pen drawing, figure 15, shows for the most part the impression (mold) of the outside surface. In places, however, the substance of the plant has clung to the mold. This is true of a part of the vascular system, and the tips of segments VI and I, giving an instructive view of the ventral (inner) surface. The two bundles are distinct, lie near the surface, and are rather widely separated. The segments have considerable thickness as seen in the break, being perhaps half as thick as wide. The impression made by the dorsal surface is longitudinally striate, as seen in the other segments of this and other specimens. The dorsal surface of the segment itself is represented in figure 17, showing the parallel striæ, and the minutely roughened or pitted surface. The photograph of the opposite side as it lies in the nodule, figure 14, gives a partial dorsal view of segments I and IV, which are crushed laterally and distorted. Segments II and III have retained their shape and are seen from the ventral (inner) view. The cone-shaped portion of matrix which originally filled the center of the organ is preserved in the Yale collection, and shows on one side, corresponding to the side from which the photograph was made, the impressions of the ventral side of the segments; while on the other side, that from which the mold serving as the basis of figure 15 came, the dorsal surface of the segments (except the tips of VI and I) are seen. Natural size.

FIGURE 16.—Enlarged detail of the petiole; showing the strong striæ and weaker cross lines. ×3.

FIGURE 17.—Enlarged detail of dorsal surface of the segment. ×3.

FIGURE 18.—An average specimen. Natural size.

Art. X.—*Note on the Dates of Publication of Certain Genera of Fossil Vertebrates;* by Lucy P. Bush.

Several years ago while carrying on bibliographic work under the direction of the late Professor Marsh, personal search resulted in the acquisition of exact data relating to the generic names of certain vertebrates, the use of which by various authors is not uniform. In the interest of science, it seems wise to give these facts publicity. The object of the present note, however, is not to decide whether the vertebrate fossils in question should be classed under a given genus; it is merely to show which term has priority, leaving the subject of synonymy to others more competent to judge in such matters.

Cardiodon and *Cetiosaurus.*

Cardiodon Owen, April, 1841, Odontography, vol. i, pt. ii, p. 291.
Cetiosaurus Owen, 1841, Proc. Geol. Soc. London, for June 30, vol. iii, pt. ii, No. 80, p. 460.

The dinosaurian genus *Cardiodon* was founded by Owen in 1841, on "an almost heart-shaped form of tooth" (*Odontography*, vol. i, pt. ii, p. 291). The work in which the name first occurs was published in three sections, and the second part, containing the paragraph relating to *Cardiodon*, appeared between April 15 and May 1, 1841.* As the paper in which

* The Publishers' Circular, London, notes the date of publication of each part of Owen's Odontography, as follows:—

Part I (Dental System of Fishes, pp. 1–178), between March 16 and April 1, 1840 (see Circular for April 1, 1840, vol. iii, p. 96).

Part II (Dental System of Reptiles, pp. 179–295), between April 15 and May 1, 1841 (ibid. for May 1, 1841, vol. iv, p. 116).

Part III (Dental System of Mammals, pp. 296–655), before March 2, 1846 (ibid. for March 2, 1846, vol. ix, p. 80; and The English Catalogue of Books published from January, 1835, to January, 1863, p. 577, 1864).

The foregoing work was issued in two editions—a quarto edition in two volumes and a royal octavo edition in two volumes. Copies of both these editions are in the library of Yale University Museum, and the pagination, numbering of plates, etc., are identical in the two. The dedication is dated June 18, 1845; the title page, preface, and table of contents were undoubtedly printed when the work was completed, while the introduction may have been in part published at the same time as the third and last section (Circular, vol. ix, p. 80), although some of it appeared earlier, as shown by the following statement taken from The Life of Richard Owen (vol. i. p. 181, 1895):—"On April 27 [1841], as the diary shows, the Introduction was printed."

Each of the 168 plates constituting vol. ii of Odontography is dated at the bottom. Those accompanying Part I (Plates 1–61, 62*B*) bear the date 1840. The plates in Part II (Plates 62–75*a*, exclusive of 62*B*) are dated as follows: Plates 62, 62*A*, 63, 64–66, 68, 70–75, 1840; Plates 63*A*, 63*B*, 67, 69, 1841, and Plate 75*a*, 1844. In Part III (Plates 76–150), Plates 77–79, 81–84, 87, 91–93 are dated 1840; Plates 76, 80, 85, 86, 89, 89*A*, 94, 1841; Plates 87*a*, 101, 106, 129, 130, and 143, 1844, while Plates 90, 95–100, 102–105, 107–128, 131–142, the genus *Cetiosaurus* was proposed was not read until June 30, 1841 (Proc. Geol. Soc. London, vol. iii, pt. ii, No. 80, pp. 457–462), it is evident that *Cardiodon* may be justly given precedence in time.

Figures of the tooth representing the latter genus are shown in *Odontography*, Vol. II, Plate 75*a*, figure 7, *a–d*. The legend at the bottom of this plate states that the latter was "published by H. Baillière, 1844." In the explanation to the plate (loc. cit., p. 20), the specific name *Cardiodon rugulosus* is proposed. Four species of *Cetiosaurus* were named and described in the Report of the British Association for 1841, pp. 94–102, London, 1842. In the case of neither genus, however, were any species noted in the original description.

Entelodon and *Elotherium*.

Entelodon Aymard, 1846, Ann. Soc. d'Agric., Sci., Arts et Commerce du Puy, tome xii, for 1842–1846, p. 227, 1 planche. Reprint, p. 1, 1 planche, 1848.

Elotherium Pomel, 1847, Bull. Soc. Géol. France (2), vol. iv, p. 1083.

In April, 1894, Professor Marsh prepared a paper on the *Restoration of Elotherium*, and in looking up the literature previous to publication it was found that much confusion existed in regard to the early nomenclature of the group. Few, if any, authors have recognized the fact that the suilline genus *Entelodon* (Ann. Soc. d'Agric., Sci., etc., du Puy, vol. xii, 1846) is prior in date to *Elotherium* (Bull. Soc. Géol. France (2), vol. iv, 1847), Aymard's paper on the former being almost invariably quoted as 1848. Before Professor Marsh's article was printed no data were obtained of sufficient accuracy to warrant the adoption of *Entelodon*, yet facts were subsequently acquired proving that *Elotherium* should be assigned a second place.

Through the courtesy of Baron de Vinols, President of the Society of Agriculture, Science, etc., at Puy, and recently of M. Léopold Delisle, General Administrator of the National Library of Paris, it has been learned that Vol. XII of the Annals of the Puy Society, containing Aymard's paper, was printed by Gaudelet at Puy, in 1846. In his letter on this subject, Baron de Vinols states: "Ce qui a pu faire confondre la dâte de 1846 avec celle de 1848 c'est que cette dernière dâte est sur

144–150 were printed in 1845. Plates I and II published with Part III are general and are dated 1845.

The facts given in a note by W. H. Brown (Woodward and Sherborn's Catalogue of British Fossil Vertebrata, London, 1890, p. xxix) do not coincide with those here stated.

la couverture extérieure du livre et la dâte de 1846 est dans l'intérieur."

In the library of the Yale University Museum, there is a perfect reprint of Aymard's original article (pp. 1–45), also printed by Gaudelet at Puy. On the title page of this extract the year 1848 appears, indicating that separate copies were not published until two years later than the volume of Annals containing the original description of *Entelodon*.

Two species, *Entelodon magnus* and *E. Ronzonii*, are defined by Aymard in his original paper; the former is regarded as the type, and is figured in the plate (figures 1–4) accompanying the article.

Bothriodon, *Ancodus*, and *Hyopotamus*.

Bothriodon Aymard, 1846, Ann. Soc. d'Agric., Sci., Arts et Commerce du Puy, tome xii, pp. 239, 246 (note). Reprint, pp. 15, 22 (footnote), 1848.

Ancodus Pomel, 1847, Arch. Sci. Phys. Nat., Genève, tome v, p. 207.

Hyopotamus Owen, 1848, Quart. Journ. Geol. Soc. London, vol. iv, p. 104, pls. vii, viii.

The argument relating to the genus *Entelodon* likewise applies to the name *Bothriodon*, the latter having been proposed by Aymard in Vol. XII of the Annals of the Society at Puy, in 1846. In regard to the genera *Ancodus* and *Hyopotamus* Dr. O. P. Hay in his recent *Bibliography and Catalogue of the Fossil Vertebrata of North America* (Bull. U. S. Geol. Surv., No. 179, p. 652, 1902) states that *Ancodus* antedates *Hyopotamus*. It will be seen, however, that *Bothriodon* has claim to priority over both the other genera.

In his original paper, Aymard proposes two species of *Bothriodon*, which he regarded as a subgenus: "l'une, *à museau très large* [*botriodon platorynchus*]; l'autre, *à museau étroit* [*bot. leptorynchus*]." He further states: "Il y en a une troisième beaucoup plus petite, qui pourra conserver le nom de *velaunus*, imposé par Cuvier à l'espèce type."

The data here presented led Professor Marsh to adopt the use of the generic names *Cardiodon* (Cetiosaurus),* *Entelodon* (Elotherium),† and *Bothriodon* (Ancodus, Hyopotamus), although the last term has not his sanction through publication.

Paleontological Laboratory, Yale University Museum, June 1, 1903.

* This Journal (3), vol. i, p. 496, December, 1895; The Dinosaurs of North America, 16th Ann. Rept. U. S. Geol. Surv., p. 242, 1896.

† Johnson's Universal Cyclopædia, vol. viii, p. 498, fig. 47, 1895; Vertebrate Fossils of the Denver Basin, Mon. U. S. Geol. Surv., vol. xxvii, pp. 522, 523 (fig. 97), p. 548, and pl. xxx, 1897.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The Spinthariscope.*—In connection with a discussion of certain properties of radium emanations, Sir William Crookes describes a striking phenomenon produced upon the zinc sulphide screen by the heavier, non-deflectable, positive atoms emitted by radium. He says: "If a solid piece of radium nitrate is brought near the screen, and the surface examined with a pocket lens magnifying about 20 diameters, scintillating spots are seen to be sparsely scattered over the surface. On bringing the radium nearer the screen the scintillations become more numerous and brighter, until when close together the flashes follow each other so quickly that the surface looks like a turbulent, luminous sea. It seems probable that in these phenomena we are actually witnessing the bombardment of the screen by the positive atoms hurled off by radium with a velocity of the order of that of light: each scintillation rendering visible an impact on the screen, and becoming apparent only by the enormous extent of lateral disturbance produced by its impact. Just as individual drops of rain falling on a still pool are not seen as such, but by reason of the splash they make on impact and the waves they produce in ever widening circles."

The spinthariscope, devised for observing this phenomenon, consists of a brass tube with a blende screen at one end of it which has a speck of radium salt in front of it and about a millimeter off, and a lens at the other end which can be accurately focussed upon the screen.—*Chem. News*, lxxxvii, 241. H. L. W.

2. *Properties of Sodium Sulphate Solutions.*—It is well known that sodium sulphate with ten molecules of water of crystallization is deposited from solutions below 32·38°, while the anhydrous compound is formed at higher temperatures. No evidence has been obtained heretofore that water combines with sodium sulphate while the latter is in solution. Marie and Marquis have, therefore, undertaken the investigation of this question by a new method. They determined the solubility of sodium chloride in a given solution of sodium sulphate at temperatures varying from 14·8° to 34·28°. It was expected that a sudden change in the solubility would occur if at some point the sodium sulphate molecules formed a combination with water. No such sudden change was observed, for the results when plotted gave a perfectly regular curve. Consequently, there is no reason for supposing that the salt with ten molecules of water exists in solution.—*Comptes Rendus*, cxxxvi, 684. H. L. W.

3. *Radio-active Lead.*—About two years ago Hofmann and Strauss announced the preparation of radio-active salts from the lead obtained by the usual chemical methods from various minerals containing uranium and thorium. Hofmann and Wölfl

have recently described further investigations in regard to this matter. They are convinced that this substance is an independent radio-active principle, and that it is distinct and separable from ordinary lead, although standing close to that metal in its chemical properties. The interesting fact was observed that solutions of radio-active lead are capable of inducing very great activity in metals which are placed for a long time in contact with them, but upon which they exert no chemical action, for instance platinum, gold and silver palladium, and particularly iridium. The metals remain perfectly bright under these circumstances; the activity, which is often greater than that of the original substances, is not removed by washing with water or by rubbing with paper, but it is quickly lost by ignition in most cases. The theory is advanced that the α radiation (the less penetrating kind, following Rutherford's designation) is a finely-divided kind of matter the particles of which, like hydrogen, are occluded by metals.—*Berichte*, xxxvi, 1040. H. L. W.

4. *Colloidal Silver.*—Some observations upon Carey Lea's colloidal silver have been made recently by HANRIOT. The work was done with a commercial form of the substance which is sold in France as a therapeutic agent under the name of *collargol*, and which corresponds to Lea's first modification of colloidal silver. It was found that solutions of this substance, upon being submitted to electrolysis, deposit silver upon the positive electrode, whereas metals are deposited from solutions of their salts upon the opposite pole. This and other properties of the solutions have led this investigator to the conclusion that colloidal silver is the salt of an acid to which he gives the name "collargolic acid." This acid is evidently composed largely of silver, and it is energetic enough to displace carbonic acid. The black deposit upon the positive electrode which has been taken for silver is not ordinary silver but collargolic acid, for, while it is insoluble in water, it dissolves in alkalies and alkaline carbonates, forming red solutions. The author believes that this acid is combined with ammonia in the original substance, and he proposes to make a further study of the matter.—*Comptes Rendus*, cxxxvi, 690.
H. L. W.

5. *The Iodides of Caesium.*—The iodides CsI_3 and CsI_5 were described by Wells and Wheeler in this Journal in 1892. H. W. FOOTE of the Sheffield Scientific School, using theoretical considerations which are mainly based upon the phase-rule of Gibbs, and employing chiefly solubility determinations, has found that the periodides mentioned are the only ones existing between $-4°$ and $73°$. The method employed appears to be novel in its application, and it will doubtless be very useful when applied to the study of other complex compounds, particularly of double-salts.—*Amer. Chem. Jour.*, xxix, 203. H. L. W.

6. *Quantitative Chemical Analysis by Electrolysis;* by ALEXANDER CLASSEN. Translated, revised, and enlarged by BERTRAM B. BOLTWOOD. 8vo, pp. 315. New York 1903

(John Wiley & Sons).—In preparing the fourth English edition of this well-known and valuable book, the translator has made important additions to the last German edition by making use of Classen's "Ausgewählte Methoden der Analytischen Chemie" and other recent publications. The book, containing, as it does, the most recent methods, improved illustrations, and full references to the literature of the subject, is to be highly recommended to those who are interested in this branch of analytical chemistry.
H. L. W.

7. *Chemisches Praktikum;* von Dr. A. Wolfrum. II Theil, Präparative und Fabrikatorische Uebungen, 12mo, pp. 580; mit einem Atlas (4to, pp. 156 and 11 plates). Leipsic 1903 (Wilhelm Engelmann).—The first volume of this excellent work was noticed in vol. xiv of this Journal. The present part deals with a large variety of chemical preparations, and the plan of giving the student a knowledge of factory operations is well carried out. The atlas contains a large number of interesting cuts, chiefly of apparatus used in chemical manufacturing. H. L. W.

II. Geology and Natural History.

1. *United States Geological Survey.*—The following publications have recently been received:

Bulletin No. 213.—Contributions to Economic Geology, 1902. S. F. Emmons, C. W. Hayes, Geologist in Charge. This bulletin was prepared in order to secure a prompt publication of the economic results of recent investigations by the United States Geological Survey. The volume is divided into two main divisions, one under the editorship of Mr. Emmons treating of metalliferous mineral deposits and the other under the editorship of Mr. Hayes of the occurrence of nonmetalliferous economic minerals. It includes some 61 different contributions from 33 members of the Survey. The papers represent three classes: (1) Preliminary discussions of the results of extended economic investigations which will later be published in more detailed form; (2) Comparatively detailed descriptions of occurrences of economic interest but not of sufficient importance to necessitate a later and more extended description; (3) Abstracts of certain economic papers of a general nature which have appeared in Survey publications during the year. W. E. F.

Oelrichs Folio, South Dakota, Nebraska; by N. H. Darton.—The Oelrichs quadrangle covers an area on the eastern edge of the Black Hills and contains features of the Black Hills proper, of the hogback rim and of the great plains. The sedimentary record deals with strata from late Carboniferous to recent. The simplicity of geologic structure exhibited in this region makes the folio of great educational value.

Water Supply and Irrigation Papers: No. 73.—Water Storage on Salt River, Arizona; by A. P. Davis. 52 pp., 25 pls., 4 figs.

No. 75.—Report of Progress of Stream Measurements, 1901; by F. H. NEWELL. 231 pp., 13 pls., 71 figs.

No. 76.—Observations on the Flow of Rivers in the Vicinity of New York City; by H. A. PRESSEY. 104 pp., 13 pls., 8 figs.

2. *New York State Museum.* BULLETIN No. 56 (Geology 5).—Description of the State Geologic Map of 1901; by F. J. H. MERRILL. 34 pp. An account of geologic mapping in New York State from 1820 to 1900 and the authorities for the map of 1901 are given. In the map itself a distinct advance is made over the Preliminary Geological Map of New York published in 1894, by the addition of topographical facts furnished by the folio sheets of the United States Geological Survey, and by the discrimination of boundaries, developed since that date. A list of thirty-three contributing geologists is given whose detailed work in the several counties of the State has been incorporated in the revised map.

The chief areas in which changes appear are the Pleistocene geology of Long Island, the igneous and pre-Cambrian geology east of the Hudson and about the Adirondacks, the Lower Paleozoics of the latter region and the Devonian of the central and southern portion of the State. The map is drawn on the same scale as the 1894 map, viz: 2½ miles to the inch.

Some confusion still exists in the mapping of the Devonian formations. The Catskill-Chemung boundary of the eastern part of the State is evidently drawn on the theory that its lower base is at a relatively higher stratigraphic position on passing westward, while the corresponding upper limits of the underlying rocks are at relatively higher horizons passing in the same direction. This is not a case of unconformity, but of change in the character of the sediments similar to the changes occurring in the Niagara, which is more calcareous to the westward, and the Lower Helderberg limestone, which as a limestone is confined mainly to the eastern half of the State. In other cases (viz: the Genesee shale, the Tully limestone, the Onondaga limestone, etc.) a similar fact is expressed by narrowing out the line of outcrop to nothing or nearly nothing. These are strictly expressive of distribution of formations, the definition of formation being based on uniformity of lithologic characters. In the case of the Portage, Ithaca and Oneonta formations, an attempt is made to express differences in the fossil contents of formations occupying the same stratigraphic interval. The confusion in this case arises from the attempt to express two kinds of facts (distribution of faunas and distribution of formations) with a single set of symbols. Thus when the Portage and Ithaca formations are represented by an abrupt change in the color scheme, between Cayuga and Seneca Lakes, the fact that the boundaries of the formations are continuous shows that the change is not in the formations but in the fossils.

Although the writer is well aware of the important facts here indicated, he continues to believe that no advantage will be gained by confusing on a geological map the distribution of fossil faunas with the distribution of geological formations which the map purports to represent.

In the text accompanying the map the State geologist has contributed an interesting and valuable detailed exhibit of the historical development of the nomenclature of the New York State geology. Among other things suggested by its examination is the real significance and naturalness of the subdivisions proposed by Mather in his report of 1840. The *Catskill*, *Helderberg*, *Ontario*, and *Champlain* series express natural divisions of the New York system, which is in great measure lost sight of in the later attempts to adjust the classification to the European scheme. As the details of our geology are developed, the grander episodes in the sedimentation of each geological basin should be emphasized rather than warped to fit any universal scheme of classification. A correct representation of the facts is far more important than uniformity of classification or nomenclature. H. S. W.

3. *Geological Survey of New Jersey*, HENRY B. KÜMMEL, State Geologist ; Report on Paleontology, vol. iii. The Paleozoic Faunas ; by STUART WELLER, 462 pp., 53 pls.—Professor Weller has presented a clear and concise account of a section of the Paleozoic in the State next adjoining New York which presents many features quite distinct from that long-time standard.

The sections fall into three quite distinct groupings in the three areas of the Delaware Valley, Kittatinny Valley and Green Pond Mountain region. In the first the Cambrian and Ordovician are wanting—the Silurian and Devonian having full complement of formations. The reverse is the case in the second area, and the Ordovician and much of the Silurian and Devonian are missing in the third.

The Hardyston quartzite holds the Olenellus fauna. The Kittatinny limestone, 2700 to 3000 feet in thickness, has a fauna resembling the Upper Cambrian fauna of Minnesota and Wisconsin and in its upper part carries Ordovician species. The Trenton limestone carries a Black River fauna below and pure Trenton fauna above ; but not the highest fauna of the New York section : it is 135 to 300 feet thick and runs up gradually into a typical Hudson River slate. The Norman's Kill shale fauna appears near the base of the Hudson River. The Shawangunk conglomerate lies unconformably upon the latter, and reaches a thickness of 1500 to 1600 feet. Above this is the Medina (Longwood) sandstone, over 2300 feet thick. These are supposed to represent the Oneida and Medina of New York, though no fossils have been seen. Then follow, in the Delaware Valley, the Poxino Island shale, the Bossardville limestone, Decker Ferry formation, Rondout formation, and the Manlius limestone. The Decker Ferry formation is correlated directly with the Coralline limestone of New York. The Rondout contains almost exclusively Leperditia, and *Leperditia alta* is in both it and the following Manlius, which is the Spirifer vanuxemi zone.

The Coeman's limestone contains the Gypidula galeata fauna and is placed as the first of the Devonian formations. It is followed by the New Scotland, Stormville, Becraft, Kingston, Oriskany, Esopus and Onondaga limestone. We note that the author concludes that "a careful study of the Helderberg and Oriskany faunas of New Jersey has brought out conspicuously the absence of any sharp dividing line between these two horizons either of a stratigraphic or of a faunal nature" (p. 96).

The Newfoundland grit, which follows in the Green Pond Mountain region, contains a fauna essentially that of the Onondaga limestone, without the mixture of Oriskany species, which was stated erroneously to be the case in the preliminary report. The Monroe shales (700 to 1000 feet thick), as well as the following Bellevale flags (1800 feet), contain the Tropidoleptus carinatus fauna with no admixture of Chemung species.

The Skunnemunk conglomerate alternating with red sandstone follows without observed fossils and terminates the Paleozoic series of the State. A considerable number of new species are described. H. S. W.

4. *Maryland Geological Survey:* WM. BULLOCK CLARK, State Geologist: VOLUME IV, 1902, 524 pp., 34 figs., 49 pls., including Part I, Paleozoic Appalachia, or the history of Maryland during Paleozoic time, by BAILEY WILLIS (pp. 23–91). Part II, Second Report of the Highways of Maryland, by HARRY FIELDING REID and A. N. JOHNSON (pp. 95–179). Part III, Report on the Clays of Maryland, by HENDRICK RIES (pp. 203–503).

CECIL COUNTY, 322 pp., 24 figs., 30 pls., and Atlas including chapters on the physical features, the physiography, the geology, the mineral resources, the soils, the climate, the hydrography, the magnetic declination and the forests of Cecil county, each one prepared by scientific experts.

GARRETT COUNTY, 340 pp., 13 figs., 26 pls., and Atlas. This Report gives full details regarding the special physical and geological features as is the case of Cecil county.

In the first volumes there are combined an interesting discussion of the changes the underground basis of the State has supposedly undergone in past geological time which must stand on a highly theoretical basis, with the thoroughly practical and economic problems connected with modern roads and the brick industry. The county reports are made as attractive and interesting as scientific reports can be made by applying the skill of experts to the interpretation of each section of the physical phenomena examined, treating each subject so as both to bring out the new scientific facts and to artistically explain them; and, throughout, the State geologist has succeeded in weaving into his reports those practical qualities which are so highly appreciated by the general public for whom they are primarily prepared. H. S. W.

5. *Geography and Geology of Minnesota.* Volume I. Geography of Minnesota; by C. W. HALL. 287 pp., 5 pls., 163 figs. Minneapolis (The H. W. Wilson Company).—The natural features of Minnesota are so varied as to illustrate nearly every

elementary principle of Physiography, and Professor Hall has done his state a service in calling attention to its wealth of natural scenery. Explanations of the peculiar drainage systems and numerous lakes are particularly interesting.

6. *Plumasite, an oligoclase-corundum rock near Spanish Peak, Cal.*; by A. C. Lawson. Bull. Geol. Dept. Univ. Cal., vol. 3, No. 8, 1903, pp. 219–229.—The author comments on discoveries made during recent years, which show that corundum is a not uncommon constituent of igneous rocks, and then describes an occurrence in which it is an essential constituent of the rock of a dike cutting a belt of peridotite on the lower east flank of Spanish Peak in the Sierra Nevada. The dike is about 15 feet wide composed of a white rock made up of feldspar, which varies from coarse to fine and which was determined to be oligoclase. In places this is found to carry considerable corundum in imperfectly formed violet-blue crystals. In the specimens examined the corundum made up 16 per cent of the rock, the remainder being oligoclase. For this type the name of *plumasite* is proposed from Plumas Co., Cal., in which it occurs.

An investigation of the peridotite was made and the results of this are also given. L. V. P.

7. *An Experimental Garden in Cuba.*—Three years ago, Mr. E. F. Atkins, of Boston, who has extensive interests in Cuba, placed at the disposal of the Botanic Garden of Harvard University such land, labor, materials, and money, as might be required for a small experimental station for the study of certain tropical plants in their economic relations, especially with the view to improvement in their yield and quality. Arrangements were completed by which the more important tropical plants adapted to the climate of southern Cuba, were obtained in abundance both as regards number and variety. A large collection of sugar-canes was secured from a very wide geographical range, and these were placed at once under conditions favorable for attempts at crossing. It is well known that almost all varieties of sugar-cane, now in cultivation, bear only very imperfect flowers which are practically incapable of impregnation without artificial aid. The interesting experiments in Java and elsewhere have shown that by intervention at the right time, it is possible in some cases to secure good seed sparingly, and from these few seeds to obtain varieties which are decidedly promising as regards content of sugar, vigor of growth, and resistance to hurtful influences. The aid of Mr. R. M. Grey, the well known hybridizer, was secured for this work upon cane, and he had access to all the varieties in stock. One very successful result was the production of a strong variety which encourages to further effort. Some doubt was felt at first whether the climatic conditions in Cuba were favorable for the early stages of crossing, but these doubts have been largely dissipated by even the moderate success which Mr. Grey obtained. A good many of his seedlings were not properly cared for by one of the station hands, and were lost shortly after Mr. Grey returned north.

Last year it was decided to obtain from Mexico a good supply of the economic plants most favorably known in that country, and to cultivate them in the grounds of the station. The management was so fortunate as to obtain the services of Mr. C. G. Pringle, the botanical collector, who is thoroughly conversant with the most desirable sources of Mexican supply. His work was exhaustive and thoroughly satisfactory in every respect. The plants were shipped directly across the Gulf, and were received in good condition. The collection now at the Station is ample for a wide series of crosses and selections.

Among the plants which had appeared to be desirable for extensive experiments was cotton in its different varieties. It soon became apparent, however, that this plant is confronted in Cuba by its most implacable enemy, the cotton-ball worm. From all the experiments upon this plant at the Station, it is plain that large plantings in the island are sure to be attended with the most complete failure until means can be devised to check the mischief done by this insect. G. L. G.

III. Miscellaneous Scientific Intelligence.

1. *United States Coast and Geodetic Survey.* O. H. Tittman, Superintendent, Annual Report 1902. 787 pp., 68 plates and maps.—The details of the Coast Survey work from July 1, 1901, to June 30, 1902, show gratifying progress in all its branches. The progress of the work in the Philippine Islands is especially noticeable. In addition to reports on the regular work of the Survey, there are two appendices of timely value: one by W. D. Alexander on Hawaiian Geographic Names (pp. 373–424), the other by J. Howard Gore on a Bibliography of Geodesy (second edition).

2. *National Bureau of Standards.*—In Circular of Information, No. 3, S. W. Stratton, Director, explains the present facilities for comparison of standards. Comparison may now be made of length and capacity measures, weights, polariscopic apparatus, hydrometers, thermometers, photometric standards, and electrical instruments.

3. *The Scientific Writings of George Francis Fitzgerald.* Edited by Joseph Larmor. xlv + 569 pp. London (Longmans, Green & Co.).—In making a collection of Professor Fitzgerald's writings "an endeavor has been made to include everything substantial of a scientific character that he wrote." One hundred and eight essays are here reproduced and the editor has added a biographical and historical introduction.

Obituary.

Professor J. Peter Lesley, the eminent geologist, whose lifelong labors contributed so much to our knowledge of the Pennsylvania Coal-measures and of the structure of the Appalachians in general, died at Milton, Mass., on June 1, aged eighty-three years.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XI.—*The Mechanics of Igneous Intrusion.* (Second Paper); by Reginald A. Daly.

(By permission of the Director of the Geological Survey of Canada.)

CONTENTS:

Introduction 107
Origin and Suspension of Basic Segregations—Bearing on Doctrine of Liquidity of Plutonic Magmas 108
Shattering at Plutonic Contacts 110
The zone of apophyses 110
The zone of inclusions; its origin 111
Shattering by differential thermal expansion 112
Exfoliation at plutonic molar contacts 114
Illustration from the Madoc-Marmora District of Ontario 117
Illustration from the Geological Structure near Trail, British Columbia 119
Stability of the Roofs of Magma Chambers 125

Introduction.—In a recent number of this Journal* the writer has presented some of the facts upon which has been based a hypothesis on the development of the larger magma-chambers now occupied by plutonic rocks. There was entailed in the working out of that hypothesis a brief treatment of a necessary corollary—abyssal assimilation of the formation invaded by stock or batholith. The hypothesis was stated in general terms, without a full discussion of some of the fundamental postulates and conclusions and without detailed reference to individual areas. In Bulletin 209 of the United States Geological Survey the application of the hypothesis to a rather complex group of stocks occurring in and about Mt. Ascutney, Vermont, has been made, and some degree of assurance attained that this view of intrusion is there of greater value in explanation than are the older theories of intrusion mechanism.

* This Journal, vol. xv, p. 269, April, 1903.

In the present communication certain other concrete illustrations will be offered along with additional discussion of some of the main premises on which the newer hypothesis is based. Among these premises are: (1) the generally high fluidity of igneous magmas during the time of active intrusion; (2) the normally extensive shattering of the invaded formations at their contacts with plutonic magmas; and (3) the reality of "overhead stoping" of the blocks so shattered and rifted off from wall or roof of the chamber. Concerning the first and last of these premises certain difficulties were hinted at or partially discussed in the former paper, but their importance demands that further attention be paid to them. A note on a particular point referring to the first-mentioned premise may well anticipate the larger division of this paper, which will have to do primarily with contact-shattering in general and with the testimony of several Canadian intrusive bodies as to the validity of the rifting and stoping hypothesis.

The origin and suspension of basic segregations: bearing on the doctrine of the liquidity of plutonic magmas.—At first sight, the common occurrence of basic segregations freely suspended in their rock-matrix always less dense than themselves seems in one way to militate against the idea of high fluidity in igneous magmas. It is true that the mere fact of that particular kind of differentiation calls for the assumption of no inconsiderable degree of mobility in the igneous mass; but the question arises as to how that substance now represented by heavy minerals could be segregated and held up in a less dense matrix possessing such liquidity. That segregations have been so suspended seems clear in the average field occurrence. The question raises a second one as to the relative densities of molten segregation and molten matrix. If it can be shown that in the *fluid* state, matrix and segregation are nearly of the same density, the difficulty disappears and therewith the objection to the theory of high liquidity.

While the variations in thermal expansion of the common plutonic rocks are confined to narrow limits, the experiments so far made on the volumetric increase observed in the passage of single crystalline minerals to the glassy condition (at room temperature) appear to show that the law of even approximately constant ratio of expansion in rock-forming minerals does not hold. The following table taken from Zirkel's Lehrbuch der Petrographie (1893, vol. i, p. 681) synopsizes the results of Deville, Thoulet and others. The percentage decrease in density suffered by the minerals investigated when these pass from the crystalline state to that of cold glass is as follows:

Quartz	16·85 %
Olivine	16·30
Augite	14·18
Hornblende	12·13
Oligoclase	12·19
Orthoclase	10·21
Microcline	9·15
Adular	7·96
Sanidine	7·63
Labradorite	6·28

Barus has shown that, for silicates, the solidification contraction decreases in proportion as the thermal expansion decreases.* Since the thermal expansion is in direct proportion to the decrease of density affecting a crystalline silicate passing to the cold glassy state, it follows that the percentages of the table are in nearly constant ratio to the percentage decreases of density affecting the respective glasses when fused to a thoroughly molten condition. According to Barus, diabase loses 10 per cent in density in passing from rock at 20° C. to glass at 20° C. and its glass loses 7·2 per cent in density in passing from 20° C. to 1400° C., at which temperature it is very fluid. It is highly probable, therefore, that olivine glass would lose in density something like $7{\cdot}2 \times \frac{16{\cdot}3}{10{\cdot}0} = 11{\cdot}7$ per cent in assuming the same temperature of 1400° C. The net result on that assumption would be to give Fogo olivine, for example (spec. grav., 3·381) a specific gravity of about 2·50 at 1400° C. The specific gravity of gabbro at 20° C. becomes, when molten at 1400° C., changed to the following values :†

Spec. grav. at 20° C. Holocrystalline gabbro.	Spec. grav. at 1400° C. Molten glass.
2·90	2·42
3·00	2·51
3·10	2·59

Assuming the approximate correctness of these figures, it is possible to credit the flotation of molten globules of the olivine substance in a highly fluid gabbro or basalt. The rock-matrix would crystallize before the segregation or, at least, would have attained an antecedent viscosity great enough to support the more dense, because crystallizing, olivine. The foregoing reasoning leads to the suggestion for actual experimentation with olivine similar to that so successfully carried out for diabase by Barus. Without such fusion tests it is not

* Bull. U. S. Geol. Surv., No. 103, p. 43, 1893.
† This Journal, April, 1903, p. 277.

possible to tread on sure theoretical ground in dealing with the origin of olivine nodules in basalt, much less in accounting for the more important basic segregations of granites, syenites, etc. It is noteworthy that, besides olivine, augite, hornblende and oligoclase appear to have unusually high coefficients of cubical expansion, and that these minerals are among the commoner constituents of segregations in granites and syenites. The highly important constituent, biotite, has not been, perhaps cannot be, directly investigated in this regard. In the absence of experimental data, the further discussion of basic nodules in the present connection cannot afford very fruitful conclusions. All that seems certain is that the existence of basic segregations does not disprove a high degree of fluidity for plutonic magmas.

Shattering at plutonic contacts.

Among the commonest phenomena associated with the contact-zones of plutonic, igneous rock-bodies (bosses, stocks and batholiths) is that of extensive shattering and disruption of the invaded formations along the contacts. A host of memoirs on exotic granite, syenite, diorite, gabbro and other deep-seated rock-masses contain references to this particular phenomenon. It consists, in its ideal development, of the appearance of two concentric zones of mixed rock occurring between the homogenous main body of igneous material and the encircling country-rock unaffected by any serious mechanical disturbance due to the intrusion. Both zones lie parallel to the average line of contact between the intrusive and the country-rock.

The Zone of Apophyses.—The belt more remote from the intrusive body is generally much the broader of the two and consists of country-rock intersected by more or less numerous apophyses from the main igneous mass. These dikes and sheets are often seen to radiate outward in directions roughly normal to the average line of contact; but others running at all angles to the contact are usually associated. The whole group of apophyses has often thus a reticulate ground-plan and a reticulate vertical section. The portions of the invaded formation bounded by the apophyses are not essentially disturbed from the relative positions they occupied before the intrusion took place. This belt may be called "the zone of apophyses." According to the prevailing views among geologists, the zone owes its origin to a mechanical process of relative simplicity, namely, the injection of the molten magma forced by great pressure into all accessible planes of weakness within the invaded formation. The force may be hydrostatic, due to the weight of the chamber-roof or of part of that roof; or, among other causes, the energy may be derived from the necessary expansion of volume suffered by the digestion of solid country-rock by the magma.* The development of the fissures now filled with apophysal material may, however, be powerfully aided by a third cause that controls as well the formation of the other of the two zones noted above. It may be believed that a common disrupting force has affected both zones; a brief description of the second zone may anticipate the analysis of the conditions which demand the energetic working of that force.

The Zone of Inclusions; its origin.—The second zone is composed of igneous rock enclosing blocks of the country-rock. As the apophyses, breaking the continuity of the invaded formation, vary enormously in number within the outer zone, so the blocks, breaking the continuity of the igneous body, show the greatest variation in the degree of their abundance. This "zone of inclusions" varies in width from a few meters to three kilometers or more. The blocks, unless very close together and possessing thoroughly massive structure themselves, usually show clear evidence of having been shifted out of their former relative positions in the invaded formation, so that their original orientation is completely lost. There are transitions to the outer zone through the gradual increase in the number of blocks left undisturbed from their original orientation; and there is, of course, no easily fixed boundary between the zone of inclusions and the main intrusive body in which country-rock inclusions are normally absent or very rare. The inner boundary of the zone of inclusions is often difficult to determine in the case of stock or batholith so exposed to view by denudation as to furnish a land-surface close to the former roof of the magma-chamber.

Whatever be the causes of the disruption of blocks now found in the zone of inclusions, those causes are directly connected with the intrusive body itself and are thus not external. The zone is, for example, not due in the normal case to the injection of magma into rock coarsely brecciated by regional dynamic movements in the earth's crust. Movements of that sort tend generally to brecciate rock along straight or open-curve lines and would not necessarily follow the complex, sinuous, closed-curve line of contact such as belongs to a plutonic body. There is certainly, on the other hand, a genetic relation between the zone of inclusions and the replacement of the country-rock by great bodies of intruded magma almost or quite free of foreign fragments. Many authors speak of the inclusions as having been "torn off" or "carried up" by the

* This Journal, April, 1903, p. 289.

ascending magma, without, however, showing the possibility of such a process when correlated with the apparently demonstrated fact of the high liquidity of plutonic magmas. On the assumption of high liquidity at the moment of the immersion of the blocks, they would, in the average case, not remain near the molar contact,* but would sink into the depths of the magma-chamber. It is further impossible to believe that any kind of current action in the magma could carry on a sort of erosion on the chamber-walls, a hypothesis which likewise would fail to explain the constant relation of the zone of inclusions to the molar contact.

Some of the blocks within the zone of inclusions have unquestionably been floated out or sunk from the molar contact after those portions of the country-rock have been completely surrounded by magma of the main body and of anastomosing apophyses. But there are reasons for concluding that apophyses of an abundance, matching the countless inclusions of many internal contact-belts, were not formed simply by reason of hydrostatic pressure forcing magma into original cracks or fissures in the country-rock. The conditions reigning at the contact imply the exhibition of a different source of energy—one which many geologists have incidentally credited with the shattering effect. A clear, positive statement of the case has been given by Crosby in his monograph on the Blue Hills Complex.† The subject is of importance and merits much more discussion than can be brought into the few pages of this paper; it is, moreover, a difficult subject, largely on account of the existing lack of experimental data, and the following treatment of it can lay claim to doing little more than open up the problem and make the attack upon it in a qualitative manner.

Shattering by differential thermal expansion in the invaded formation.—It is manifestly impossible to determine the exact rise of temperature which will occur in a formation at the contact with an invading magma. Both elements, the pre-eruption temperature of the country-rock and the temperature of the magma itself, are partly indeterminate. If the former be regulated by the normal law of the vertical distribution of the isogeotherms, that temperature will be about 200° C at a depth of four miles below the earth's surface—possibly a rather liberally estimated average depth for the upper limit of a granitic magma-chamber. If we assume that the temperature of an intruding magma is approximately that at which the rock resulting from its crystallization becomes thinly molten under plutonic pressures (an assumption apparently justifiable from

* The main contact, that of igneous body *mass* against country-rock *mass*, as distinguished from the minor contact of inclusion and intrusive rock.

† Occasional Papers, Boston Soc. Nat. Hist., iv, 1900, p. 315.

the known properties of lavas and notwithstanding the presence of mineralizing agents), there should occur by conduction *at* the molar contact, a rise of temperature in the invaded formation, of something like 1000° C. That would mean a cubic expansion in the solid rock of between 2·5 per cent and 3·0 per cent, corresponding to a linear expansion of about 0·9 per cent.* The force required to prevent that degree of expansion is equal to the amount of pressure required to compress the rock by the same amount. The coefficient of compressibility for ordinary crystalline and well-cemented sedimentary rock is not far from that of glass, viz.: about 0·0000025 per atmosphere of pressure. Assuming that the thermal expansion should so occur that the volumetric change would be exactly in the reverse sense of the volumetric change observed during compression tests for solids, and assuming that the just mentioned coefficient of compressibility should apply at very high pressures, it follows that the inconceivable pressure of more than one million atmospheres, or about 8000 tons to the square inch, would be required to prevent the expansion of rock raised 1000° C. in temperature. However great the expansion transverse to the plane of the molar contact may be, a large proportion of the force of expansion must pass into the form of compressive strain, developing lines of force in the plane of the contact. If only one per cent of the total force of expansion were applied in that plane, the integrity of the rock must be destroyed, for the crushing strength of rock is in no case as much as fifteen tons to the square inch.

It is extremely difficult, if not impossible, to imagine the enormous and complicated stresses set up in this way. Although the heat of the intrusion would be conducted outwards in all directions from the igneous body, the supposition is reasonable that the temperature reigning only a few hundreds of meters from the intrusive would be very much lower than that at the contact. Differential expansion and consequent intense shearing stresses far above the breaking strain of rock-material might thus be produced. That action would be complicated and intensified by the variable values of heat-conduction in the invaded formation which is always more or less heterogeneous. The following table of relative values calculated from Everett's "Units and Physical Constants" (1879, pp. 101 and 103) shows the importance of differential conduction in different rocks. For ease of comparison all the other values are referred to the conductibility (taken as unity) of calcareous sandstone.

* This Journal, April, 1903, p. 274.

Rock.	Conductibility.
Calcareous sandstone	1·00
Clay slate	1·24
Slate, across cleavage	1·60
Trap	1·97
Micaceous flagstone, across cleavage	2·09
Limestones (mean)	2·44
Granites (mean)	2·51
Sandstones and hard grit (dry)	2·58
Sandstones and hard grit (wet)	2·80
Slate, along cleavage	2·84
Micaceous flagstone, along cleavage	3·00
Sandstone of Craigleith quarry	5·06

The table illustrates the well known fact that, in a rock-mass possessing the plane-parallel structure, the rate of conduction is widely different according as the heat passes along or across the planes of schistosity or cleavage. Such differential conduction and consequent differential expansion may be held responsible for the opening of fissures for the entrance of apophysal igneous matter in spite of the general tendency of the expansion to close preëxisting cavities in the country-rock. The apophyses themselves by virtue of their own high temperature must hasten the destructive action.

Part of the stress-energy set free might be added to that of injection and expended in the minute crumpling of relatively plastic bedded country-rock. Another portion is conceivably expended in irregular and perhaps very complete shattering of the rock, which by that action is relieved from the strains by sudden rending and fracturing rather than by any form of rock-flowage. Still a third portion of the energy might become potentialized as in Rupert's drops, Bologna glasses or certain slickensided rock surfaces,* and only finally expressed as a shatter-force after sudden faulting or other shock in the country-rock had precipitated the destruction, repeating on a large scale, the destruction of a Rupert's drop.

Exfoliation at plutonic molar contacts.—The complexity of these mighty interacting forces is such that the shattering produced by them cannot be referred to simple strain-categories. Experiments and certain observations made in rock-quarries seem to throw light on one of the more important and simpler methods by which disruption of the country-rock may take place. A short statement of the facts derived from each kind of study will serve to place the question of the efficiency of this process in a clearer light.

Reade has given so concise an account of his experiments on the differential expansion of stone that his descriptions of cer-

* A. A. Julien, Jour. Franklin Inst., cxlvii, 1899, p. 382.

tain typical trials may be given in full. "A bar of fine hard light brown sandstone, square-dressed to a smooth surface, measuring between two fixed points 7·346 inches long at 61° F., and roughly speaking $1\frac{3}{4}$ inch by 1 inch scantling, was placed with its ends resting flatways on two supports. The flame of the blowpipe was brought to bear upon the upper surface until it expanded to 7·385 inches. The stone was hot enough to melt solder but not lead—perhaps 500° F. on the top surface. As the blowpipe played upon the stone it became, in places immediately under the flame, momentarily heated on the surface to a bright red heat, and the sharp edges were burnt off; the stone became when cool of a darker brown, but apparently was not otherwise altered by heat. The stone arched upwards against gravity in a most remarkable manner to the extent of $\frac{1}{32}$ of an inch. A second heating brought it up to not less than $\frac{1}{16}$ inch, at which it took a permanent set."* Bars of Sicilian white marble and of oolitic marble, about 14·5 inches in length, were similarly arched $\frac{1}{16}$ inch and permanently distorted. A square slab of Sicilian marble 12 inches on the side and $\frac{3}{4}$ inch thick was placed upon two bars of slate. "It was heated with a blowpipe on the upper surface. The flame was rather small, and was kept mostly near the centre within the circle of dotted lines (shown in Reade's figure), but was also moved about. The slab became very slightly convex. Eventually it cracked. . . . . The crack was the result of the circumferential and radial expansion of the centre part of the slab, within the dotted lines, and shows that a considerable bursting strain was developed."†

The conditions of differential heating in these experiments are analogous to those found at intrusive contacts. The warping of the shell of country-rock immediately adjacent to the molar contact must be of a higher order than in the case of the stone slabs because of the fact that the shell is nowhere free to expand in the plane of the heated surface. The warping would not be interfered with by the pressure of the magma if the latter had access through opening fissures to the outer, cooler surface of the shell. Such fissures would be formed along original planes of fission roughly parallel to the contact, or along shearing planes produced in the same position by virtue of the differential expansion itself. With the intrusion of this apophysal material and the more thorough heating of the warped shell, expansion would be intensified, and, as has been seen, a force would be developed vastly greater than the strength of the rock could withstand. The bending or shearing shell must finally collapse and become shattered into separ-

* Origin of Mountain Ranges, London, 1886, p. 22.
† Ibid, p. 23.

ate masses of solid rock now wholly or partially immersed in the magma.

The process is thus one of exfoliation on a large scale. It is comparable to the rifting action of heat on masonry and on granitic masses "said to have been made a matter of quarry utility in India. It is stated (Nature, January 17, 1895) that a wood fire built upon the surface of the granite ledge and pushed slowly forward causes the stone to rift out in sheets six inches or so in thickness, and of almost any desired superficial area. Slabs 60x40 feet in area, varying not more than half an inch from a uniform thickness throughout, have been thus obtained. In one instance mentioned, the surface passed over by the line of fire was 460 feet, setting free an area of stone of 740 square feet of an average thickness of five inches."* Merrill gives a striking illustration of the exfoliation of granite consequent on thermal expansion and general weathering of the rock composing Stone Mt., Georgia.† Again, the observations made by Niles in connection with operations in several New England quarries corroborate the belief that the exfoliation at plutonic igneous contacts must be well qualified to shatter the invaded formations. At a gneiss quarry of Monson, Mass., the rock is under notable stress due to local crustal compression. A rough measure of the amount of that pressure is found in the sudden visible expansion affecting great slabs of the gneiss which, in the quarrying process, are freed from their beds. "In one mass of rock, 354 feet long, 11 feet wide and 3 feet thick, the amount of expansion after dislodgment was $1\frac{1}{2}$ inches up the slope of the hill. When the fracture by wedging is suddenly and thoroughly made, the expansion takes place immediately, and sometimes the expansive force itself completes the desired work, the stone suddenly springing into the elongated state. Spontaneous fractures also occur, of which one was fully 4 inches wide. On removal of overlying beds, spontaneous upward bendings and swellings of the lower beds also occur, most frequently in the thinner sheets, up to 4 feet in thickness, with formation of miniature anticlinals. The amount of elevation varies from $\frac{1}{4}$ inch to 3 or 4 inches, even in a single afternoon. The span of the arch thus formed is sometimes 50 feet, while some are only 3 feet broad; the crests always trend in easterly and westerly directions, are sometimes ruptured, and are evidently caused by expansive thrust in northerly and southerly directions, since the edge of the sheet at each base of the anticlinal arch remains so closely attached to the underlying bed that no lateral slipping of this edge of the rock could possibly have taken place."‡ Similar exfoliation and arching of limestone is reported by Niles from Lemont, Ill.

* G. P. Merrill, Rocks, Rock-weathering and Soils. p. 182, New York, 1897.
† Ibid, p. 245.
‡ Julien, op. cit., p. 386.

"In one quarry, also, there was an elevation of a part of the bed forming the floor. It was an anticlinal axis of more than 800 feet in length, and its trend was nearly east and west. In its most conspicuous part the elevation was from 6 to 8 inches, and the arch measured from 16 to 18 feet from base to base over the crest."*

Notwithstanding the spectacular nature of these sample phenomena observed in different quarries, the forces engaged in their production are almost insignificant compared with those which must be produced in the shell of country-rock concentric with the molar contact of a still molten stock or batholith. The latter forces may be compared with the force of compression which has so often developed peripheral cleavage and schistosity concentric with molar contacts of stocks and batholiths; but fracture is the necessary product of the one kind of energy applied suddenly, as rock-flowage is the product of the other applied slowly and for a much greater period of time.

Differential heating of the invaded formation will, then, through exfoliation and still more irregular shattering, cause the mechanical destruction of the chamber-vault. If the magma be thoroughly molten, the rock-fragments so immersed in it, will, by the balance of probabilities for the average case, sink in the magma. The new surface of the country-rock so exposed to the hot magma must undergo a similar process. The magma chamber may in this way be gradually enlarged so long as the magma preserves sufficient heat for the purpose. Near the time of final solidification the high viscosity must prevent the sinking of the blocks which are last isolated in the magma. The "zone of inclusions" and its organic relation to the molar contact actually to be observed in plutonic rock-bodies seem to find adequate explanation by this hypothesis.

Illustration from the Madoc-Marmora District of Ontario.

The best published example of a granite stock mapped with the distinct purpose of illustrating a shatter-zone is doubtless that due to the labors of Coste and White in the Madoc-Marmora Mining District of Ontario.† A reduced copy of the map is represented in fig. 1. The legend expresses practically all the information yet printed in connection with the region since the survey was made. Mr. Coste has kindly given the writer certain additional statements on this interesting group of granite bosses; the following quotations are taken from his letter dealing with the matter. "You are quite right in your

* Julien, op. cit., p. 391.

† Geol. and Nat. Hist. Surv. of Canada, Special sheet; ½ mile to 1 inch, published without text, 1886.

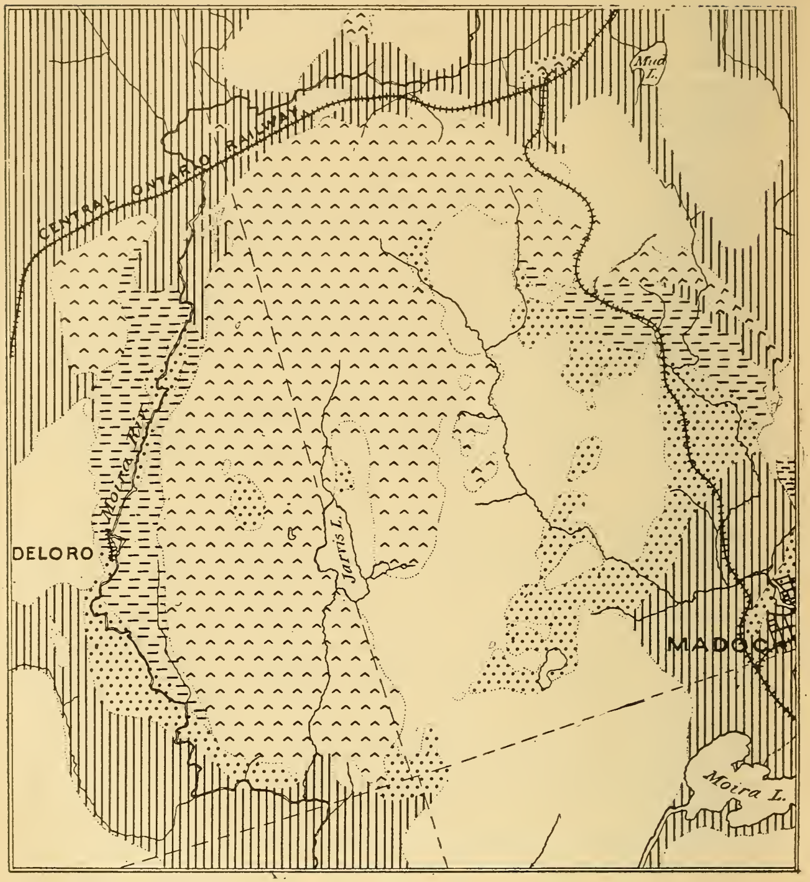


FIG. 1.

Bird's Eye and Black River Limestone ; Ordovician.

Intrusive granite.

("Gr. A.B.") Granite enclosing fragments of Archean—Zone of Inclusions.

("A.B. Gr.") Archean altered by the granitic intrusion and cut by many dikes—Zone of Apophyses.

Archean ; chiefly crystalline limestone and calc schists.

Scale: 1:126,720.

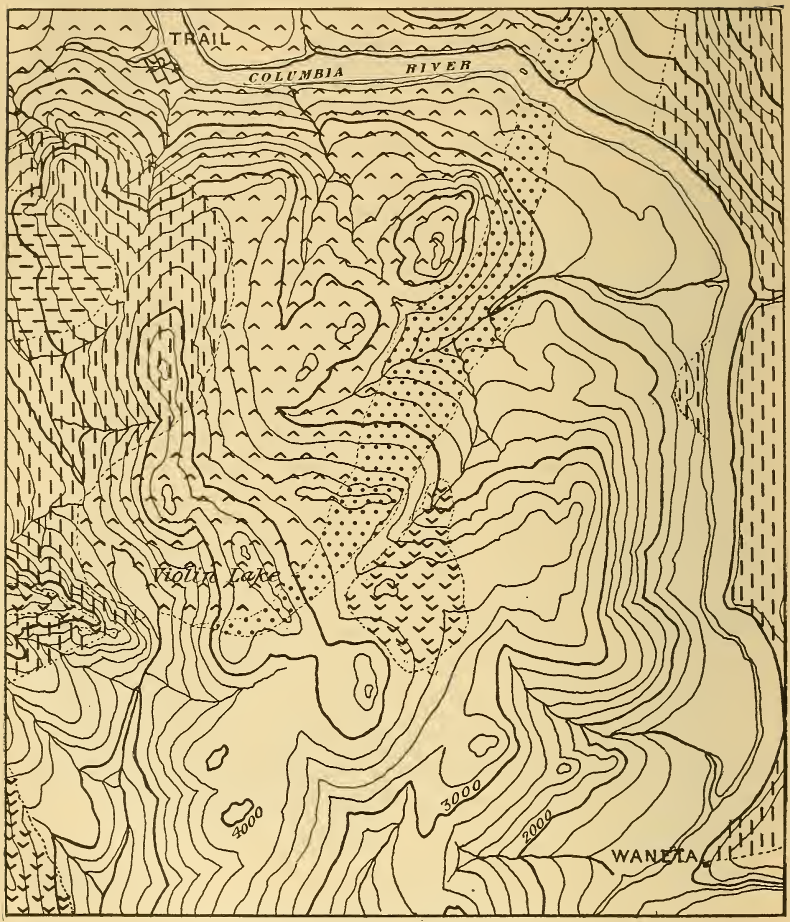
understanding of the Madoc and Marmora District as a fine example of contact-shattering by an eruptive. The zone on my map ‘A. B. / Gr.’ is preëminently a zone of apophyses, these being very numerous, running in every direction, more numerous than elsewhere (except in the zone ‘Gr. / A.B.’) and being mostly fine-grained granite with little or no mica . . . Both zones form decidedly a zone of strong shattering about the intrusive, extending, to a less degree, beyond, all around it, as shown by the separate granite masses and dikes marked (and many not marked) on the map. . . . . . The typical granite of that intrusion is a rock of medium-size grains of reddish orthoclase and of round, blue quartz with a little mica, but this passes into a great variety of other rocks.”

Mr. Coste holds that there has been some chemical modification of the magma in the zone of inclusions by the incorporation of the limestone and calcareous schists, but has given no details on the evidence.

Owing to the overlap of the Ordovician limestone lying unconformably on both the Archean schists and the granite, the whole story of the shattering cannot be made out at the present land surface; yet the exposure of the shatter-zone is nevertheless remarkably instructive. The general aspect of the map, the breadth of the zones, the existence of patches of the invaded formation lying isolated in the largest stock, and the numerous smaller bosses which occur like satellites about the main granite body—all lead to the conviction that the present erosion-surface is close to the position occupied by the roof of the chamber when the magma of the largest stock was solidifying.

Illustration from the geological structure near Trail, British Columbia.

The second illustration of extensive shattering at granite contacts is selected from the many that might be described from southern British Columbia. The selection has been made not because the phenomena are qualitatively different from those to be seen about other molar contacts in the region, but for the twofold reason that the shatter-zone has here been actually mapped and that the zone is wide enough to be sketched on a map of small scale. The area concerned is shown in fig. 2. It is seen to lie between the town of Trail and the 49th Parallel Boundary with the United States. It is only a few miles east of Rossland and for the most part on the right bank of the Columbia River. This little sketch-map is based on the “Trail Sheet” issued by the Geological Survey of Canada



INTERNATIONAL BOUNDARY

Fig. 2.

Alkaline granite.

Tonalite-granite of Nelson Batholith.

Shatter-zone of Nelson Batholith.

Rossland Basic Stock.

Rossland Volcanic Series.

Older Volcanic Series.

Scale: 1 : 95,000.

(topography by J. McEvoy; geology by R. G. McConnell, 1896) and on the writer's observations made in the same area, 1902. The heavy terrace-deposits of the Columbia Valley average nearly a mile in breadth and consequently the boundaries of the different formations are there not to be fixed with absolute precision. On account of the thick cover of drift and a dense forest, the same remark applies to the formation-limits indicated in the remainder of the area. The errors are, however, known to be of an order that cannot affect the usefulness of the map for present purposes.

The great complexity of the structure and the high degree of alteration characteristic of the rocks have put still greater difficulties in the way of defining the formations. This is particularly true of the attempt to subdivide the old volcanic rocks which form a large part of the area. There appear to be at least two volcanic rock-groups. The older is the oldest formation exposed in the area, consisting of hard, dark-colored, slaty ash beds interstratified with thick bands of squeezed and much altered basic, amygdaloidal lava-flows, and agglomerates, and cut by irregular dikes and boss-like dioritic, gabbroitic and peridotitic masses, which are probably genetically related to the lavas. As yet the required palaeontological and structural evidences as to the age and thicknesses of these rocks are lacking. In this paper the whole group may be called simply the Older Volcanic Series; the probabilities are, as suggested by McConnell, that it belongs to the Carboniferous or at least to the upper Paleozoic.

Overlying these rocks is a much younger (probably early Tertiary) formation, which, within the limits of the map, is purely volcanic—a group of greatly dislocated breccias, tuffs and flows derived from basaltic and essexitic magmas. Since this formation chiefly composes the mountains northwest, west and south of Rossland, it may be called the "Rossland Volcanic Series." There also appears on the map the eastern extremity of the coarse-grained basic rock-mass marked "gabbro" on the Trail sheet, and referred by McConnell to an origin contemporaneous with that of the Rossland effusives, probably representing the deep-seated portion of the main conduit through which these eruptions took place. This mass is highly variable and has gabbroitic, monzonitic and essexitic facies.

Both of these older series of rocks had been intensely folded, crumpled, and, in places, crushed by mountain-building forces before the intrusion of the great "Nelson batholith" took place. That huge granitic body covers an area of more than 3000 square miles. Its extreme southern end enters the area mapped in the form of a curved tongue narrowing to the southward and terminating in that direction at Violin Lake (see fig. 2).

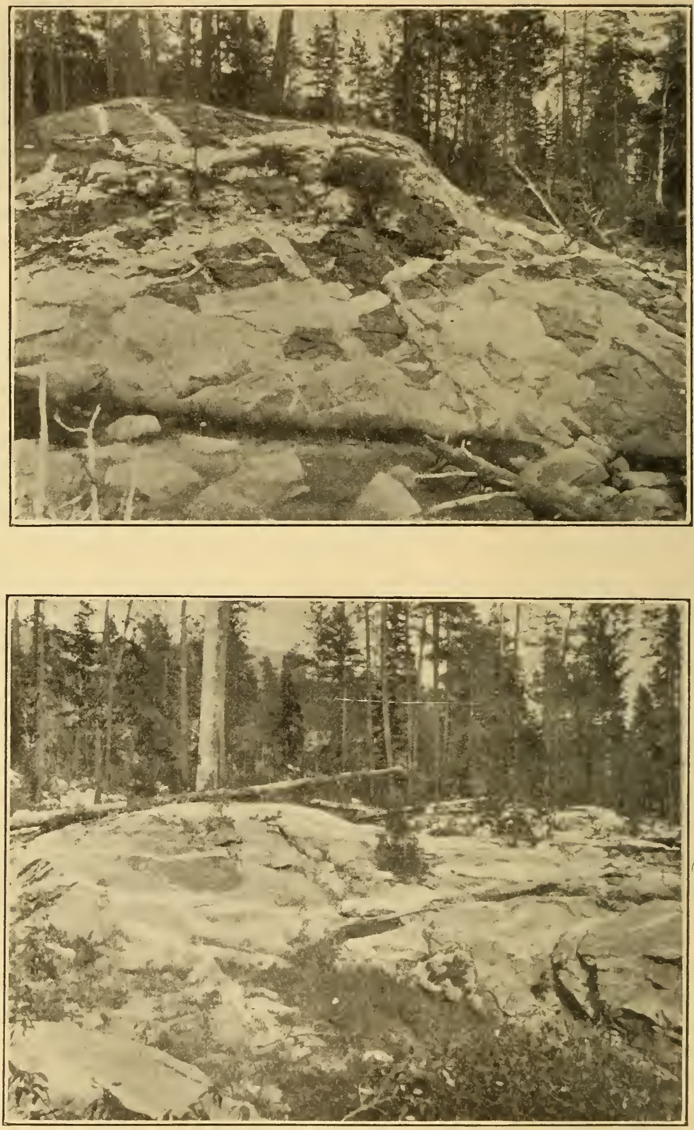


Fig. 3. Two views of the Shatter-zone, Columbia River near Trail, B. C.

Even in this small part of the batholith there is to be seen a noteworthy variability in mineralogical composition. East, west and south of Trail the rock is a gray, coarse-grained tonalite with essential andesine, biotite, hornblende, orthoclase, and accessory augite. Here and there, with apparently gradual transition, the dominant tonalite passes into a true basic to medium-acidic hornblende-biotite granite. The triclinic feldspar (again basic andesine, near $Ab_4\ An_3$) here becomes quite subordinate and orthoclase assumes its position as the chief light-colored essential. Notwithstanding these and other variations in the character of the igneous body, it is to be regarded as the crystallized product of a single intrusive magma.

The shattered contact-zone which is the matter of interest in the present connection, has been crossed in three places on the line of contact running from the Columbia River to Violin Lake, and has been mapped on the basis of the information thus gained. The shatter-zone has not been mapped on the western side of the batholith since the lack of exposures made search for its limits unprofitable. It is highly probable, however, that the zone exists on that side, though it seems to be narrower than on the southeastern boundary of the granitic tongue.

An unusually fine exposure of the zone outcrops three miles below Trail on the left bank of the Columbia. The local rocks invaded by the magma are a coarse peridotite (hornblendite) and an associated gabbro, both of which apparently belong to the oldest series of rock in the area. For a distance of about 600 meters down the river and thus transverse to the molar contact, the well-washed ledges are composed of a giant breccia. Innumerable, sharply cut, angular masses of peridotite and gabbro are enclosed in the granite and are transected by many veins of the younger rock (fig. 3). The inclusions are of all sizes up to blocks ten meters or more in diameter. Three kilometers to the southwestward the shatter-zone is more than a kilometer in width; the invaded formation is diorite which is markedly schistose in many of the inclusions, becoming at times a true amphibolite. It has proved impossible to separate a zone of inclusions from the zone of apophyses because of their intimate association and because of the massive character of the rocks invaded; hence the two have been combined in the map as a zone of shattering. It is of rather extraordinary breadth in this instance but there is illustrated the same kind of dynamic action as that found along normal granitic contacts.

At the granite-peridotite contact on the river bank, many of the larger apophyses display an interesting case of differentiation. At both walls of each apophysis the essential and normally abundant bisilicates of the granite are absent or are represented by rare shreds or plates of chloritized biotite. The feldspars are here orthoclase, and microperthite with accessory oligoclase-albite. Quartz is the remaining essential. Other veins seemingly contemporaneous with these just described, are composed entirely of the same aplite. The discovery of the patent differentiation throws light on the origin of the small plutonic bodies of alkaline granite indicated on the map. The edge of one of these appears in its SW corner. That stock covers an area of about 6 square kilometers north of the international boundary and extends over perhaps as many more south of the line. The mineralogical composition, structure and specific gravity are identical with those of the aplite in veins at the river. The alkaline granite is younger than the tonalite since angular inclusions of the latter are to be found in the more acid rock, which sends strong apophyses into the tonalite-granite at various points. Many wide dikes of the alkaline granite also cut the older basic formations south and west of the batholith tongue. The two granitic types seem to have been differentiated in the deeper levels of a common magma-basin after the upper portion of the magma had consolidated.

The application of the above mentioned facts to the general problem of intrusion must be made in the light of the determinations of specific gravities. These are noted in the following table, which gives the results acquired from the use of 30 specimens taken from the granites and from fair representatives of their respective country-rocks.

Rock.	Average Spec. grav.
Tonalite	2·76
Hornblende-biotite granite	2·76
Average of batholith	ca 2·75
Lavas of older volcanic series	2·85
Dioritic rocks associated with the last	2·82
Banded ash-rocks of older volcanic series	2·79
Peridotite at contact, Columbia River	3·22
Rock of Basic Stock at Rossland	2·91
Rossland volcanic series (aver. of 8 specimens of agglomerates, tuffs and flows)	2·85
Younger, alkaline, granite stocks	2·61

It appears from the table that the rock of the main intrusive body, the batholith, is in every case of lower density than any type among the country-rocks exposed in the area. When molten the tonalite-granite would have at ordinary atmospheric pressure a specific gravity of about 2·30*. Under plutonic pressures the same strong contrast of densities between intrusive rock and invaded rocks would persist with but little change. If, then, the magma were thinly molten or even but approximating the condition of perfect fluidity, blocks rifted off from the shattered wall must sink in the magma. The presence of the existing zone of inclusions is only explicable on the supposition

* This Journal, April, 1903, p. 277.

of high viscosity in the magma in its latest phase of intrusion. By reason of the enormous pressures in depth, this strong viscosity would not prevent the injection of the magma into the shattered zone. On the other hand, the long, narrow apophyses running out to great distances from the tonalite-granite mass must have been formed in the longer period of high fluidity. To that period of maximum shattering, rifting and stoping, the opening of the magma-chamber is to be referred.

Since the specific gravity of the younger granite averages but 2·61, and since the stocks of that intrusive have invaded formations practically identical with those displaced by the tonalite-granite, the foregoing argument applies with equal or greater force to the later intrusions. The shattering is again found about these stocks, but it is much less impressive than it is along the S.E. contact of the batholith tongue—perhaps because of the smaller size and more effective stoping power of the alkaline granite bodies.

Stability of the Roofs of Magma Chambers.

The problem remains as to how far in a vertical direction such stoping has gone in the case, for example, of such an immense batholith as that represented in the Nelson granite. Did the destructive action go on until the magma had worked its way to the earth's surface? Was there at any time an extensive foundering of the thinned crust overlying the batholith? Is plutonic energy so nicely balanced with, or controlled in its exhibition by, the enormous amount of work to be performed in opening a batholith chamber that the stability of its vault is never endangered by prolonged stoping? There seems to be no evidence of such foundering and world-shaking catastrophe in the later geological ages or even in Paleozoic times. According to Kelvin's classic speculation there has occurred a great break in the history of the earth. That break was coincident with the final encrustation of the planet as it cooled from a molten state—"the date of the first establishment of that *consistentior status*, which, according to Leibnitz, is the initial date of all geological history."* Kelvin has concluded that previous to final, complete encrustation, the earth attained its present high rigidity by the submergence of the partial crusts produced by the freezing of a less dense fluid mass. The close knitting together of these foundered crust-blocks thus afforded a pre-Paleozoic earth so far cooled down, so strongly bound in its continuous crust, as not to suffer further from the catastrophic violence of wholesale crustal foundering. The speculation leads directly to the further query whether the peculiar structural complexity of the Archean

* Lord Kelvin, Math. and Phys. Papers, London, 1890, vol. iii, p. 297.

areas of the globe may not be related to that process of foundering in its latest, local phase. The refrigeration of the planet must have progressed so far even in the Cambrian period as to prevent a recurrence of life-destroying, world-circling catastrophe. In others words, the possibility of foundering depends, according to Kelvin's view, among other things, upon the amount of residual heat within the earth. By the same view the Nelson batholith takes its place among the post-Archean batholiths which may be believed to have penetrated a crust already sufficiently buttressed through secular cooling so as to withstand the strain due to the differential density of vault and molten batholith. Other general considerations relative to the problem have already been presented in the writer's first paper. All of them are offered rather to emphasize once more the difficulty and importance of the problem than to suggest that a complete solution has been found.

Geological Survey of Canada, Ottawa, Canada.

ART. XII.—*Stellar Revolutions within the Galaxy;* by FRANK W. VERY.

ATTEMPTS have been made to determine roughly the dimensions of the system of stars constituting the Galaxy. By assuming various values for the total mass of the stars and various laws of stellar distribution, approximate mean velocities of bodies moving under the combined attractions of the masses may be deduced and compared with observation. In this way a preliminary conception of the size of the galactic system may be obtained, subject to the uncertainties of the assumptions made.

If we can measure the parallax of a body in one of the galactic streams, a further check on these estimates is given. Such an object we probably have in *Nova Persei* of 1901. All of the novae have been galactic objects. We may safely assume that *Nova Persei* lies either in the main galactic stream, or on a side branch of no great length relatively to the thickness of the stream.

Consistent measures make it certain that the parallax of the star is less than 0″·1. This gives a velocity of expansion for the surrounding nebula which can not be much less than that of light. We have no experimental evidence of any motion of matter that is swifter than light, while cathode rays are known to move with over half the velocity of light and to increase their speed as the vacuum improves. Theory appears to indicate that 300,000 km. per sec. is the limit of velocity which can be produced by the transmission of electromagnetic strains in the ether. Consequently, I shall assume that the nebulous material has been moving, at least in the first part of its course, with this speed. Applying this assumption to individual forms in turn, on the supposition that the initial motion was nearly radial, the maximum radii of the inner and outer nebulous rings (89″ and 149″), and of an arc on the northeast side (321″), observed by Perrine on March 29, 1901, 36 days from the outburst of the nova,* give:

		km.	
Inner ring, $1'' = (9{\cdot}33 \times 10^{11}) \div 89$	=	$10{\cdot}44 \times 10^{9}$,	$\pi = 0''{\cdot}014$.
Outer ring, $1'' = (9{\cdot}33 \times 10^{11}) \div 149$	=	$6{\cdot}26 \times 10^{9}$,	$\pi = 0''{\cdot}024$.
N. E. arc, $1'' = (9{\cdot}33 \times 10^{11}) \div 321$	=	$2{\cdot}91 \times 10^{9}$,	$\pi = 0''{\cdot}052$.

If the largest motion is definitely assumed to have taken place with the velocity of light, the speed of the material forming the outer ring was presumably one-half as great, or 150,000 km.

* Astrophysical Journal, xvi, 252, 1902.

per sec., and that of the inner ring one-fourth as great, or 75,000 km. per sec.

On September 20, 1901, Mr. G. W. Ritchey obtained a photograph* which shows nebulous material on the south southeast side at a distance of 20′, after an interval of 211 days from the appearance of the nova. Subsequent photographs demonstrate that this material had almost ceased to move by the end of September. We may assume, therefore, that the tangential component of motion has carried the material of this projection along a magnetic line of force nearly to the limiting radial distance; and as the path along such a line is 50 per cent. greater than the direct one, the radial distance on September 20th was:

$$\tfrac{2}{3} \times 300{,}000 \times 211 \times 86{,}400 = 3{\cdot}65 \times 10^{12} \text{ km.},$$

and
$$1'' = (3{\cdot}65 \times 10^{12}) \div 1{,}200 = 3{\cdot}04 \times 10^{9} \text{ km.}$$

This gives a parallax of $0''{\cdot}049$, agreeing well with the determination from the outer arc of March 29th.

The parallax $0''{\cdot}05$ may therefore be definitely adopted as that of the nova,† and inferentially of that of the Milky Way in its vicinity.

We must next form some idea of the structure of the galactic system, and of the nature of the motions within it.

The investigations of Kapteyn‡ show that when the total proper motion (which forms the best criterion of stellar distance available at the present time) falls between $\mu = 0''{\cdot}04$ and $\mu = 0''{\cdot}05$, the stars having spectra of type II exhibit no tendency to aggregate in the neighborhood of the Milky Way, but those of type I already have a marked preponderance in the lower galactic latitudes. For $\mu = 0''{\cdot}00$ to $\mu = 0''{\cdot}03$, the solar stars also begin to be condensed in low galactic latitudes, while the stars of the first type have nearly seven times as great a density in the Milky Way through a zone 20° wide, as in the galactic zones ±60° to ±90°. Consequently, at a mean distance corresponding to $\mu = 0''{\cdot}04$, the confines of the galactic stream have been entered. If this distance also corresponds to the parallax $\pi = 0''{\cdot}05$, the annual motion of these galactic stars is $1{\cdot}2 \times 10^{8}$ km., and the mean linear velocity is $120/150 \times 4{\cdot}75 = 3{\cdot}80$ km. per sec. The mean galactic distance must be five times as great as this, or $\pi = 0''{\cdot}01$, if the mean linear velocities are equal to that of the sun.

* Astrophysical Journal, xv, 129, pl. vi, 1902.

† The most reliable parallax of *Nova Persei* by the direct method is that of Dr. O. Bergstrand of Upsala, in which the effect of the dispersion of the air on the photographic measures is taken into account, giving absolute parallax $= 0''{\cdot}033$ (Astronomische Nachrichten, No. 3834).

‡ "On the Distribution of the Stars in Space," Knowledge, xvi, 114, 1893.

Now if the outer and more thinly distributed stars are revolving around great galactic aggregations of sufficient mass to control the general motion, the orbital velocities must increase in the vicinity of the controlling mass. Nevertheless, the dense aggregation of stars itself, having been accumulated during an immense time by gravity, ought to be relatively at rest, because of frequent collisions in the crowded centers. We have seen that stars of the first type are more abundant in the Milky Way. Kapteyn has shown that, between magnitudes 0 and 6·5, there are 19·3 times as many stars of type II as of type I having annual proper motions greater than 0″·50, but only 0·6 as many with proper motions less than 0″·03. This, taken in conjunction with the galactic condensation of the first-type stars, doubtless means, primarily, that there are comparatively few stars of the first type outside the Galaxy; but the small proper motions of stars of the first type may, in part, be due to the smallness of their linear motions. Professor Frost announced at the meeting of the Astronomical and Astrophysical Society of America, held in Washington, December, 1902, that the members of a group of Orion stars (all presumably galactic) have exceptionally small velocities in the line of sight (about 6·5 kilometers per second).* As far as it goes, this observation favors a value for the galactic parallax not far from 0″·03, with the consequences which have been noted. It is desirable that a large number of galactic first-type stars shall have their velocities in the line of sight and their proper motions measured, in order that this important point may be definitely settled.

Starting from these general principles, let us take up the mechanism of the Galaxy more in detail.

(1) Considering the form and structure of the Galaxy: *(a)* From analogy with nebular forms, we may say that the Milky Way is either spiral or annular in its major stream, but in any case it is substantially uniplanar in its leading features. *(b)* The Galaxy, however, taken as a complete system, is divisible into these directed or segregated stellar streams, and subordinate or satellite hosts whose interlacing movements weave a common envelope to the more condensed portions, which is presumably of spheroidal form, and which, judging from analogy with the outer shell of a spheroidal cluster, may extend to possibly ten times the radius of the condensed nucleus.

(2) I assume that, in the stellar universe, there are both

* "Radial Velocities of Twenty Stars having Spectra of the Orion Type": Edwin B. Frost and Walter S. Adams, Science, xvii, 324, 1903. I have applied corrections for the solar motion. "The angular proper motions of these stars are also small." In the Publications of the Washburn Observatory, vol. xi, p. 34, Mr. Albert S. Flint shows that the proper motions of the stars diminish more rapidly than their parallaxes.

movements of approach, produced by the attraction of gravity, and movements away from the attractive centers, probably due in the first instance to explosive agencies; also that the limits of agglomerative and dispersive movements are conditioned by the dimensions of the component bodies taking part in the systematic motion, as follows: (*a*) Agglomeration is characteristic of matter in the condition of collections or swarms of meteors, condensing into stars. Proof follows from the law of gravitation and the admitted existence of meteors. (*b*) Dispersal prevails after a certain limiting magnitude of mass has been attained as a result of agglomeration, presumably owing to instability under great pressure and high temperature, and the increase of explosive or repulsive forces. Proof follows from the structure of stellar clusters, which contain no single star of surpassing magnitude as in the solar system, and from the development of clusters as inferred from the spectra of the stars composing them, the less condensed clusters having more advanced spectra, indicating that the progression of a group of stars is towards more complete separation.

(3) The following are a few of the consequences of a theory of combined stellar concentration and dispersal:

(*a*) Comparative permanence of the potent, controlling, stellar streams, which are the loci of galactic agglomeration, is indicated by theory, since the attractive force increases as the mass enlarges, while dispersal sets a limit to the growth of aggregations, but does not obliterate them. Hence the original centers of condensation survive. In the surrounding regions there is presumably motion controlled from the loci of condensation, and with velocities increasing as the agglomerations are approached; but within the galactic agglomerations relative rest prevails, because in these dense regions opposing motions have been largely destroyed by collisions.

(*b*) Hence dispersal of satellite hosts from centers of dispersal in the galactic belts must produce outlying shells of sparsely distributed stars, and an excessively slow circulation of individual members of the accompanying starry hosts around definite galactic streams, which thus become the axes of a revolution remotely resembling that of a vortex ring, somewhat as a basaltic column resembles a crystal—not that there is consistent direction or parallelism in the orbits, any more than there is in the crystallization, but, on the contrary, a great variety of positions and paths, conditioned only by general agreement in a tendency to helical motion.

(*c*) Although the form of the condensed part of the Galaxy may be either a ring, or some kind of spiral branching from a center, as suggested by Easton,* the limiting volume which includes the sparsely distributed, but controlled, outlying members of the host, may be approximately a sphere. A different history, or mode of formation, is indicated for the central forms and their surroundings.

(*d*) If velocities occasionally generated exceed the controlling power of the combined mass, such portions escape. Hence instances of this sort can not accumulate, and must be rare.

1

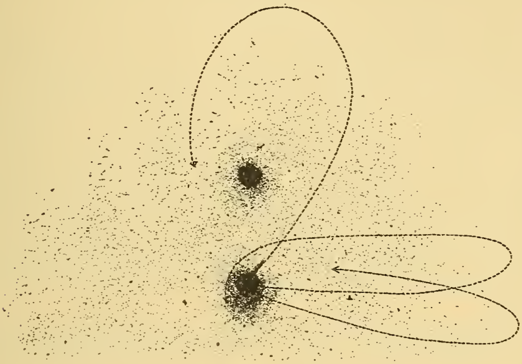


Figure 1 shows the paths of stars thrown off from a central condensation in various directions with velocities insufficient to produce separation from the system. If the direction is such that another branch or condensation has mass enough to draw the return path to one side, the circulation may be around this, rather than around the original member. Owing to the complex form of the Galaxy, perturbations are of a magnitude equaling or excelling the attraction of a parent center.

The revolutions shown are of excessive slowness, and of sufficient duration to allow a majority of the encompassing host to have passed through the stages of development characterized by first-type spectra, and to have attained the solar type.

(4) In order to reach some conception of the dimensions and periods of stellar revolutions around the Galaxy, I propose to take the galactic parallax $= \frac{1}{20}$ of a second of arc, corresponding to a distance $D = 600 \times 10^{12}$ km. in round numbers, as that of the sun from a galactic center of attraction, and to trace some of the consequences. Let D_1 be Neptune's distance from the sun. For a constant mass, the parabolic velocity is proportional to $\sqrt{1/D}$; hence the parabolic velocity from solar attraction at the sun's assumed galactic distance is

* Astrophysical Journal, xii, 136, 1900.

$$U_1 = \left(\frac{D_1}{D}\right)^{\frac{1}{2}} \times 7{\cdot}624 = 0{\cdot}02079 \text{ km.}$$

The velocity of the sun's motion among the stars is about 20 km. (Campbell's value is $-19{\cdot}89$ km. per sec. $\pm 1{\cdot}52$ km.),* and the ratio of the squares of these numbers gives a value for the galactic attracting mass, on the supposition that the solar motion is due to such attraction. If the present solar velocity were that of a circular orbit around a galactic cluster, undisturbed by the attraction of outlying masses, the solar parabolic velocity would be $U = 20 \times \sqrt{2}$; the central cluster must then have a mass 1,850,000 times that of the sun; and the period of one complete revolution would be nearly 6,000,000 years. But if the orbit is a very eccentric ellipse, reaching to the outer boundary of the galactic enclosing sphere, let us say 6×10^{15} km., the period must be lengthened. The circular orbit presupposes a center of attraction nearer than the main galactic stream, and not in its plane, since otherwise the present position of the sun, which is not far from the galactic plane, ought to be accompanied by a motion in the direction of the galactic pole.

Still considering the attraction of a mass $M = 1{,}850{,}000 \times M_1$, situated entirely within the solar orbit (M_1 being the sun's mass), let

perigalacteum	=	60×10^{12} km.,
present solar distance....	=	600×10^{12} "
apogalacteum	=	6000×10^{12} "

The corresponding velocities are $20 \times \sqrt{10} = 63\frac{1}{4}$, 20, and $63 \times \sqrt{\frac{1}{100}} = 6{\cdot}3$ kilometers per second. The period is nearly 70,000,000 years. With such a recession, however, we can no longer neglect the immense mass of surrounding stars, no matter how symmetrically they may be disposed.

A conveniently simple hypothesis for a first approximation is that the mass is uniformly distributed throughout the stellar sphere, of which we need only consider that part within the sun's actual radius at each moment of its revolution. With such a disposition of material, an individual sun might vibrate, pendulum-wise, on either side of the center, between extreme positions. The acceleration of gravity in such a cluster increases in proportion to the radius, and the velocities fluctuate between narrower limits.

If there are 1,000,000,000 stars, uniformly distributed within a sphere of radius $6{,}000 \times 10^{12}$ km., each star has to itself a volume $9{\cdot}05 \times 10^{38}$ cubic km. The mean distance of the stars

* Astrophysical Journal, xiii, 83, 1901.

is then ten billion kilometers (English numeration). As the distance of the nearest star, α Centauri, is forty billion kilometers, the adopted radius of the sphere is too small for the assumed uniform distribution ; but for the actual stellar distribution it is not an unreasonable value, because of the concentration of stars in the galactic centers, and provided the number 10^9 is acceptable for the total number of stars. Photographs of long exposure with telescopes having a large ratio of aperture to focal length, increase the number of stars to such an extent that 10^9, or possibly even 10^{10}, will not be an unreasonable estimate. The following considerations, however, prove that, if there be as many as 10^{10} stars concerned in the control of the solar motion, their average individual masses must be considerably less than that of the sun (I assume that the ether is devoid of mass, and that matter outside the Galaxy is on the whole symmetrically disposed, and is separated from our stellar system by such wide vacant intervals that the galactic motions may be treated independently): The solar acceleration of gravity at Neptune's orbit being $0{\cdot}000{,}651^{\text{cm}}$ per sec., the galactic acceleration at the distance $D = 6000 \times 10^{12}$ km. is :

$$f = \frac{M}{M_1} \times 0{\cdot}000{,}651 \times \left(\frac{4{\cdot}461 \times 10^9}{6{\cdot} \quad \times 10^{15}}\right)^2$$
$$= \quad 3{\cdot}6 \times 10^{-16} \times \frac{M}{M_1}.$$

Assume $\frac{M}{M_1} = 10^{10}$, and f to be uniform for 200,000 years. The velocity $v = 227$ km. per sec. at the end of this time, attained before one-sixth of the distance to the center of attraction has been traversed, is already larger than the maximum velocity permissible. Hence the attractive mass must be less than $10^{10} \times M_1$.

Let us next try the ratio $\frac{M}{M_1} = 10^9$, with the same radial dimensions. I have shown that the motion of the sun can be accounted for, if the central portion of the sphere within the sun's present radius vector contains less than 2,000,000 stars of the same mass as itself. Since the spherical volume of this space is $\frac{1}{1000}$ of the total volume of the assumed stellar sphere, the supposition of uniform distribution gives 2×10^9 stars for the larger volume; but with central condensation the outer portions of the sphere have not only a more open distribution of stars, but a smaller mass to the unit of volume, and both the number of stars and their mass must be less than 2×10^9. If $n = 1{,}000{,}000{,}000$, and the stars are uniformly distributed, it will take 6,000,000 years for the sun to traverse the distance from the boundary of its assumed sphere of motion to its present position, and the velocity acquired will be approximately 47 km., or more than twice that assigned from investigations of the solar apical motion.

With a galactic mass of 10^7, and the same dimensions as before, the sun will travel over the path from apogalacteum to its present position in about 19,000,000 years, but the final velocity is less than 15 km. per sec., or probably a little less than the actual one, still not so much smaller but that the increased acceleration produced by central condensation may bring the velocity up to the required amount.

Twenty million stars of the same mass as the sun, after 13½ million years, will give a velocity of 21 km. per sec. with uniform distribution, and more with central condensation.

Extreme condensation is improbable. Professor Newcomb has shown* that, for equal areas of sky, the brightness of the sky in the Milky Way is more than twice as great, but not as much as three times as great, as that near the galactic pole. If the general light of the nocturnal sky is due to small stars, this observation seems to indicate that the stellar distribution is more nearly uniform than is commonly supposed.

Some 20 years ago Professor Newcomb† calculated that 500,000,000 stars with masses equal to the sun's mass, and uniformly spread out in a thin circular layer or disk, $284{,}000 \times 10^{12}$ km. in diameter, will produce a velocity of 40 km. per sec. in a body falling from infinite distance to the center of the system. Such a disposition of attracting masses can hardly be considered a probable scheme of present stellar distribution, and I presume its proposer will prefer to modify it in the light of his own more recent photometric observations. The same mass distributed through a sphere of equal diameter has 50 per cent greater attraction, and central condensation would still farther increase the mean velocity.

Lord Kelvin‡ assumes a uniform stellar sphere with a radius five times as great as mine. This may be a better value than mine for an outer boundary of the galactic system, but comparatively few stars attain it, and the velocity possessed by our sun does not point to so large a recession. Vogel and Scheiner obtained an average velocity in the line of sight of 16·5 km. from fifty-one stars.§ Professor W. W. Campbell, after separating the solar motion, obtained for the numerical average of the velocities of 280 stars in the line of sight ±17·05 km. per sec.,

* Astrophysical Journal, xiv, 297, Dec. 1901.
† "Popular Astronomy," 2d ed., p. 501.
‡ Phil. Mag. (6), ii, 161, 1901; also iii, 1, 1902.
§ Scheiner's "Treatise on Astronomical Spectroscopy," Frost's translation, p. 350, 1894.

whence "the average velocity *in space* of each star in the system is $2 \times 17{\cdot}05 = 34{\cdot}10$ km. per second."* With this may be compared Lord Kelvin's calculation that if 1,000,000,000 stars, each of the sun's mass, started from a state of rest thousands of millions of years ago (a considerably larger time allowance, it will be noted, than has hitherto been admitted), and are now uniformly distributed in a sphere whose radius is $30{,}900 \times 10^{12}$ km., the present mean velocity should be about 50 km. per second.

If we assume that the individual stellar motions at perigalacteum are controlled both in direction and speed by some cluster, branch, or portion of a galactic ring, and that the general stellar sphere has then but little influence, it must, nevertheless, be conceded that at the larger distances and throughout the greater part of the stellar revolutions, if these are eccentric, the general sphere exercises control, and that the subordinate condensations or branches act only by the perturbations which they produce. It seems probable that much greater stellar velocities than those which have been measured, remain to be discovered on the borders of the denser galactic aggregations. Campbell finds that the velocity in the line of sight for stars fainter than the 4·0 magnitude, is about 50 per cent greater than for stars equal to, or brighter than, 3·0 magnitude. These stars, however, were not classified galactically.

Speaking only of observed stellar motions and the *effective* attractive mass which they indicate, it appears that a galactic mass equivalent to 20,000,000 suns like ours, with a moderate central condensation sufficient to quicken the stellar motions in our vicinity by one third of their amount with homogeneous distribution, is a probable value. Stars, presumably belonging to the galactic system, exist in numbers approaching or exceeding hundreds of millions; hence there are either a great many stars of small mass, our sun being larger that the average, or else much the larger number of stars is so situated that the attractions are mutually annulled.

The radius of the stellar sphere surrounding the main streams of the Galaxy and under the control of their attraction, is possibly 30,000 billion kilometers, as predicated by Lord Kelvin; but the solar apogalactic recession does not seem to be so great. The motion in a homogeneous swarm is of the nature of a simple oscillation; and between limits of $\pm 6 \times 10^{15}$ km. with the total efficient mass just given, the movement from one extreme to the other will consume a little less than 30,000,000 years. Such an arrangement, however, can not endure, because the intersecting paths entail numerous collisions near the cen-

* Astrophysical Journal, xiii, 84, 1901.

ter, with destruction of linear motion and the formation of a condensed nucleus. With such a nucleus, assuming a perigalactic approach to 0·01 of the apogalactic distance, or a short-radius swing around some dominant galactic agglomeration, the galactic period of revolution of a star, under the attraction of a mass $M = 20,000,000 \times M_1$, may approximate 25,000,000 years. Mr. Maxwell Hall, by combining the positions, proper motions, and parallaxes of a small number of stars for which these quantities have been satisfactorily determined, and assuming circular orbits around a general center of motion, obtained for the length of the "Annus Magnus" 20,000,000 years.* A revision with improved data gave for the period of general revolution 13,150,000 years,† the center of motion being in Andromeda. Kapteyn considers the center of the Galaxy to lie in the direction of Lacerta; and Easton has given reasons for placing this center in Cygnus. The presumption that the orbits are ellipses rather than circles, and ellipses of large eccentricity, which require longer periods, follows from the principles adopted in the present paper, while the solar motion favors Easton's position; and as it is not necessary to suppose that the nearer stars are moving around the same center, arguments from the structure of the Galaxy itself deserve the most weight.

(5) When the proper motions of the stars are charted, the divergence from the apex and convergence to the anti-apex of the sun's way immediately attract attention; but after allowing for this, there is no very obvious preponderance in the residual directions of the true proper motions, either with or across the galactic plane. Upon the hypothesis that the stellar movements have originated in dispersals produced by explosions, this result indicates that the explosive forces have acted indiscriminately in all directions. The primary forces which have given the condensed part of the Milky Way its structure have acted in a plane; but the motions of the outlying stars have probably had a different and secondary origin, and this is further indicated by the advanced types of their spectra.

(6) According to the assumption that the stars have been thrown off from centers of dispersal distributed along the galactic axes of condensation, and that explosive division of stellar masses in the galactic zone is still in progress, the Milky Way must include both stars of great mass, as yet undivided, and large numbers of small stars, together with star clusters resulting from recent division, as well as dark meteor swarms not yet ready for stellar existence. The concentration of mass in a narrowly limited central region may be great, but we are

* "On the Sidereal System," Mem. Roy. Astr. Soc., xliii, 196, 1876.
† Monthly Notices, Roy. Astr. Soc., xlvii, 539, 1887.

unable to distinguish between the relative numbers of large and small stars, and can give no numerical estimate of the degree of (mass) condensation. Scheiner derives a relative numerical condensation of 1:16 for the periphery and center of the great cluster in Hercules,* but Newcomb's ratio of galactic brightness does not favor so marked a variation in the distribution of galactic density, at least not unless there are many dark bodies—incipient novae, not yet ready to shine—situated within the galactic streams. The possibility of such dark bodies must of course be admitted, but no estimate can be made of the amount of matter thus concealed.

(7) If we may assume that the life of a sun surpasses in duration that of a single revolution about the galactic axis, our solar system has endured much longer than is commonly supposed by astronomers, and its age is more nearly in agreement with the time estimates deduced from geological reasoning. The suggestion of a galactic year, embracing many millions of solar years, and perhaps attended by changes in meteoric accessions received in different parts of the orbit, which modify the planetary atmospheres and alter their absorptive power for the solar rays, or change conditions affecting the life of plants and animals, is worth considering. Thus, as Sterry Hunt has shown, the amount of carbon stored up by our earth in the Carboniferous age exceeds that which can have existed at any one time in an atmosphere suitable for supporting life, many times over. Accordingly, during this age, there were probably continual or successive additions of carbon, or its compounds, to the atmosphere; and the carbon came from regions of space richer in this material than any traversed before or since.

The Ice age, which has never been satisfactorily explained, may have been produced in the same way either by changes in the sun itself and its radiant power, or by variations in the constitution of the earth's atmosphere affecting the atmospheric absorption of solar and terrestrial radiation, and thus controlling surface temperatures.

(8) The hypothesis of stellar revolutions around controlling galactic centers may be illustrated by the case of our own sun which is assumed to be well on its way toward perigalacteum.

Since the projection of the Milky Way upon the celestial sphere divides the sphere into nearly equal parts, our sun at present must be near the plane of the ring or spiral of condensation. Also, since the apex of the sun's way is not over 20° from the central line of the galactic stream in Cygnus, the sun is probably moving obliquely at a small angle with the plane of the ring, around some dominant mass. A right line

*Abhand. d. k. Akad. d. Wissensch. zu Berlin, p. 36, 1892.

through this mass, parallel with the sun's motion, will intersect a plane through the sun at right angles to the direction of motion and meeting the celestial sphere in a great circle 90° from the apex, in a point whose projection may lie anywhere on this great circle; but if the motion is actuated by the predominating attraction of a part of the galactic stream, the plane of motion is probably nearly perpendicular to the general direction of the Galaxy on either side of the chief attractive center, because the attraction of the adjacent portions of the galactic stream, if at all symmetrical, will bring the plane of motion into approximate coincidence with a radial plane through the rectilinear axis of curvature of the stream. It is also probable that the dominant region of attraction for our sun lies in the Milky Way not far from the apex of the sun's way.

The projection of a line through the center of attraction, parallel to the sun's path, will be a portion of a great circle through the apex, cutting the Milky Way in Cygnus, and intersecting the trace of the plane through the sun at right angles to the line of motion, somewhere in the constellation Aquarius. The projected line is nearly parallel to the direction of proper motion of our near neighbor, 61 Cygni, which very likely forms one system with the sun.

The axis of orbital revolution can not be placed at present; but as our sun approaches perigalacteum, the apex of motion will recede to a point on the celestial sphere 90° from the Milky Way, and the direction of motion of the apex will then determine the axis of the orbit. Long before that time, however, the present constellations will have been entirely broken up, and only the more general shapes of portions of the Milky Way will preserve a kind of fixity. All that can be said at this time is that the sun has advanced toward the Galaxy from its northern side, passing through its plane to its southern side, and that the sun is now within the stellar coil and nearly in the galactic plane.

Arcturus, Va.

Art. XIII.—*The Little Cottonwood Granite Body of the Wasatch Mountains;* by S. F. Emmons.

The Wasatch Range, from a geological standpoint, is the most important of the many more or less parallel mountain uplifts that go to make up the Cordilleran Mountain System in its widest part—that is, between the latitudes of 39° and 41° N. It has, from the earliest geological time of which we have any record, formed the dividing line between the geology of the west or Pacific slope and of the eastern Rocky Mountains, there being an essential difference on either side of this line, not only in the lithological constitution of the respective geological formations but in their faunal characteristics.

From a Tectonic point of view it is equally important, presenting as it does examples of most of the varied phenomena involved in mountain building, the latest phase having been a great meridional fault which has cleft it in twain, so that its western half is now buried beneath the floor of the Great Salt Lake Valley; it is thus well worthy of the characterization given it by the elder Dana, as "the grandest exhibition of facts pertaining to an individual case of mountain building in geological literature."*

It was in the summer of 1869 that the geologists of the 40th Parallel undertook the geological examination of this range. The two previous seasons had been devoted to geological mapping† of the Desert Ranges of Nevada and western Utah. In these isolated ridges, standing like islands in a great ocean of recently deposited sediments, the rocks were found to be mainly eruptives and members of a great Paleozoic series whose extent, position, and faunal characteristics in the vast region west of the Mississippi Valley were as yet completely unknown, and the facts gathered so far had afforded no clue whatever as to the extent or order of superposition of the different members of this portion of the sedimentary column.

As our weary march across the desert in the season of 1869 had finally, in the month of November, led us along the western foot of this magnificent range through the smiling

* This Journal (3), xlv, 181.

† It is perhaps questionable whether the word "mapping" is the correct term in this place, for at the time no maps of the region were extant and topographer and geologist did their field work side by side. It was not until 1875 that the paleontologists had furnished their final determinations of the age of the various groups of fossils collected and the topographers had completed their maps so that the geological outlines might be laid down upon them.

fields and orchards of the Mormon farmers, we looked with delight at the deep clefts of the many canyons that scored its flanks, foreseeing that here at last might be found a key to the problem that so long had troubled us, in the actual superposition of the complete Paleozoic series.

As originally planned, the season of 1869 was intended to complete the field work of the 40th Parallel Survey. There remained of the Desert Region all the ranges from the Wasatch westward to the western edge of the Great Desert, and east of the Wasatch the western end of the Uinta Range and a portion of the Tertiary Basin of Green River were included within our field of work, an extent of country 125 miles long in an east and west direction and with a normal width of 102 miles north and south or 12,750 square miles. To cover this area required the utmost diligence and careful allotment of the time from May to November, in which alone field work was possible at that latitude and elevation. Three weeks were all that could be allotted for the topographic and geological reconnaissance of the whole Wasatch range south of the latitude of Salt Lake City, which fell to the lot of my party. It can readily be conceived that under such relations of time to area many phenomena would necessarily be but imperfectly observed. As regards the completeness of the geological column, expectations were more than realized. It was found that not only was the entire Paleozoic section completely developed but representatives of two series of pre-Cambrian formations and of a remarkably full suite of Mesozoic and Tertiary formations were exposed in this range. In the field, therefore, attention was mainly devoted to the working out of the columnar section, and it was not until many years afterwards, when, by the completion of the topographic maps, it was made possible to represent their relations graphically, that the true import of some of the great structural problems involved could be fully appreciated.

I have gone somewhat at length into these preliminary observations because the purpose of this paper being to acknowledge that an important mistake was made in the course of the work, it seems no more than justice to those that carried it on —more particularly to our deceased chief, Clarence King, to whose genius and energy was due the conception and carrying out of this great work and who personally drew all its most important conclusions—that geologists of the present day should have a realizing sense of the conditions under which it was carried on. During the nearly thirty years that have elapsed since its conception, I have had opportunities of verifying the work in many parts of the field in the light of the more complete knowledge of later times, and it has always been a matter of wonder to me that so few mistakes were made.

The problem which had the most important bearing upon the earlier history of the Wasatch Range proved to be that with regard to the age of the Little Cottonwood granite. This is a huge, homogeneous body, somewhat in the shape of a half dome, which forms the mass of Lone Peak and the lower two-thirds of Twin Peak, and is well exposed in the deep glacial trough of Little Cottonwood Canyon that runs in a nearly straight west line between the two. Around this mass and in general dipping away from it on the north, east, and south wrap the series of Paleozoic sediments, which curve in strike from northwest on the north through north-south to northeast on the south. The lowest member of this series consists of 12,000 feet of Cambrian beds, mainly quartzites, which alone come in contact with the Cottonwood granite body. On the west face of the granite rest a series of westerly dipping crystalline schists of assumed Archean age. These beds are unconformably overlaid by the Cambrian beds, which differ from them nearly 90° both in strike and dip. That the granite was intruded into and hence later than these Archean beds is readily evident, the contacts lying along the valley slope of the range, where they can easily be seen. The contacts of the granite with the Cambrian beds, on the other hand, are less easy of access, being mostly high up on the steep mountain slopes and covered by brush and talus, so that in the time allotted for exploring this region few were actually observed. Two alternative solutions of the problem presented themselves, which are indicated by Mr. King* as follows:

"It is very evident that the granite is either an intrusive mass or else an original boss on which the sedimentary material was deposited." The close lithological resemblance of this granite to the Jurassic granites of the Sierra Nevada had at first suggested its later intrusion, but after careful weighing of all the evidence it was concluded that the preponderance was in favor of its pre-Cambrian origin. The Clayton Peak mass farther eastward, at the head of Big Cottonwood Canyon, though separated at the surface by several thousand feet of easterly dipping quartzites and limestones, and of somewhat different structure, was assumed to be part of the same boss. This assumption necessitated in Mr. King's reconstruction of the Archean surface, on which the Paleozoic sediments were deposited, the existence in this part of the original range of a steep cliff of about 30,000 feet elevation.

While there is abundant evidence in other parts of the 40th Parallel region to support Mr. King's statement that the pre-

* 40th Parallel Reports, vol. i, "Systematic Geology," p. 48.

Cambrian topography must have been of far bolder type than that of the present day, the existence of this 30,000 foot cliff has been regarded by geologists with some incredulity.

As the result of a brief personal visit to the region, Professor (now Sir) Archibald Geikie published a criticism* of Mr. King's views, based largely upon improbability of the existence of a cliff of such enormous dimensions, and concludes that the intrusion must be of post-Carboniferous age. Later in his text-book of geology he quotes this occurrence as "shown to be of post-Carboniferous age."†

A reply to Professor Geikie's criticism, on the part of Mr. King and myself, has awaited the opportunity of making a further study of the region which should be conducted with sufficiently greater thoroughness than either of the previous examinations to settle the question once for all. In consequence, however, of the extreme ruggedness of the region and the difficulty of access by most of the contact lines, lying as they do along the edges of precipitous mountain summits, such an examination would require several weeks' work with a camping party and the opportunity of making it has hitherto not presented itself. In Chapter VI of my report on the "Geology of Leadville," however, in discussing the extent of the absorbability of sedimentary rocks by eruptive masses, I took occasion to refer to one of the arguments that had influenced us in arriving at the conclusion that the Little Cottonwood granite was pre-Cambrian. This was, briefly, that the other assumption, namely, that it was later than the Cambrian quartzites that rested upon it, involved the absorption of some 500 cubic miles of these quartzites by the intrusive magma which ought to have resulted in making the magma unusually acid, whereas in point of fact, the Cottonwood granite has only 71·78 per cent of silica, which is but normal and not a specially acid type. I also referred to the fact that no included fragments of Cambrian quartzites had thus far been found in granite, although along the Archean contact, near the mouth of the canyon, such included fragments are of frequent occurrence. On the other hand, I did not mention the fact that occasional pebbles of granite had been found in the quartzite, for the reason that we had not yet observed marginal zones of basal conglomerates, such as Professor Geikie very justly observed ought to be found at the base of such slopes of land.

Van Hise‡ examined the canyon in 1889 and found granite pebbles in the Cambrian quartzite which he, however, regarded as lithologically unlike the Cottonwood granite. He considered the Cottonwood and Clayton Peak granites as identical

* This Journal (3) xi, p. 363. † Edition of 1882, p. 646.
‡ U. S. Geological Survey, Bull. 86, p. 294, 297.

in character and found the limestones in contact with the latter exceedingly metamorphosed. He does not, however, appear to have found any evidence of intrusive nature at the actual contact of the Cottonwood granite body with the Cambrian quartzite. In reviewing the published evidence on the subject, he is more inclined to favor the view favored by Geikie than that of the 40th Parallel geologists, though he admits that he does not regard the objections to the latter view of so insuperable a nature as did Geikie.

In the past few seasons several pieces of Survey work have been carried on under my supervision in this portion of Utah, and I have taken advantage of the opportunity of having younger legs than my own at my disposal to have the more inaccessible portions of the granite contact along Littlewood Canyon more closely investigated.

Already in the summer of 1900, at the close of his field work in Bingham Canyon, Mr. J. M. Boutwell at my request examined the contact of granite and quartzite on the south face of the Twin Peak ridge, a few miles below Alta, and found several apophyses of granite cutting into the quartzite beds above the contact. Mr. Boutwell courteously refrained from publishing the results of his examination until I should have an opportunity of personally examining the contact. This occurred during the past summer, when Mr. Boutwell's party was making a survey of the Park City district, within a few days' ride of this locality, and the object of this paper is to state the result of this examination.

That the Cottonwood granite body is intrusive in the Cambrian quartzite is proved by the existence of apophyses of the former running across the bedding of the latter for some distance and in one observed instance spreading out again between the beds in a considerable body.

On the other hand, no metamorphism of the contact could be distinguished megascopically, and in the canyon bottom the upper surface of the granite is smooth and even, conforming with the bedding planes of quartzite, while small, rounded pebbles of a granitoid rock are found in the bed of quartzite immediately above the contact. At the mouth of the canyon the western contact of the granite body with the Archean schists is much more distinctly intrusive, being very ragged and uneven, while fragments of the former, both large and small, are included within the granite.

For a distance of over a mile above the eastern contact of the granite, quartzites and limestones, dipping steeply eastward, occupy the bed and sweep up on either wall of the canyon, thus separating the Cottonwood from the Clayton Peak eruptive body by an estimated thickness of two to three thousand feet of sedimentary beds.

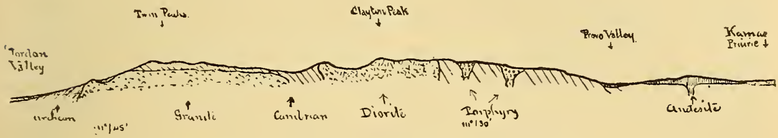
The outcrop of the Clayton Peak body occupies the divide between the heads of Little and Big Cottonwood canyons, the basin at the head of the latter canyon, and the mass of Clayton Peak which forms its eastern rim; it also extends for some distance east of the latter peak in the plateau-like basin at the head of Little Snake River, where its outcrops are obscured by surface accumulation.

In my original visit to the head of Big Cottonwood Canyon, in 1869, I collected a specimen of crystalline garnet rock which presented something of a schistose structure and was thought to belong to the Archean complex. At that time the results of the studies of contact metamorphism by Doelter and others in the Predazzo-Thal and other classic localities in Europe had not been published, and even to Prof. Zirkel, who examined the specimen microscopically, the suggestion did not present itself that this was probably a phase of contact alteration of limestone. At the present day, however, when the original dense forest-covering has been cleared away and prospectors have sunk holes wherever the contact of limestone and granite is exposed, these contacts are readily observed and show conclusive evidence of the later intrusion of the granite into limestone in the abundant development of contact minerals, such as vesuvianite, garnet, etc., and of contact deposits of ores of the metals, in which the association of magnetite with pyrite, chalcopyrite, galena, etc., is most common. Marmorization of the limestone is abundant in the region and by no means confined to the contact belt, but, as Mr. King observes, spreads out over large areas in the limestone beds that have no definite relation to any known outcrop of eruptive rock.

The prevailing rock of the Clayton Peak rock is a granular diorite of the same general mineralogical composition as the Cottonwood granite, but of finer grain and apparently carrying less quartz and a greater proportion of basic silicates. The western portion of this body on the divide between Big and Little Cottonwood canyons, however, is of somewhat coarser grain and resembles the granodiorites of the Sierra Nevada. A small body exposed in Big Cottonwood Canyon, about two miles below the bend and in the same general geological horizon as the Clayton Peak mass, but some four miles north of the outcrop of the Cottonwood granite, is of the fine-grained dioritic type characteristic of the Clayton Peak mass.

Each of the diorite body of the Clayton Peak, the eastern spurs of the Wasatch Mountains, are made up of Paleozoic beds cut through quite irregularly by stocks and dikes of eruptive rocks of distinctly porphyritic structure, though of the same general mineralogical composition as the diorite. These general relations are shown in the accompanying profile of the range on a general east and west line running through Twin Peak, the head of Little Cottonwood Canyon, and Clayton Peak.

1



A broad depression between the eastern foothills of the Wasatch Mountains and the western flanks of the Uinta Mountains is largely covered by andesitic lavas, overlying bedded tuffs of an undoubted extrusive nature, which are of Tertiary (probably post-Eocene) age. These rocks have a striking resemblance in their mineralogical composition to the diorites and porphyries of the Clayton Peak mass.

While, therefore, it must be admitted that the geological history of the region, as traced by the geologists of the 40th Parallel, is not entirely correct, it is yet too early to state exactly how far and in what way it should be modified. This must await a thorough resurvey of the region based on large scale maps, a work which has already been inaugurated by the geologists of the Survey; inasmuch, however, as it will probably be several years before this work will be sufficiently far advanced to afford final solutions of some of the most critical problems, it may be permitted to state what these problems are and to present some alternative hypothesis as to their probable solution. It is certainly a most striking fact that these several eruptive bodies, which apparently are of sufficiently similar mineralogical and chemical composition to have originated in the same general magma, occur along the line running a little north of east, which, if extended westward, would pass through the mining district of Bingham Canyon where occur the most important intrusions of porphyritic eruptive rocks in the Oquirrh Mountains, and where there have also been outpourings of later extrusives of consanguineous character along the flanks of the range. The same line, extended still farther westward to the parallel range of the Aqui Mountains, passes through a small body of extrusive, andesitic lavas and tuffs on the east flanks of that range, which, so far as known, is the only point where eruptive rocks are found in it. Attention was called to this fact in my original description of the geology of this region,* and also to the fact that along this line in the

* 40th Parallel Report, vol. ii, Descriptive Geology, p. 459.

Oquirrh and Wasatch Mountains there has been the greatest concentration of ore deposits. This generalization holds good at the present day, but modern developments show that there is an evident genetic connection with the older eruptives, while none is apparent with the extrusive flows.

The further statement in my original report,* that in the Wasatch range the mineral deposits are mostly concentrated within a radius of 6 or 7 miles around Clayton Peak, also holds good in the light of present developments, which, moreover, point to a more intimate genetic relation of ore deposition to the Clayton Peak than to the Cottonwood body, for as far as known no ore deposits have been found on the contact of the latter with the surrounding rocks, whereas they are most common around the Clayton Peak mass. It must be noted, however, that these deposits occur for the most part in calcareous rocks, and no calcareous rocks are known to occur in contact with the Cottonwood granite. It may be assumed that the Cottonwood granite, if regarded as a distinct body, did not reach a higher horizon than a thousand feet or more below the top of the Cambrian quartzite. That the Cottonwood and Clayton Peak granite beds were part of the same mass and hence of contemporaneous origin, was a plausible assumption as made by the 40th Parallel geologists but one which has not yet been supported by the finding of any connection between the two on the surface. In the absence of such connection a possible alternative hypothesis is that there have been successive eruptions in this region from the same general magma, each of which reached a higher geological horizon than the preceding one. On this hypothesis it may be assumed that the Cottonwood batholith was intruded while the Cambrian beds were still resting undisturbed upon the upturned edges of the Archean, and that it did not reach the top of the Cambrian; that this eruption was followed later by the mountain-building movement which threw the Paleozoic beds into anticlinal and synclinal folds, and that after they were thus upturned, the Clayton Peak mass intruded into the Carboniferous limestone and produced the well recognized contact phenomena now seen. The stocks or dikes of porphyry in the somewhat higher geological horizons to the eastward might have been contemporaneous or slightly later eruptions from the same general magma, and have owed their less completely crystalline structure to the differing conditions under which they consolidated. The abundant mineralization in the region has evidently been in part a direct and in part an indirect result of this phase of activity.

As regards the extrusive flows in the depression between the Wasatch and Uinta Mountains, they rest on a surface from

*Ibid, p. 364.

which not only Mesozoic but a great thickness of Eocene Tertiary beds must have been denuded, hence a long period must have elapsed between the older eruptions and this one, which, by analogy with the regions to the westward, may be assumed to have occurred during the Miocene period.

It has been assumed as a result of the 40th Parallel work—an assumption that has not yet been seriously modified by later investigations—that while there was in the Cordilleran region toward the close of the Carboniferous a general elevation of the Great Basin region accompanied by greater or less erosion, the main mountain-building movement occurred at the close of the Jurassic. In the Wasatch some evidence of a transgression at this period was found by the 40th Parallel geologists, but it was not insisted on in their reports because without a reëxamination of the field it could not be considered absolutely conclusive. It would now appear probable that the eruption of the Clayton Peak mass must have been contemporaneous with or closely followed this Jurassic movement. If future investigations prove that the Cottonwood body is of the same age as the Clayton Peak mass, there will be found exposed here in unusual detail the contact phenomena of an enormous granitic batholith, extending in horizon from the Archean across a vertical column of 25 to 30,000 feet of sedimentary beds of varying composition, and an opportunity will be afforded to study what influence, if any, has been exerted on the intrusive magma by the rocks through which it passed and which, presumably, must have been absorbed by it.

U. S. Geological Survey, Washington, D. C.

ART. XIV.—*A Contribution to a List of the Fauna of the Stafford Limestone of New York;* by MIGNON TALBOT.

THE Stafford limestone, as stated by Dr. J. M. Clarke,* is the western of the two comparatively persistent limestones of the Marcellus shale of New York, and extends from a point near Phelps, Ontario County, to Lake Erie. Several outcrops have been recorded and studied. These may be found along Flint Creek and near Baggerly Corners in Ontario County; at Littleville and at another spot near Avon, in Livingston County; at Stafford, Leroy, and Batavia, in Genesee County; and at Wende, at Lancaster, and near Buffalo,† in Erie County. Borings from various salt shafts show its presence at York, Livonia, and the outlet of Conesus Lake, in Livingston County, and Miss Elvira Wood‡ reports it from a sewer excavation in Buffalo.

Three small collections of this limestone, one from Batavia and two from Leroy, N. Y., have been worked out in the paleontological laboratory of the Yale University Museum, and a number of species not previously reported from this horizon has been found, sufficient to warrant the publication of a list supplemental to those given by Dr. Clarke and Miss Wood.

In Miss Wood's account of the section at Lancaster, the lowest bed of the limestone is described as made up largely of *Strophalosia truncata* and *Ambocœlia nana*. This same rock, together with typical Stafford material, is in the collection from Batavia, about forty miles to the east of Lancaster. Without visiting the section, it would be unwise to attempt to interpret the occurrence of this bed at Batavia, as, unfortunately, its exact horizon was not reported. Of the two collections from Leroy, only ten miles farther east, neither contains this rock.

In studying the Batavia and Leroy material in the Yale University Museum, comparison with the lists as given from the typical Stafford limestone and including the lower beds of the Lancaster section resulted in the following:—

	Number of species previously reported.	Species from Batavia and Leroy not heretofore recorded.
Anthozoa	7	4
Crinoidea	1	.
Bryozoa	4	2
Brachiopoda	38	5

* Bull. 49, N. Y. St. Mus., pp. 115-138, 1901.
† 15th Ann. Rept. N. Y. St. Geol., 1895, pt. i, p. 316.
‡ Bull. 49, N. Y. St. Mus., pp. 139-181, 1901.

	Number of species previously reported.	Species from Batavia and Leroy not heretofore recorded.
Pelecypoda	10	9
Gastropoda	14	8
Pteropoda	3	
Cephalopoda	11	5
Crustacea	7	1
Annelida	1	
Total	96	34

From this comparison it will be seen that an addition of thirty-five per cent has been made to the known fauna of the Stafford limestone. All of the additional species in the appended list, except the Anthozoa, one of the Cephalopoda, and four of the Gastropoda, are typical Hamilton species.

Supplemental Faunal List from the Stafford Limestone.

	Batavia.	Leroy.
Anthozoa.		
Amplexus, sp. undet.		×
Cystiphyllum, sp. undet.		×
Syringopora, sp. undet.		×
Zaphrentis, sp. undet.		×
Bryozoa.		
Stictopora sinuosa Hall	×	×
Trematopora immersa Hall		×
Brachiopoda.		
Cranæna Romingeri Hall	×	×
Lingula ligea Hall	×	
Liorhynchus, sp. undet.	×	×
Spirifer macronotus Hall	×	
S. Marcyi Hall	×	
Pelecypoda.		
Aviculopecten insignis Hall	×	
Grammysia Eriopia Hall		×
Macrodon Hamiltoniæ Hall		×
Modiomorpha subalata Hall	×	×
Nucula corbuliformis Hall		×
Palæoneilo constricta Hall		×
Panenka, sp. undet.	×	×
Sphenotus arcæformis Hall		×
Sphenotus, sp. undet.		×

	Batavia.	Leroy.
Gastropoda.		
Bellerophon, cf. *brevilineatus* Conrad		×
B. curvilineatus Conrad *		×
B. Leda Hall		×
Euomphalus planodiscus Hall		×
Platyceras carinatum Hall	×	×
P. erectum Hall	×	×
Platyostoma lineatum Conrad		×
Pleurotomaria Ella Hall	×	×
Cephalopoda.		
Gomphoceras lunatum Hall	×	
Goniatites discoideus Hall	×	×
Nautilus acrœus Hall		×
Orthoceras Thestor Hall	×	×
Orthoceras, sp. undet.		×
Crustacea.		
Cyphaspis ornata, var. *baccata* Hall		×
Total	15	29

Paleontological Laboratory, Yale University Museum,
April, 1903.

* *Bellerophon curvilineatus* Conrad has not been reported above the Upper Helderberg limestone, and at that horizon has been found only in the eastern part of the State, at Schoharie and in the Helderbergs.

ART. XV.—*On the Formula of Bornite;* by B. J. HARRINGTON.

THE subject of the formula of bornite is one which has long required investigation. If we refer to the standard works on mineralogy we generally find that the formula of the *crystallized* mineral is given as Cu_3FeS_3 (or $3Cu_2S{\cdot}Fe_2S_3$ as originally written by Plattner) and that numerous analyses of the *massive* mineral from various parts of the world show little agreement with this formula and often differ widely from one another. The difference in the composition of the massive specimens has been explained by saying that they were mixtures of bornite with chalcopyrite and chalcocite, and no doubt in the case of some analyses these or other mixtures have been called upon to do duty for bornite.

So far as the writer is aware, crystallized bornite has not been met with in Canada. The massive mineral of evident purity, however, occurs at many localities, and it was thought that an examination of carefully selected specimens might throw some light on the question under consideration. Those chosen were from widely separated points in the Provinces of Quebec, Ontario, and British Columbia, and the results of their analysis are as follows:

	I.	II.	III.	IV.	V.
Copper	63·55	62·78	62·73	63·34	63·18
Iron	10·92	11·28	11·05	10·83	11·28
Sulphur	25·63	25·39	25·79	25·54	24·88
Insoluble	----	0·30	----	0·38	0·24
	100·10	99·75	99·57	100·09	99·58
Sp. gr. at 15°C	5·085	5·055	5·090	5·029*	----

I. Harvey Hill, P. Q.
II. Bruce Mines, Ontario.
III. Dean Channel, How Sound, B. C.
IV. Copper Mountain, South Fork of Similkameen River, B. C.
V. Texada Island, B. C. The two last analyses were made by Mr. J. E. A. Egleson.

It will be observed that the results agree well with one another and also with the formula Cu_5FeS_4, which gives:

	Cu_5FeS_4
Copper	63·27
Iron	11·18
Sulphur	25·55
	100·00

* The fragment used for this determination contained a little malachite, the effect of which would be to lower the specific gravity slightly.

Nor are such concordant results likely to have been obtained from mere mixtures of different sulphides. Furthermore, they are in close accord with a number of previously published analyses of massive bornites. Out of fifty analyses cited by Hintze* about one-fifth agree well with the formula Cu_5FeS_4 and the average of eight of these gives:

Copper	62·85
Iron	11·57
Sulphur	25·34
	99·76

We pass now to the consideration of crystallized bornite. Through the kindness of Professors Dana and Penfield of Yale University, the writer has been able to obtain a specimen of the crystallized mineral from Bristol, Connecticut, which, though long known, had apparently never been analyzed.† It came from the Brush collection (specimen No. 805) and though partly massive showed at one end a group of fairly distinct rhombic dodecahedrons, which, so far as could be ascertained microscopically, were entirely free from other minerals and were found to have a specific gravity of 5·072 at 15° C. Their analysis gave:

		Cu_5FeS_4
Copper	63·24	63·27
Iron	11·20	11·18
Sulphur	25·54	25·55
	99·98	100·00

Here then we have a *crystallized* bornite which does not agree in composition with the commonly accepted formula Cu_3FeS_3. As to this formula, which has so long been assigned to the crystallized mineral, we find that it was based upon the analysis of a Cornish specimen published by Plattner in 1839.‡ This was followed in the same year by an analysis of another Cornish specimen by Varrentrapp,§ while a third analysis by Chodney appeared in the same journal in 1844.‖ These three analyses, together with two others, also of Cornish specimens, are given below:

* Handbuch der Mineralogie, 1901, p. 915.

† For an analysis of the massive mineral from Bristol see Dana, "System of Mineralogy," 1892, p. 77.

‡ Pogg. Ann. xlvii, p. 351, 1839.

§ Ibid., p. 372.

‖ Ibid., lxi, p. 395, 1844.

	I.	II.	III.	IV.	V.	Cu_3FeS_3
Copper	56·76	58·20	57·89	57·71	57·68	55·58
Iron	14·84	14·85	14·94	13·89	15·11	16·36
Sulphur	28·24	26·98	26·84	27·17	26·46	28·06
	99·84	100·03	99·67	98·77	99·25	100·00

I. Condorra Mine, Cornwall. Analysis by Plattner.
II. No locality is given, but the description makes it practically certain that the specimen was from Cornwall. Analysis by Varrentrapp.
III. Redruth, Cornwall. Analysis by Chodney.
IV. and V. Cornwall. Exact locality not known. Analyses by the writer.

It is obvious that none of these analyses agrees well with the formula Cu_3FeS_3, nor could it be expected that satisfactory results would be obtained from the analysis of the Cornish crystals, all of which, so far as the writer has had an opportunity of observing, are very impure.* Not only have they generally been altered by oxidation, but they almost always contain a yellow sulphide with the characters of chalcopyrite. In some specimens nearly every crystal when broken shows a yellow nucleus of chalcopyrite and the writer found it impossible to obtain material which could be regarded as pure. The early analysts, too, evidently found difficulty, if we are to judge from their descriptions. Plattner, for example, tells how he broke up the crystals and picked out the pieces which he considered to be free from copper pyrites. He further trusted to washing with distilled water in order "as far as possible" to remove the superficial portion of the crystals which appeared to be somewhat oxidized. Varrentrapp, again, states that the small cubical crystals examined by him all contained a nucleus (kern) of chalcopyrite and had their surfaces covered with a layer of copper oxide. He admits also that his results do not agree well with those of Plattner.

There is then good reason for believing that the formula Cu_3FeS_3 was deduced from analyses of impure material, and, as we have seen, it does not apply to the crystallized mineral as found at Bristol, Connecticut. If a mineral having this formula really exists, then we have two distinct species—bornite and something else. Artificial products agreeing well with the formula Cu_3FeS_3 are said to have been prepared,† and there

* Professor Penfield has kindly sent me a number of crystals broken from specimens of Cornish bornite in the Brush collection and these are also very impure.

† See Hintze, "Handbuch der Mineralogie," 1901, p. 914.

Doelter states that by heating a mixture of CuO,Cu_2O and Fe_2O_3 in a current of H_2S at a temperature not above 200° he obtained the "normal bornite $Cu_2S + CuS + FeS$" in aggregates of little cubes. He, however, gives no analysis of these (Zeitschr. f. Kryst., xi, 1886, 36).

is no evident reason why such a mineral should not occur in nature.

Many of the published analyses of so-called bornite show a composition which could be easily explained by the presence of chalcopyrite, which would reduce the proportion of copper and increase the proportions of iron and sulphur. In other cases chalcocite would appear to be present. In this connection it is interesting to note that a mixture of one molecule of bornite with one of chalcopyrite would give the old formula, thus:

Bornite	Cu_5FeS_4
Chalcopyrite	$CuFeS_2$
	$Cu_6Fe_2S_6 = 2Cu_3FeS_3$.

Such a mixture would contain 73·20 per cent of bornite and 26·8 per cent of chalcopyrite.

The range for the specific gravity of bornite is sometimes stated to be 4·9 to 5·4; but a substance with as definite a composition as pure bornite evidently possesses should not show so great variation, and it will probably be found that when the material is carefully selected the range will be more like 5·05 to 5·10. As we have seen, the crystallized mineral from Bristol gave 5·072.

Department of Chemistry and Mineralogy,
McGill University, May, 1903.

Art. XVI.—*The Iodometric Determination of Gold in Dilute Solution*; by Ralph N. Maxson.

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

In a former paper from this laboratory* it was shown that under suitable conditions potassium iodide acts normally upon auric chloride according to the equation

$$3KI + AuCl_3 = 3KCl + AuI + I_2$$

and it appeared that this reaction may serve as the basis of a trustworthy method for the determination of small quantities of gold,—the freed iodine being estimated by careful bleaching with sodium thiosulphate and the final addition of standard iodine to the incipient coloration of the starch indicator, rose in most cases, or only blue at the outset when the starch has not undergone hydrolytic change.† Three series of experiments were made upon solutions of auric chloride standardized by the ferrous sulphate method and by the method of Vanino,‡ and one series upon auric chloride made from pure gold foil.

In the first series the solutions of auric chloride (0·8710 grm. to the liter) sodium thiosulphate nearly $\left(\frac{N}{100}\right)$, and iodine nearly $\left(\frac{N}{100}\right)$ were of such strength that an inaccuracy of $0·01^{cm^3}$ in measurement would correspond to about 0·000009 grm. for the gold solution and to a little more than 0·00001 grm. in terms of gold for each of the other solutions. It is hardly to be supposed that individual readings can uniformly approximate the truth within $0·01^{cm^3}$, and as there are six readings to be made in every complete determination, the chances for inaccuracy amounting to several hundredths of a milligram of gold, dependent to a great extent as to direction and amount upon the personal equation of the operator, are considerable. Should all these reasonable errors chance to lie in the same direction, the cumulative errors are likely to reach at least ± 0·00005 grm., and may be even more.

The actual error, due to all causes, found in the first series of twelve determinations, excepting a single determination manifestly not in line with the others, and tending to make the average error smaller, amounted in the mean to −0·00005 grm. of gold between extremes of +0·00003 and −0·00010 grm.

In the second series of twenty experiments, in which the solution of gold was ten times as dilute as in the experiments

* Gooch and Morley, this Journal, viii, 261 (1899).
† Hale, this Journal, xiii, 379 (1902).
‡ Ber. Dtsch. Chem. Ges., xxxi, 1763.

of the first series, the other solutions being of the original strength, the total average error actually observed was considerably lower, as would be expected, and amounted to +0·00002 grm. of gold between extremes of +0·00006 grm. and −0·00002 grm.

In a third series of ten experiments, in which the dilute gold solution (0·0871 to 1 liter) was used, nearly $\frac{N}{1000}$ iodine and nearly $\frac{N}{1000}$ thiosulphate were employed. The average error amounted to less than 0·000004 grm. between extremes of +0·000020 grm. and −0·000029 grm., but in these determinations the sensitiveness of the starch indicator to iodine becomes an important factor, and it was necessary to introduce a correction of $0·1^{cm^3}$ for the amount of the $\frac{N}{1000}$ iodine necessary to bring out the starch reaction in the volume of liquid used, when tested in blank.

In still another series of fourteen experiments, made upon a gold solution ($0·0104$ to 200^{cm^3}) prepared by dissolving pure gold foil in chlorine water and destroying the free chlorine by ammonia, the average error amounted to +0·000002 grm. between extremes of +0·00001 grm. and −0·000008 grm.

The results of these experiments may be summarized as follows:

	Number of determinations.	Gold taken.	Strength of solutions.			Error. Average.	Extremes.
			Iodine	Thiosulphate	Gold		
Series I	11	$8·71^{mg}$ to $4·35^{mg}$	$\frac{N}{100}$	$\frac{N}{100}$	0·871	$-0·05^{mg}$	$+0·03^{mg}$ / $-0·1^{mg}$
Series II	20	$0·87^{mg}$ to $0·087^{mg}$	$\frac{N}{100}$	$\frac{N}{100}$	0·0871	$+0·02^{mg}$	$+0·06^{mg}$ / $-0·02^{mg}$
Series III	10	$0·871^{mg}$ to $0·087^{mg}$	$\frac{N}{1000}$	$\frac{N}{1000}$	0·0871	$+0·004^{mg}$	$+0·020^{mg}$ / $-0·029^{mg}$
Series IV	14	$0·520^{mg}$ to $0·052^{mg}$	$\frac{N}{1000}$	$\frac{N}{1000}$	0·052	$+0·002^{mg}$	$+0·01^{mg}$ / $-0·008^{mg}$

It is plain that the average experimental errors, due to all causes, do not very much exceed the errors which might naturally be expected to arise from errors of reading. In repeating the work of Gooch and Morley I have obtained results of a reasonably similar order of accuracy. The process has, however, been recently criticized unfavorably by Rupp* on the

* Ber. Dtsch. Chem. Ges., xxxv, 2011.

ground that the *percentage errors* are found to be large. It is to be noted, however, that large percentage errors are inevitable, in the application of volumetric methods to the determination of total weights measured in hundredths of a milligram, or tenths of a milligram, or even in a few milligrams, inasmuch as the reasonable errors to be expected in the measuring of solutions strong enough to be visibly reactive are of themselves large when reckoned as percentages of small absolute amounts. These errors, small as they are, Rupp attributes to the secondary reactions of potassium iodide on aurous iodide, in which gold is reduced and iodine set free. I have been unable, however, to find evidence of such action under the conditions of experimentation during periods much longer than those required for the completion of the analytical process. Thus aurous iodide, obtained by treating a solution of auric chloride containing 0·0125 grm. of gold, with potassium iodide according to the directions of Gooch and Morley, adding starch and bleaching the starch with sodium thiosulphate, gave no color of starch blue after the interval of an hour. A second similar experiment gave the same result. Inasmuch as an interval of ten minutes is enough for the complete manipulation of a single determination, it is plain that the stability of the aurous iodide does not figure in the accuracy of the determination of the small amounts of gold for which the process was designed.

As a substitute for the method described by Gooch and Morley and sustained by the fifty-five analytical determinations mentioned, Rupp announces a process for the estimation of gold depending upon the precipitation of that element from auric chloride by means of standard arsenious acid in excess, according to the equation

$$3As_2O_3 + 4AuCl_3 + 6H_2O = 3As_2O_5 + 12HCl + 4Au,$$

and the titration of the excess of arsenious acid by iodine. To show the reliability of the process Rupp cites six determinations, in one of which the titrations were made in two portions. Four of these six deal with $61{\cdot}2^{mg}$ of gold each, while in two the gold amounted to $6{\cdot}1^{mg}$. These figures, which cover the entire range of the amounts used in Rupp's analytical determinations, do not represent the order of magnitude or range of the amounts of gold handled by Gooch and Morley, which varied from $8{\cdot}7^{mg}$ to $0{\cdot}052^{mg}$. Only two determinations upon amounts comparable with those used by Gooch and Morley were made, and in only these two were suitably dilute solutions of iodine $\left(\frac{N}{100}\right)$ and of arsenious acid $\left(\frac{N}{100}\right)$ employed.

The gold solution employed in all the determinations was of such strength that a single error of $0{\cdot}01^{cm^3}$ in reading would amount to an error of 0·00006 grm. of gold: while the arsenious acid employed in three determinations was so strong $\left(\frac{N}{2}\right)$ that an inaccuracy in reading to the extent of 0·01$^{cm^3}$ would introduce an error of 0·0003 grm., actually greater than the whole amount of gold involved in each of the individual determinations of the greater part of the entire series of Gooch and Morley, and nearly six times greater than their minimum amounts. It is plain, therefore, that Rupp's experiments do not relate to the small amounts of gold handled by Gooch and Morley, and that experiments made with such solutions as Rupp employed cannot form a basis upon which to found a method for the determination of the very small amounts of gold determined by Gooch and Morley.

It has seemed to be desirable, therefore, to submit the process of Rupp to further investigation. In these experiments the procedure of Rupp was followed in general, but the reagents were all used in solutions reasonably dilute, as must be the case if accuracy is to be attained. The gold solution used was prepared from pure gold chloride, and was carefully standardized by means of metallic magnesium, and electrolytically with the revolving cathode, according to the method of Gooch and Medway.* The solution contained 0·0580^g of metal in 1 liter, and was free from nitric acid. The arsenic solution was $\frac{N}{100}$ and was made by properly diluting a standard solution of $\frac{N}{10}$ arsenious oxide. The iodine solution used was approximately $\frac{N}{100}$, and was made by properly diluting an iodine solution, which had been carefully standardized against the $\frac{N}{10}$ arsenic solution mentioned above.

In reducing and determining the gold the procedure was as follows:—A measured quantity of the slightly acid solution of standard auric chloride was drawn from a burette into a 100$^{cm^3}$ graduated flask and to this was added a measured excess of a standard solution of arsenious acid dissolved, as usual, in acid potassium carbonate. In every case the excess of the arsenious acid was considerable and the acid carbonate introduced simultaneously was enough to more than neutralize the slight acidity of the auric chloride. Rupp states that the reduction takes place in acid solution, but I have been unable to effect the precipitation of the gold when free acid is present, but from a solution made so acid that the carbonate present in the

* This Journal, xv, 320 (1903).

Exp.	Fraction titrated.	Gold found in each fraction. grm.	Gold computed for the whole solution. grm.	Gold taken. grm.	Error. grm.
I	¼	0·00010	----	----	----
	¼	0·00011	----	----	----
	¼	0·00013	----	----	----
	----	----	0.00045	0·00087	—0.00042
II	¼	0·00010	----	----	----
	¼	0·00013	----	----	----
	¼	0·00010	----	----	----
	----	----	0·00044	0·00087	—0·00043
III	¼	0·00017	----	----	----
	¼	0·00016	----	----	----
	¼	0·00014	----	----	----
	----	----	0·00063	0·00087	—0.00024
IV	¼	0·00060	----	----	----
	¼	0·00060	----	----	----
	¼	0.00062	----	----	---
	----	----	0·00242	0·00232	+0·00010
V	¼	0.00056	----	----	----
	¼	0·00058	----	----	----
	¼	0·00058	----	----	----
	----	----	0·00229	0·00232	—0·00003
VI	¼	0·00043	----	----	----
	¼	0·00043	----	----	----
	----	----	----	----	----
	----	---	0·00172	0·00232	—0·00060
VII	¼	0·00075	----	----	----
	¼	0·00074	----	----	----
	¼	0·00074	----	----	----
	----	----	0·00297	0·00232	+0·00065
VIII	¼	0·00061	----	----	----
	¼	0·00058	----	----	----
	----	----	0·00238	0.00290	—0·00052
IX	¼	0·00082	----	----	----
	¼	0·00081	----	----	----
	¼	0·00080	----	----	----
	----	----	0·00324	0·00290	+ ·00034
X	¼	0·00072	----	----	----
	¼	0·00073	----	----	----
	----	----	0·00290	0·00290	0·00000
XI	¼	0·00066	----	----	----
	¼	0·00071	----	----	----
	¼	0·00075	----	----	----
	----	----	0·00283	0·00290	—0·00007

standard arsenic is insufficient to neutralize the free acid the gold may be precipitated upon the further addition of a suitable amount of acid potassium carbonate. The flask containing the gold, the arsenite and the acid carbonate was heated thirty minutes upon a steam bath, then cooled and filled to the 100^{cm^3} mark. Measured portions of the solution, 25^{cm^3} each, were titrated with the standard iodine in presence of acid potassium carbonate and potassium iodide. The details of these experiments are shown in the accompanying table.

A comparison of the figures obtained in the individual titrations of portions of a single reduction show that the difference due to the errors of analysis are reasonably small, rarely exceeding a few units in the fifth decimal place—or a few hundredths of a milligram. The errors of the process, however, computed by comparing the average of these single determinations with amount of gold actually taken, range from $-0·6^{mg}$ to $+0·65^{mg}$, are wholly irregular, and are approximately ten times as large, reckoned absolutely or in percentages, as the errors obtained by Gooch and Morley when handling similar amounts of gold. So far as the evidence of these experiments goes, it is plain that the process of Rupp is wholly untrustworthy for the determination of the very small amounts of gold concerned.

I take this opportunity to thank Professor F. A. Gooch for much kindly aid and advice in the preparation of this paper.

ART. XVII.—*Radioactivity of Thorium Minerals;** by GEORGE F. BARKER.

THE discovery of the spontaneous radioactivity of uranium and its compounds, by Becquerel in 1896† has affected most profoundly our views not only of the constitution of matter, but also of the relations existing between matter and energy. The extraordinarily delicate means which he proposed for the detection of this radioactivity, first the photographic method, and second the electric, made possible the remarkable discovery by the Curies and Bemont in 1898‡ of the new element radium, whose quantity in uraninite is so infinitesimal as to be far beyond our power of detection by the balance, or even by the spectroscope. Indeed, only the enormous ratio of the energy of radium to the radioactive matter concerned in emitting it, enabled it to be recognized even by the electrometer.

In February, 1898, G. C. Schmidt presented to the Physical Society of Berlin§ a preliminary paper on the rays emitted by the element thorium and its compounds. This paper was printed in extenso in *Wiedemann's Annalen* in the following April.‖ On the 12th of the same month, a communication from Mme. Sklodowska Curie was presented by Lippmann to the Academie des Sciences of Paris¶ giving an account of her examination of the radioactivity of a number of substances, including the compounds of thorium. Like Schmidt, she used both the photographic and the electric methods in her investigations, making the latter quantitative. Two condenser plates were employed, 8 centimeters in diameter, separated 3 centimeters from each other, and having a potential difference of 100 volts maintained between them. A uniform layer of the substance to be examined, finely pulverized, was placed on the lower plate; and since the emitted rays ionized the air between the plates and rendered it conducting, a current traversed the condenser and charged the electrometer to which the upper plate was connected. Knowing the capacity of the electrometer, inasmuch as the speed of deviation of the needle is proportional to the current-strength, it is possible to determine the current in absolute measure. It was found preferable, however, to measure the counter potential difference required to maintain the electrometer at zero. As its charge was feeble, this compensation was accomplished by means of a piezoelec-

* Read before the National Academy of Sciences, April 22, 1903.
† Comptes Rendus, cxxii, 420, 501, 689, 1896.
‡ Comptes Rendus, cxxvii, 1215, December, 1898.
§ Verh. Phys. Ges. Berlin, xvii, 14, February, 1898.
‖ Ann. Phys. Chem., II, lxv, 141–151, April 15, 1898.
¶ Comptes Rendus, cxxvi, 1101, April 12, 1898.

tric quartz, one armature of which was connected to the upper plate. By placing weights in a scale-pan attached to the quartz plate, the difference of potential produced was so regulated as to secure compensation between the quantity of electricity traversing the condenser and that of opposite sign yielded by the quartz. With a given condenser, and a given substance, it was observed that the current increased with the difference of potential between the plates, and with the gas pressure. It also increased as the plates were separated. With high potential difference, the current tends toward a constant limit, the *saturation-current.* This saturation-current was taken as the measure of the radioactivity, the number of ions produced per second being greater in proportion as the radiation absorbed is greater.

With this apparatus, the radioactivity of uranium is measurable with considerable precision; the current having an order of magnitude of 10^{-11} ampere. It varied but little with temperature, was not affected by light, and did not seem to vary sensibly with time. The value of the current obtained with Moissan's metallic uranium (probably containing a trace of carbon) was $2{\cdot}4.10^{-11}$ amperes. Tested in this way it was found that thorium compounds were very active, thoria surpassing even metallic uranium. It was observed that the current increased with the thickness of the material, a layer 0·25 millimeter thick giving a current of $2{\cdot}2.10^{-11}$ ampere, and one of 6 millimeters one of $5{\cdot}3.10^{-11}$ ampere. Thorium sulphate gave a current of only $0{\cdot}8.10^{-11}$ ampere. The phenomenon was most regular with a layer only 0·25 millimeter thick, varying between wide limits when the thickness was 6 millimeters, especially with the oxide. Thorium rays were found to be more penetrating than those of uranium, those emitted by thoria from thick layers being more penetrating than those from thin ones.* Subsequently Owens studied the radiations from thorium compounds, determining the conditions affecting its constancy, the form of the saturation curve, the character of the radiations from different salts, the types of radiation, selective absorption, the effect on the rays of suspended particles, the variation of conductivity with air pressure and the absorption of the radiations by air.†

Inasmuch as uranium and thorium were the only elements then known possessing radioactive properties, it was natural to examine the minerals in which these substances occur, with a view to determine their properties in this regard. Accordingly Mme Curie, using the electric method and the apparatus above described, tested thirteen well-known minerals,

* Rapports au Congrès International de Physique, iii, 79, Paris, 1900.
† Phil. Mag., V, xlviii, 359, 1899.

containing both uranium and thorium. They all were found to be radioactive, though in very different degrees. Measured, as above, in terms of current, xenotime gave $0{\cdot}03.10^{-11}$ ampere, niobite 0·3, fergusonite 0·4, monazite 0·5, aeschynite 0·7, samarskite 1·1, thorite 1·4, cleveite 1·4, orangeite 2·0, autunite 2·7, chalcolite 5·2, carnotite 6·2 and pitchblende (uraninite) from 6·5 to $8{\cdot}3.10^{-11}$ ampere. The remarkable fact that four of these minerals were more active than metallic uranium and especially that the uraninite from Johanngeorgenstadt was nearly four times as active, led, as is well known, to the discovery in it of the three new radioactive substances, polonium, radium and actinium.

In February, 1902, Hofmann and Zerban published a paper on Radioactive Thorium* obtained from certain minerals allied to uraninite. In connection with Strauss, the former of these chemists had previously prepared thoria from bröggerite, cleveite and samarskite, and had found it to be radioactive. Hofmann and Zerban now observe that the activity of these thoria preparations may be materially increased by fractional precipitation with potassium sulphate or chromate, with hydrogen peroxide or with sodium thiosulphate, the most active fractions being those most readily precipitated. By using ammonium carbonate as the precipitant, on the other hand, the most active material is found in the most soluble fraction. To their surprise, however, they found that the thoria thus obtained, on keeping it for five months, even in closed vessels, lost a large part of its radioactivity. Thus the most active thoria, which in June blackened the photographic plate very strongly even through glass, acted very feebly in the following November. Electroscopic tests also confirmed this diminution in radioactivity. A specimen of thoria from bröggerite which in November discharged the electroscope in 1 minute required 3m. 45s. to do the same thing in January. A specimen from cleveite, which in November took 1m. 10s. to discharge the electroscope, required in January 2m. 5s. And a preparation from samarskite, which took 1m. 30s. in November to effect this discharge, did the same thing in January only after 1m. 50s.

These results lead the authors to assume (1) that the thoria prepared from bröggerite, cleveite and samarskite possesses, not a primary but a secondary induced activity, and (2) that this induced activity is due to the uranium always present in the minerals referred to. In proof of this assumption, the authors prepared thoria from Brazilian monazite sand, which they assert contained no trace of uranium, and found it to be absolutely inactive, whether tested by the photographic plate

* Ber. Berl. Chem. Ges., xxxv, 531, 1902.

or by the electroscope. They then rubbed one gram of this thoria with five grams of a specially purified uranoso-uranic oxide, heated the mass to 400° for four hours and allowed the mixture to stand for fourteen days. It was then dissolved in nitric acid, the thoria precipitated as oxalate, washed and ignited. On testing it, it was found to be strongly active, discharging the electroscope in 1m. 5s., even after four weeks.

In the course of some experiments on the photographic action of radioactive substances made in December, 1899, I obtained an intense darkening of the plate after an exposure of 8 hours, with uranyl chloride, uranium chloride, metallic uranium and uraninite, the darkening being in the order named. A few weeks later, using uraninite as the radioactive source, with an exposure of 16 hours, I observed that the penetrating power of the rays it emitted, through metal plates ·0025 inch in thickness, were in the order aluminum, tin, copper, silver, lead, platinum. Similar experiments with de Haen's radium salts, brought from Europe in September of that year, showed much more powerful action, an exposure of fifteen minutes giving a distinct effect upon the plate.

During the past winter these experiments have been resumed, with especial reference to the compounds of thorium and the minerals containing it. To compare the intensity of these radioactive minerals, an exposure of 48 hours was made with uraninite (from Bohemia and from Saxony), gummite (North Carolina), autunite (Limoges), euxenite (Norway), thorite (Norway), samarskite (North Carolina), and orangite (Norway). While the intensity of the darkening was in general in the order above given, the effect of the first three minerals far exceeded any of the others. Moreover the penetrating power of the emitted rays was examined at the same time by placing each of the minerals upon a thin brass stencil plate, having its initial cut through it. The rays from gummite seemed to penetrate the brass the most readily; then followed the uraninite, the autunite, the euxenite, the samarskite and the thorite.

The investigations were then continued with especial reference to the mineral monazite, the chief source of the thoria now so largely used in this country and Europe, for the manufacture of the Welsbach gas mantles. By the courtesy of Mr. M. C. Whitaker, of the Chemical Department of the Welsbach Company, I was furnished with authentic samples of Brazilian monazite sand, of monazite sand from North Carolina and of pure thoria from each of these; this thoria having been obtained in the course of analysis. I also obtained a sample of pure ammonium-thorium nitrate and one of thorium oxalate. On exposing these six substances on a sensitive photographic plate thoroughly protected from the light, for 48 hours, satisfactory impressions were obtained from all of them. Of the two monazites, that from Brazil gave perhaps a trifle the darker stain; that specimen containing 90 per cent of monazite and about 6 per cent of thoria, while the North Carolina sand contained about 66 per cent of monazite and 4 per cent of thoria. For purposes of comparison a piece of metallic uranium was exposed under the same conditions upon the same plate.* The darkening effect was very considerably greater than that produced by the thoria.

In view of the assertions of Hofmann and Zerban already stated, to the effect, first, that Brazilian monazite sand contains no uranium, and second, that in consequence of this, the thoria obtained from this source is not radioactive, the above described experiments were carefully repeated. The results obtained were practically the same. The plate was darkened, during an exposure of 48 hours, by all the six substances placed upon it; by the two monazite sands from Brazil and from North Carolina, by the two thorium oxides obtained from these, by the ammonium-thorium nitrate and by the thorium oxalate. The oxalate stain was perhaps a little darker than the nitrate and the Brazilian stain a trifle darker than the North Carolina one. Apparently, therefore, the second of Hofmann and Zerban's conclusions, to wit: that thoria prepared from Brazilian monazite sand is "absolutely inactive," can hardly be accepted as final.

The claim, however, that the radioactivity of thorium compounds is not a primary but a secondary induced activity due to the presence of uranium in the minerals in which it occurs, needs to be considered here. The monazite sands are complex and variable in composition, and may in isolated cases contain even uranium. The specimens used in the experiments above described therefore were submitted to several competent chemists, all of whom reported that they were entirely free from this element. The main conclusion would therefore seem legitimate, that radioactive thorium compounds may be prepared from minerals which do not contain uranium. If so, the conclusion can hardly be evaded that thorium is a primary radioactive substance.

The composite character of the rays emitted by radioactive substances appears to have been observed about the same time by Becquerel,† by the Curies‡ and by Giesel.§ According to Becquerel‖ these rays are of three sorts: (1) those deviable

* Given me in 1899 in Moissan's Laboratory, by the courtesy of Professor Lebeau.

† Comptes Rendus, cxxix, 1205; cxxx, 206, 372; cxxxii, 371.

‡ Comptes Rendus, cxxix, 996; cxxx, 73, 76, 647; cxxxii, 133.

§ Ann. Phys. Chem., II, lxix, 834, 1899.

‖ Proc. Roy. Inst., xvii, 1, March 1902.

by a magnetic field, which are apparently identical with cathode rays; (2) those not so deviable, but very readily absorbed; and (3) non-deviable rays, which like Röntgen rays have great penetrating power. He states that the rays emitted by uranium are substantially of the first kind, those from polonium are of the second kind, and those sent out by radium and thorium consist of all three kinds. In subsequent investigations, Rutherford,* in connection first with Grier† and afterward with Soddy,‡ made this classification more rigid. Radium rays were divided into three distinct types; α rays, easily absorbed by thin layers of matter, and producing the greater part of the ionizing effect; β rays, consisting of negatively charged particles moving with high velocity and similar in all respects to cathode rays; and γ rays, non-deviable in a magnetic field and of a very penetrating character. The energy radiated in the form of α rays is about 1000 times greater than that emitted as β rays. During the present year Rutherford§ has succeeded in obtaining the deviation of the α rays both in the magnetic and the electric fields, and has thereby proved these rays to consist of positively charged material particles having a much greater mass and a lower velocity than those constituting the β rays. In fact the mass of those particles is of the same order as that of the hydrogen atom and they travel with a speed only about one-tenth that of light. Moreover, it has been shown‖ that the α rays contribute by far the greater part of the electrical effect, while the β rays produce practically all of the photographic effect. Thus uranium when freed from UrX, though inactive to the photographic plate, possesses a nearly normal activity when examined by the electric method.

In his investigations upon thorium, Baskerville says:¶ "The oxide (sp. gr. 9·25) obtained from the insoluble citrate affects the sensitive plate in the dark after an exposure of seventy-two hours but slightly, while the oxides of higher specific gravity are quite active. A number of plates have been exposed using oxides obtained through the research, monazite sand from which the thorium salts were prepared, uranium nitrate, acetate, uraninite and blanks for comparison. The radioactivity increased with increase in specific gravity." Hearing that he had finally obtained a thoria so pure that it did not affect the photographic plate, I wrote him asking for the loan of a small sample to compare with my own specimens. In the letter accompanying the specimen which he was good enough to send me, he says: "I have secured pre-

* Phil. Mag. VI, v, 177, 1903.
† Phil. Mag. VI, iv, 315, 1902.
‡ Phil. Mag. VI, v, 445, 1903.
§ Rutherford, l. c.
‖ Phil. Mag. VI, v, 441, 1903.
¶ J. Am. Chem. Soc., xxiii, 761, 1901.

parations which did not affect a sensitive photographic plate noticeably after an exposure of seventy hours." He prefers, however, the electric method, and says: "I have prepared a large number of thorium preparations, several hundred, and have not yet succeeded in securing a thorium compound or derivative which did not possess some radioactivity by the latter method." Upon testing the "*very* pure" specimen received, by an exposure of 96 hours, a satisfactory darkening of the photographic film resulted; though much less intense than the stain given by the thoria previously employed. Were it possible to separate by fractionation or otherwise a sample of thoria into two portions, one of which had only a photographic and the other only an electric action, it might suggest that the constituent of the thoria which emits the β rays may be separable from the one emitting the α rays. Inasmuch as all the thoria preparations examined by Baskerville were obtained from monazite sand, coming either from North Carolina or Brazil, and inasmuch as none of these preparations failed to show a radioactivity either photographic or electric, the conviction is strengthened that thorium does not owe its activity to an induction from uranium existing in the minerals from which it was obtained.

The fact that inactive substances acquire under the influence of radium a temporary activity was first observed by the Curies,* who called the effect "la radioactivite induite." On exposing a disc of zinc for example, 8^{cm} in diameter, opposite a surface of radium 4^{cm} in diameter and 3^{cm} distant, an activity 2000 times that of uranium was obtained; practically the same results being obtained with nickel, brass, bismuth, aluminum and lead. Solutions of radium salts appear to produce the phenomenon with more intensity than the solid salts. Gases even may in this way be made radioactive. Water distilled from radium solutions is radioactive. When barium sulphate is precipitated from a solution of barium chloride by sulphuric acid in presence of a salt of uranium, it is found to be radioactive. Debierne,† proceeding in this way and using actinium in place of uranium, obtained a barium salt of great activity, which could be concentrated by fractionation, the most active fractions being 1000 times as active as uranium. The result was a radioactive barium, carrying its properties into all its salts and distinguished from radium mainly by its spectrum and by the gradual loss of its properties.

The discovery in 1899, almost simultaneously by the Curies‡ and by Rutherford,§ of the emission by both radium and

* Comptes Rendus, cxxix, 714, 1899; cxxx, 1013, 1900.
† Comptes Rendus, cxxxi, 333, 1900.
‡ Rapports au Congrès Intern. de Physique, iii, 79, 1900.
§ Phil. Mag., V, xlix, 2, 1900; VI, v, 95, 1903.

thorium, of a gas or vapor itself temporarily radioactive and capable of emitting rays, has thrown much light upon this so-called induced radioactivity. This "emanation," as Rutherford calls it, diffuses without change through gases and liquids, and even porous substances, but not through glass or mica. It is chemically inert, and may be passed through ignited platinum black and lead chromate without change. It appears to be a new member of the argon family, with an atomic mass between forty and one hundred. The emanations from thorium and radium differ somewhat in properties, that from the former liquefying at —120° and that from radium at —150°. Moreover, the radioactivity of the thorium emanation rapidly decays, falling to half its value in one minute; while that of the radium emanation retains its active properties for several weeks. On the other hand, the "excited" radioactivity, as Rutherford prefers to call it, produced by the former emanation, is much more permanent than that produced by the latter. Since excited radioactivity can be produced on bodies if the emanation be present, even in the absence of a radioactive substance, and since the amount of effect is directly proportional to the amount of the emanation, it follows, first, that the production of excited radioactivity is a property of the emanation and therefore is always produced on bodies when the radioactive emanations from thorium and radium are present; and second, that uranium and polonium which do not give off any emanation, do not possess the power of exciting radioactivity. In the present view of science, therefore, it would not seem probable that the radioactivity of thorium is a secondary or excited radioactivity due to the uranium associated with it in the minerals above mentioned.

ART. XVIII.—*Significance of Silicic Acid in Waters of Mountain Streams;* by W. P. HEADDEN.

WHILE engaged in some work on the waters of the San Luis Valley I was struck by the unusually high percentage of silicic acid, from 25 to upwards of 40 per cent, in the residues obtained on evaporation. I was, at the time, inclined to attribute this to some accident, or perhaps error. The water had been shipped in jugs, and this may have had some influence, but several conditions lead me to believe that this influence, if any at all, was wholly negligible. The water was evaporated as soon as possible after it was received at the laboratory, so that the water was in these jugs but a few days—from seven to ten at the longest. The quality and character of the residue did not support this view, and the action of the water on the jugs may be left out of consideration.

The waters to which reference is here made were of excellent quality and were either artesian or spring waters, but I also observed that the water of the Rio Grande del Norte, at Del Norte, was richer in silicic acid than is usual for river waters, and richer here than further down the stream. There was nothing in the composition of the dissolved mineral matter apparently worthy of special attention except it be the high percentage of silicic acid, and while this was common to several waters from different sources, I did not feel that this characteristic was sufficiently well established to entitle it to acceptance. We gained but little that at the time would bear any interpretation, beyond the fact that the spring and artesian waters of this large basin are of exceptionally good quality. This statement does not apply to a subordinate basin in which the towns of Mosca and Garrison, formerly called Hooper, are situated. The wells of this basin at a depth of 500 to 880 feet yield a brown water rich in alkalies, but relatively and as a rule absolutely poorer in silicic acid than the artesian waters.

There are a number of springs along the eastern margin of the valley and some larger ones in the southern part of it, the waters of which are of good quality and carry from 5·3 grains to 17·6 grains of mineral matter to the imperial gallon, of which silicic acid constitutes as much as 30 per cent.

This line of work was laid aside in order to take up others which seemed more urgent and perhaps more important also, but recently, while studying the changes suffered by river waters used for the purposes of irrigation, my attention has again been called to the presence of silicic acid as a characteristic mineral constituent of the waters of mountain streams whose collecting grounds are granitic areas and whose courses have not yet traversed a long enough reach of open country, or the plains, to have received either water from collecting areas of a different character or drain waters from lands adjacent to their courses.

I shall now set forth such facts as have fallen under my observation which seem to me to amount to reasonable proof that this high percentage of silicic acid, varying greatly within the limits of 15 and 46 per cent, is, in the instances which I have studied, specifically due to the action of water and carbon dioxid, and, perhaps, also of the acid products arising from the decomposition of vegetable matter on the felspars of the granite of the region. The action of the organic matter on the felspars is, in the first phase of their decomposition, at the very utmost insignificant if not nil, such, at least, is the result obtained by an experiment made to ascertain how great a part is played by such agents. In passing I will mention, apropos to the presence of organic matter, the fact, that on evaporating a large quantity of water from our mountain streams, from the Cache a la Poudre for instance, one obtains at last a solution which is strongly colored by humus-like substances and possesses an extremely disagreeable odor. In the case of the Cache a la Poudre water used there was no question of pollution by sewage, for in all the distance traversed by its waters from their several sources to the point where the sample was taken, a distance of about sixty miles, the total population does not exceed 150 souls, and the number of cattle grazing in this district is so small that the question of pollution arising from either of these sources is absent, and would be even if the flow of the river were very small, but this seldom falls as low as 200 second feet and is usually much greater—still this water, when larger quantities of it are evaporated down, shows the presence of a significant amount of organic matter which, despite its odor suggestive of an animal origin, I feel justified in assuming to come from decaying vegetable matter. I shall subsequently set forth the facts on which I base the statement that this organic matter plays no important role in determining the amount and character of the mineral matter dissolved out of the rock and carried in solution in such river waters.

The amount of silicic acid usually carried by river waters is small, the maximum shown in the analyses of forty-five European river waters being 21 per cent of the total solids, the Rhine at Strassburg, which carried in the sample analyzed 16·1 grains mineral matter per gallon—but this sample seems to have been an exception even for the Rhine, for other samples of its water show much smaller quantities of substances in solution and materially lower percentages of silicic acid; at Basle for instance, the water carried 11·8 grains of mineral matter in each imperial gallon, 1 per cent of which was silicic acid; at Bonn it carried 11·9 grains, 5 per cent of which was silicic acid; at Arnheim, 11·1 grains, of which 6 per cent was silicic acid. The Rhone, sample taken near Geneva, yielded 13 grains total solids to the imperial gallon, of which 8·2 per cent was silicic acid; this, 8·2 per cent, is, with the exception of the 21 per cent for the sample of Rhine water taken at Strassburg, the maximum shown by the forty-five European rivers.

Spring waters as a rule carry still smaller amounts of silicic acid than the river waters. Thirty-two analyses given in Watts Chem. Dict., Art. Water, show 17 and 22 as maximum percentages, the total solids being 7·3 and 4·3 grains respectively. Analyses of twenty-nine artesian waters show 3 per cent as the maximum quantity of silicic acid present in their mineral matter, which in this sample equalled 36·7 grains per gallon.

Mineral springs sometimes show larger percentages of silicic acid in their mineral constituents, but even these, the springs of the Yellowstone National Park and one or two others, geysers, excepted, show maxima of 18 and 23 for the percentages of silicic acid in their total solids. This statement is based on the analyses of 179 American and 66 foreign mineral springs.

I deem these data sufficient to justify the assertion that silicic acid usually constitutes a comparatively small percentage of the total solids contained in the waters of fresh and mineral springs as well as of those contained in river waters.

The lake and oceanic waters, particularly the latter, have suffered such varied and deep changes in regard to the composition of their mineral content that the silicic acid has either been entirely removed or its quantity has been reduced to a mere trace; the maximum that I can find given is 0·05 per cent of the total solids present. It is usually absent.

The water of the springs of the Yellowstone National Park, and of a few others, contains silicic acid in very notable quantities. Such springs frequently, if not always, have an elevated temperature. This, however, is not the case with the springs and wells referred to; and the rivers, as is well known, have a low temperature, their waters being cooled by the melting of snow accumulated within the areas of their drainage. The presence of silicic acid in the waters of the former class of springs is attributed to the action of heated water aided by pressure and the presence of alkalies. The heat in these cases is of volcanic origin, a residual volcanic effect, while the alkalies are supposed to be obtained from the alteration of the various kinds of felspars, one or more of which is present in most kinds of rocks, especially in volcanic rocks. Such theories are in no manner applicable to the river waters of our mountains and it is very doubtful whether they would apply at all to any of the springs occurring in the San Luis Valley. It is true that eruptive rocks occur in the southern part of the valley; it is also true that some of the springs mentioned later are located on the northern edge of this belt of lava occurrences. I do not, however, believe that the presence of silicic acid in the waters is influenced by the lava which occurs here as remnants of a sheet which formerly covered the country, especially to the southward, but whose point of eruption was probably quite remote. If these waters do come in contact with eruptives of any sort in their course to the surface, they are cold and the waters would act upon them as they would if they were on the surface plus whatever effect the pressure, molecular or other, under which the water exists in the rocks may produce. These springs are bringing no subterranean heat to the surface, the temperatures observed being 59° F. and 70° F. There are warm and hot springs south and southwest of this, but they are many miles away and the water is relatively poor in silicic acid; that of Ojo Caliente, temperature 122° F. contains about 75 grains total solids per imperial gallon, of which less than one per cent is silicic acid. The range of the temperature of the artesian wells throughout the valley is from 53° F. to 71° F. It seems then that the part played by heat in taking the silicic acid into solution in these cases is as good as nothing, while in the case of the rivers receiving their supply directly from fields of melting snow it is patently out of the question. All the statements that I recall relative to the source of silicic acid occurring in waters derive it principally from the felspars, to which I think no serious objection can properly be taken. The contexts as well as the examples given lead one to infer that it is derived from the felspars of eruptive rocks. Such a supposition would not be admissible in this instance. The waters, especially of the rivers, are surface waters, the volume of which in the summer season varies regularly with the periods of sunshine and darkness, twelve hours of greater and twelve hours of lesser flow, corresponding to day and night. Their flow in autumn and winter is greatly diminished owing to the retention of the surface waters in the form of snow and ice. There are no large springs nor any considerable number of small ones except such as are supplied by the soil-covered valleys of the mountains and whose waters are likewise surface waters. There is comparatively a very small amount of igneous rock occurring in their various drainage areas.

In the case of the Cache a la Poudre there are a few porphyry dikes and one inconsiderable body of lava within its drainage area. These observations are not applicable to the

Rio Grande del Norte in the same measure as to the Poudre and other streams mentioned in this paper. In these cases we cannot assign the presence of the silicic acid in the waters to the causes usually cited as explaining it, and I do not believe that it is necessary that we should even in other cases.

In regard to the San Luis Valley it should be explained that there is a bed of volcanic ash, bombs and even a sheet of lava at or near Antonito, of no great northward extension, this place being apparently at its northern limit, and it is doubtful whether the silicic acid in the artesian well waters is derived from felspars of volcanic origin, either in the form of ash or lava, as the wells are driven through the clays, shales, and sands deposited in the bed of the lake formerly filling the valley. If any doubt were entertained of the origin of these strata, the fish vertebræ, shells and fragments of wood found in them would dispel it. The most striking character of the sands is the presence of kidney-shaped concretions of calcic carbonate, having a smooth exterior coating. Some of them are filled with a cellular mass, others are composed of concentric layers of calcic carbonate which, like the exterior one when scaled off from the interior mass, is, owing to its extreme thinness and smoothness, somewhat translucent. The other grains making up these sands are fragments of granite, some of them even showing particles of pyrites, quartz both light and dark, and grains of felspar. There may be some grains of eruptive rocks, but I am not fully enough convinced of this to assert their presence.

The granites of the respective areas are the metamorphic granites of this region, many of them closely resembling the Pike's Peak type, others identical with them.

The residue obtained by evaporating the water of the Rio Grande del Norte, sample taken near the town of Del Norte, contained 27·15 per cent of silicic acid; that from an artesian well in the town of Alamosa, Spriesterbach's Well, 27·0 per cent; from a large spring in the southern or rather southeastern portion of the valley, McIntyre's Spring, 29·64 per cent; from the McNieland Well 36 per cent; and that from the Bucher Well 46·9 per cent of silicic acid.

The conditions under which these waters occur preclude the application of the theory advanced to explain the presence of silicic acid in the waters of geysers and hot springs in general. The maximum temperature observed in any of the springs or wells in the San Luis Valley was 71° F. and the minimum 53° F. These waters do not issue from, and probably do not, in any portion of their course, pass through eruptive rocks of any sort, except it be as surface waters in the lava cappings prevalent to the west of this valley. The river and artesian waters probably have a common source, the melting snows on the peaks of the Sangre de Cristo range on the east and on those of the San Juan country on the west. The percentage of silicic acid in the total solids, however, is as great as that in the residues obtained from any of the geysers or other hot springs in the world. The highest percentages that I have found for the latter are: for the Great Geyser of Iceland 42 per cent, calculated of course on the total mineral matter held in solution; for the Coral Springs in the Yellowstone National Park 32 per cent; for the Hot Spring, Garland, Arkansas, 23 per cent; for the White Terrace Geyser, New Zealand, 22 per cent; and for the Calistoga Spring in California, 18 per cent. These examples suffice to show the relative richness of the Rio Grande del Norte water and that of the springs and artesian wells of the San Luis Valley in silicic acid.

It is perfectly plain that the absolute amount of silica carried by the waters is not given by the statement of the percentage of this substance in the total solids, but will depend upon this latter, or the total amount of mineral matter held in solution. In this respect, too, some of the spring and well waters carry more significant quantities than one would expect.*

The Great Geyser of Iceland carries 86·1; the Coral Spring, Yellowstone National Park, 133·7; White Terrace Geyser, New Zealand, 185·5; and the Hot Spring, Arkansas, 5·0 grains in each imperial gallon. The Rio Grande del Norte at Del Norte carried 6·2; Dexter's Spring 13·7; McIntyre's Spring 12·8; McNieland's Well 17·4; the Bucher Well 15·8; and Spriesterbach's Well 28 grains.

I considered the high percentages of silica in the total solids of these waters as anomalous until a study of the waters of the Cache a la Poudre and some neighboring streams led me to change my view and to consider it as normal in the case of such waters, and to attribute the absence of silicic acid from ordinary waters to the character of the drainage area, the character of the rocks through which the waters pass before they rise as springs or artesian waters, and to changes suffered during the course of their flow.

The following analyses were made of residues obtained by evaporating the samples to dryness; both copper and porcelain vessels were used without appreciable difference in the results. The residues were dried at temperatures varying from 180° to 200° C. The ignition is put in brackets to designate that it is

* I have reduced my data to the common basis of grains to the imperial gallon because my own results have been calculated on this basis, and further because grains per imperial gallon are easily converted into parts per thousand or million according as one may prefer.

by difference, but an ignition was made in each instance to assure myself that the ignition given is correct within reasonably close limits.

The first analysis of Cache a la Poudre water given is of a sample taken above the mouth of the North Fork, on Oct. 3, 1902. This point was chosen because there are no tributaries entering above this point whose waters are not wholly gathered within and run for their whole course over an area whose surface rocks are the metamorphic granites and schists of the region. The sample was taken at a time when the water was perfectly representative of the drainage water of this area. The analysis resulted as follows:

Analysis of Cache a la Poudre Water, Sample taken above the Mouth of the North Fork.

Analytical results.	Per cent.	Grs. Imp. Gal.	Combined.	Per cent.	Grs. Imp. Gal.
SiO_2	20·871	0·6053	$CaSO_4$	11·782	0·3417
SO_3	6·928	0·1946	$CaCO_3$	24·781	0·7186
CO_2	20·790	0·6029	$MgCO_3$	9·063	0·2628
Cl	3·575	0·1037	K_2CO_3	4·325	0·1254
Na_2O	12·931	0·3750	Na_2CO_3	9·146	0·2652
K_2O	2·949	0·0855	NaCl	5·899	0·1711
CaO	18·741	0·5238	Na_2SiO_3	8·772	0·2544
SrO	trace	trace	Fe_2O_3, Al_2O_3	0·388	0·0113
MgO	4·336	0·1257	Mn_3O_4	0·063	0·0018
Fe_2O_3, Al_2O_3	0·388	0·0113	Ignition	(9·233)	0·2678
Mn_3O_4	0·063	0·0018			
Ignition	(9·233)	0·2678	Sum	83·452	
			Excess of SiO_2	16·546	0·4798
Sum	100·805				
O equiv. to Cl	·805		Total	99·908	2·8999
Total	100·000	2·8974			

Total solids 2·9 grs. per imp. gal.

The second sample of which I shall give an analysis was taken July 30, 1902, on which date the river was carrying about double its usual flow for this season. The flow had been 300 second feet for the preceding fortnight, to which it fell again within a few days, but at the time the sample was taken the flow was 600 second feet. In this analysis I did not test for either strontia or lithia.

Analysis of Cache a la Poudre Water, Sample taken 150 feet above Headgate of Larimer Co. Ditch.

Analytical results.	Per cent.	Grs. Imp. Gal.	Combined.	Per cent.	Grs. Imp. Gal.
SiO_2	20·542	0·5341	$CaSO_4$	8·420	0·2198
SO_3	4·951	0·1287	$CaCO_3$	36·431	0·9471
CO_2	21·626	0·5622	$MgCO_3$	10·758	0·2797
Cl	7·619	0·1980	NaCl	12·573	0·3276
Na_2O	8·874	0·2307	K_2SiO_3	5·391	0·1402
K_2O	3·286	0·0854	Na_2SiO_3	4·342	0·1129
CaO	23·884	0·6209	Fe_2O_3, Al_2O_3	0·894	0·0232
MgO	5·147	0·1338	Mn_3O_4	0·093	0·0024
Fe_2O_3, Al_2O_3	0·894	0·0232	Ignition	(4·802)	0·1248
Mn_3O_4	0·093	0·0024			
Ignition	(4·802)	0·1248	Sum	83·704	
			Excess of SiO_2	16·296	0·4237
Sum	101·718	2·6443			
O equiv. to Cl	1·718	0·0446	Total	100·000	2·6005
Total	100·000	2·5997			

Total solids 2·6 grs. per imp. gal.

The sample of water from Boulder Creek was taken from a tap in the town of Boulder which is supplied with water taken from the creek at a point where the water is perfectly representative, being gathered wholly within a granitic area. The analysis follows:

Analysis of Water from Boulder Creek, Sample taken from a tap in the town of Boulder.

Analytical results.	Per cent.	Grs. Imp. Gal.	Combined.	Per cent.	Grs. Imp. Gal.
SiO_2	21·985	0·6156	$CaSO_4$	14·124	0·3955
SO_3	8·305	0·2325	$CaCO_3$	31·317	0·8769
CO_2	17·037	0·4770	$SrCO_3$	0·235	0·0066
Cl	7·425	0·2079	$MnCO_3$	6·143	0·1720
Na_2O	6·870	0·1924	$MgCl_2$	4·305	0·1205
K_2O	2·720	0·0762	KCl	4·304	0·1205
Li_2O	trace	trace	NaCl	3·586	0·1004
CaO	23·373	0·6544	Na_2SiO_3	9·818	0·2749
SrO	0·165	0·0046	Fe_2O_3, Al_2O_3	1·098	0·0307
MgO	4·760	0·1313	MnO	0·341	0·0095
Fe_2O_3, Al_2O_3	1·098	0·0307	ZnO	trace	
MnO	0·340	0·0095	Ignition	(7·607)	0·2130
ZnO	trace	trace			
Ignition	(7·607)	0·2130	Sum	82·878	2·3205
			Excess of SiO_2	17·144	·4789
Sum	101·676	2·8451			
O equiv. to Cl	1·676	0·0469	Total	100·022	2·7994
Total	100·000	2·7982			

Total solids 2·8 grs. per imp. gal.

The waters of Clear Creek are less representative than the others, not because their gathering grounds are different or that they have their courses through territories of different geological formations, for such is not the case, but there is a very much larger population within its area of drainage, the towns of Central City, Black Hawk, Idaho Springs, Georgetown, and some smaller towns being within it and above the point where the sample was taken, which was from the Welch Ditch a mile above the town of Golden. Further, mining and particularly milling is actively carried on within its drainage area and on its branches. The tailings of twenty odd mills are discharged into its waters, to say nothing of the mine water which daily mingles with that of the creek. The effect of these conditions is plainly shown in the analysis but does not obscure the true character of the water to any extent. I will not abridge the analysis, though parts of it are superfluous for the present purpose.

Analysis of Water from Clear Creek, Sample taken from Welch Ditch, one mile above Golden.

Analytical results.	Per cent.	Grs. Imp. Gal.	Combined.	Per cent.	Grs. Imp. Gal.
SiO_2	17·953	1·3644	$CaSO_4$	42·252	3·2111
SO_3	24·844	1·8881	$CaCO_3$	6·483	0·4927
CO_2	6·870	0·5221	$MnCO_3$	7·707	0·5856
Cl	2·479	0·1884	$MgCl_2$	0·764	0·0581
Na_2O	7·073	0·5375	KCl	4·017	0·3053
K_2O	3·506	0·2665	K_2SiO_3	1·578	0·1196
Li_2O	trace	trace	Na_2SiO_3	13·952	1·0604
CaO	21·041	1·5991	Al_2O_3	2·477	0·1883
SrO	trace	trace	Fe_2O_3	1·916	0·1450
MgO	4·011	0·3048	ZnO	0·207	0·0157
ZnO	0·207	0·0157	CuO	trace	trace
Al_2O_3	2·477	0·1883	PbO	none	none
Fe_2O_3	1·916	0·1456	Mn_3O_4	0·691	0·0525
Mn_3O_4	0·691	0·0525	Ignition	(7·491)	0·5693
CuO	trace	trace			
PbO	none	none	Sum	89·535	6·8036
Ignition	(7·491)	0·5693	Excess of SiO_2	10·464	·7953
Sum	100·559	7·6423	Total	99·999	7·5989
O equiv. to Cl	·559	·0425			
Total	100·000	7·5998			

Total solids 7·6 grs. imp. gal.

It will be observed that the lowest percentage of silicic acid in these residues is 17·9 and the highest 22, while the intermediate ones are about 21 per cent. In an analysis made of Poudre water in 1897, I obtained upwards of 36 per cent of silica. My attention was attracted by the general agreement of these analyses, especially by the fact that three of them agree in showing almost the same excess of silica after having combined all of the bases. This is in strong contrast to the residues obtained by the evaporation of ground waters, drainage waters, or river waters taken in the lower portion of their courses which, especially in the case of the Cache a la Poudre, consist very largely, and at times wholly, of return waters, i. e. such as have been taken from the river, have been used for irrigating purposes, and have found their way back again. The residues from such waters frequently show an excess of bases over the quantity necessary to saturate the inorganic acids. The excess of acids in these analyses is so pronounced that there is no question about its being actually the case. The same is shown by the analyses of the geyser waters and those of the hot springs previously alluded to. There can be no question raised about the silicic acid having been in solution for the waters were perfectly clear, but as a matter of precaution were filtered before being evaporated to dryness, and there is no difference in the results whether the evaporation was conducted in copper or porcelain vessels.

The difference between these waters as mountain streams and when they have become plains streams suggests that the difference observed may be a characteristic of mountain streams, whose waters have not come in contact with any other rocks than granites, gneisses or schists. This suggested that an examination of water from a greater depth might add interesting information. I accordingly obtained a sample of water from the Running Lode mine at a depth of 825 feet. The water is clear and of good quality. The vein at this point is tight and there are no ore bodies immediately above this point along which the water has to move. The country rock is that characteristic of Gilpin County, varying from a schist to a compact granite. The hanging wall in this instance is frequently composed of a white orthoclase. The vein matter is highly silicified but there is not much kaolin, though there is a little scattered through the ore. The residue from this water gave the following results:

Analysis of Water from the Running Lode Mine.

Analytical results.	Per cent.	Combined.	Per cent.
SiO_2	11·298	$CaSO_4$	39·835
SO_3	23·423	$CaCO_3$	13·610
CO_2	16·099	$MgCO_3$	13·724
Cl	1·936	K_2CO_3	2·433
Na_2O	8·262	Na_2CO_3	5·276
K_2O	1·659	NaCl	3·195
Li_2O	trace	Na_2SiO_3	6·861
CaO	24·039	Fe_2O_3, Al_2O_3	0·102
SrO	trace	Mn_3O_4	0·120
MgO	6·563	Ignition	(6·935)
Fe_2O_3, Al_2O_3	·102		
Mn_3O_4	·120	Sum	92·091
Ignition	(6·935)	Excess of SiO_2	7·915
Sum	100·436	Total	100·006
O=Cl	·436		
Total	100·000		

Total solids 23·0 grs. per imp. gal.

On combining the results of this analysis we find here as in the other cases a decided excess of acids which can scarcely be supposed to be due to other than free silicic acid.

The uniformity of these results indicate that these waters are entirely normal for the conditions under which they occur, i. e. within or in contact with granite or rocks rich in felspar. In this case the rocks do not belong to the eruptives, but I cannot see why the class of rock in which the felspar might occur should make any material difference in the general result. The composition of the residues might be considered as suggesting a lime mineral other than felspar as having furnished the mineral matter to the waters, but local conditions make it very probable, and direct experiment will, I think, establish it, that the felspars do in these cases furnish the mineral matter to these waters. I do not by any means intend to claim that the felspars are the only minerals acted on by water and carbon dioxid, but simply that our waters represent the products of such action and it is evident that neither high temperature nor great pressure have played any part in producing the solutions. These two factors have been appealed to to account for the excessive silicic acid in the geysers and hot springs, but my results indicate that these are not necessary to account for the presence of the silicic acid. These points seem to me to have been well tested in some experiments which I have made with finely powdered felspar. The object of the experiment was to discover the line of decomposition suffered by this mineral under ordinary conditions and at or near the surface of the rock masses. In passing I will state that my observation upon the effect of the presence of sodic carbonate, in so far as the conditions of observation are applicable, is that it does not increase the amount of silicic acid present. This fact may be due to the removal of the silicic acid by precipitation; be this as it may, the alkaline waters of our foot hills are always poor in silicic acid even though they percolate through a sand rich in felspar. I notice too that the geysers in the Yellowstone National Park richest in silicic acid have an acid reaction.

The experiments with felspar were conducted as follows: In the first experiment felspar was placed in a gallon aspirator, and treated with distilled water in separate portions, each portion remaining in contact with the felspar 48 hours. In order to keep the powdered felspar agitated a current of air was caused to pass through it continuously, and to still further imitate the actual conditions, a small amount of carbonic acid (CO_2) was mixed with the air. This was continued until nearly 35 gallons of water were collected, which was evaporated to dryness in platinum dishes. I feared to heat the residue above the temperature of boiling water before analyzing it. I would have evaporated it at a lower temperature had it been feasible for me to do so, for it can scarcely be doubted but that some of the CO_2 besides that which was probably present as bicarbonates, was expelled during the continued boiling. The residue, as I analyzed it, was as nearly representative of the solution as I could make it.

The amount that went into solution in this experiment was equal to 1·6 grains per gallon. The maximum quantity that I succeeded in getting into solution was 4·536 grains per imperial gallon, in which case I treated the pulverized felspar with a saturated solution of CO_2 for 16½ days. The solution of CO_2 was put on the felspar and the bottle sealed. The whole was shaken very frequently, on an average three times hourly during the day. This sample of felspar was pulverized in an agate mortar to avoid bringing any iron into the solution, as water charged with CO_2 dissolves finely powdered iron quite readily. The distilled water used in all of the experiments had been freshly distilled and left no residue on evaporation. The action of the water upon the glass of the containing vessels has been assumed to have been so small as to be negligible.

The felspar used was a flesh-colored orthoclase from a point of the mountains locally known as the Horsetooth. It was such as is characteristic of the granites of this range. The sample analyzed was perfectly fresh and resulted as follows:

Analysis of Felspar used in Experiments.

SiO_2	65·760
SO_3	0·003
P_2O_5	0·040
Cl*	
Al_2O_3	19·291
Fe_2O_3	trace
CaO	0·314
SrO	trace
BaO	none
MgO	0·029
Mn_3O_4	0·061
K_2O	11·592
Na_2O	2·728
Li_2O	trace
	99·818

The residue obtained from the first experiment with this felspar showed the following composition:

Analysis of Residue—First Experiment with Felspar.

Analytical results.	Per cent.	Combined.	Per cent.
SiO_2	40·724	$CaSO_4$	16·801
SO_3†	9·879	$CaCO_3$	5·921
CO_2	5·473	$MgCO_3$	1·611
Cl	3·170	K_2CO_3	6·380
Al_2O_3	2·704	KCl	6·667
Fe_2O_3	0·311	K_2SiO_3	3·950
CaO	10·241	Na_2SiO_3	10·354
SrO	trace	Al_2O_3	2·704
MgO	0·771	Fe_2O_3	0·311
K_2O	10·972	SrO	trace
Na_2O	5·249	Li_2O	trace
Li_2O	trace	Ignition	16·366
Ignition	16·366		
		Sum	71·065
Sum	105·860	Excess of SiO_2	34·075
Less $CO_2 + O{=}Cl$	6·187		
			105·140
Total	99·673	Less CO_2 expelled	5·473
		Total	99·667

* The chlorin was not tested for in the felspar, but the aqueous extract shows it abundantly, and as the P_2O_5 probably exists as apatite the presence of some chlorin would be accounted for if it were a chloro-apatite. Fluorin was not tested for.

† The SO_3 and Cl were not determined in this residue. These determinations are taken from the other residues.

Without discussing the probable combinations which actually existed in solution, it is evident that an unduly large amount of silica had been taken up. The result presented by this analysis represents the action of rain or snow water under ordinary conditions. The carbonic acid introduced was moderate in quantity and was thoroughly mixed with the air before being drawn through the water. Both the carbon dioxid and air were well washed; this was done to prevent the introduction of organic matter, chlorin or other impurity with the air.

The second experiment was conducted differently. A quantity of felspar was powdered, passed through a 100 mesh sieve and treated with water saturated with CO_2, without any attempt to remove the iron derived from the buckboard by means of the magnet or otherwise. The containing vessels were sealed and allowed to stand for twenty-two days with frequent shaking. When the vessels were unsealed some of them showed a little pressure. As the iron derived from the buckboard had very largely gone into solution, I passed a current of air through the vessels before I filtered off the felspar—this was a mistake. The iron was easily oxidized and precipitated. It required only about forty-five minutes for the oxidation to become apparent to the eye, but the air current was continued for forty hours when the whole was filtered and evaporated in platinum vessels, the same precautions being taken as in the previous case. The analysis of this residue resulted as follows:

Analysis of Residue—Second Experiment with Felspar.

Analytical results.	Per cent.	Combined.	Per cent.
SiO_2	14·353	$CaSO_4$	16·806
SO_3	9·879	$CaCO_3$	29·432
CO_2	19·874	$MgCO_3$	4·013
P_2O_5	0·381	KCl	6·668
Cl	3·170	K_2CO_3	10·367
Al_2O_3	1·119	Na_2CO_3	3·736
Fe_2O_3	0·136	Na_3PO_4	1·257
CaO	23·412	Na_2SiO_3	6·765
SrO	heavy trace	Al_2O_3	1·119
MgO	1·919	Fe_2O_3	0·136
K_2O	11·279	Ignition	5·464
Na_2O	6·491	Excess of SiO_2	11·018
Li_2O	trace		
Ignition	25·337	Total	96·783
Sum	117·370		
Less $CO_2 + O = Cl$	20·588		
Total	96·782		

I stated above that it was a mistake not to have filtered off the felspar before precipitating the iron oxid, for had I done so I could have determined how much silica, if any, was carried down with the oxid, but as it is we have an imitation of what takes place in all river and spring waters where ferrous salts occur, i. e. oxidation and precipitation of the ferric hydrate. The analysis is too low when we subtract the whole of the carbonic acid and oxygen equivalent to the chlorin found. There is no doubt but that the most if not all of the CO_2 was expelled upon ignition. I have found it to be almost completely expelled even when there was not enough silicic acid to account for it, and there is no means of judging how much was left in this residue, if any, so I have subtracted the whole of it. If the analysis were really badly made and the missing 3·3 per cent were all sodic oxid, which is by no means the case, there would still be a very considerable excess of acids.

The general resemblance of these results except in the relative quantities of potassic and sodic oxids is striking, the more so as they agree with one another and are unlike ordinary river waters.

The experiments with the felspar and the character of the mine water show that they are such as are normally produced by the action of water and carbonic acid upon this mineral without the aid of higher temperatures or pressures.

These experiments further indicate the course and character of the action of water upon felspar—i. e. it attacks those molecules containing calcium and sodium, possibly existing as molecules of labradorite and albite, more readily than those containing potassium—further that the silicic acid is dissolved as such by a process of hydration and exists in the solution as free silicic acid or as a very complex or condensed acid: the former seems much more probable.

These facts, if they be accepted as such, account for the character of the Rio Grande water, it being just such a water as the local conditions would account for. The spring and well waters are simply the same water—i. e. water running into the valley from the mountain streams and sinking into the lower strata, which are composed of sands derived from the breaking down of the rocks composing the adjacent mountains containing an abundance of felspar, and are not mixed with other water or subjected to conditions which cause radical changes in their dissolved mineral matter.

These facts easily account for the silicification of vein matter and the deposition of chalcedonic quartz, etc. in veins and elsewhere. The possible influence of organic acids, especially at the surface, has been suggested because it is so often mentioned. I had an aqueous solution of humic acids and some precipitated and washed humus; a quantity of felspar was treated with distilled water just as in the experiments described with the addition of a liberal quantity of these; the results agreed well with those obtained with water and CO_2 alone after deducting the fixed residue contained in the humus; the duration of this experiment was twenty-two days. I am not prepared to state that such acids play no part in the decomposition of rocks, but the result of this experiment indicates that they play a less important part than the statements frequently met with would indicate, and which, furthermore, the composition of the ash obtained by incinerating them would also suggest.

A remarkable feature in the result of these experiments is the fact that while the felspar contains only a small percentage of lime, less than two-tenths of one per cent, the residue obtained on evaporating the water to dryness shows a large percentage of it, 10 to 23 per cent. The strontia was detected only when as much as five grams of felspar were used; the lithia, however, was detected in one gram, but both were easily detected in the residue. This accounts for a characteristic of our waters, i. e. the presence of strontia and lithia, and I interpret this as strong corroborative proof that, however changed the waters may be, they originally obtain the greater part of their mineral constituents from the decomposition of the felspars. The uniform presence of strontia and lithia in our waters puzzled me greatly until the results of these experiments revealed the source from which they might be derived, as I knew of no lithia or strontia-bearing mineral in the mountains which would account for their presence. Apropos to the occurrence of these elements in felspar I may add that of 271 analyses of felspars of all varieties which I have found given, only three show lithia even in traces, and only two show strontia. But being present in our case they serve to confirm the view that the felspars principally furnish the mineral constituents of the waters. The amounts of sulphates and chlorids have their own particular interest, but the same importance does not attach to them as to the silicic acid already more fully discussed.

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SCIENTIFIC INTELLIGENCE.

Geology and Mineralogy.

1. *U. S. Geological Survey;* Chas. D. Walcott, Director.—The following publications of the Survey have been recently issued:

Monograph XLII. The Carboniferous Ammonoids of America, by James Perrin Smith, pp 1–211, plates i–xxix, 1903.

Monograph XLIII. The Mesabi Iron-Bearing district of Minnesota, by Charles Kenneth Leith; Charles Richard Van Hise, Geologist in charge, pp. 1–316, plates i–xxxiii, figs. 1–12, 1903.

Monograph XLIV. Pseudoceratites of the Cretaceous, by Alpheus Joseph Hyatt, edited by T. W. Stanton, pp. 1–351, plates i–xlvii, 1903.

Bulletin No. 205. The Mollusca of the Buda limestone, by George Burbank Shattuck, with an appendix on the Corals of the Buda limestone by Thomas Wayland Vaughan, pp. 1–94, plates i–xxvii, fig. 1, 1903.

Bulletin No. 206. A study of the Hamilton Formation of the Cayuga Lake Section in Central New York, by Herdman Fitzgerald Cleland, pp. 1–112, plates i–v, figs. 1–3, 1903.

Bulletin No. 207. The action of Ammonium Chloride upon silicates by Frank Wigglesworth Clarke and George Steiger, pp. 1–57, 1902.

Bulletin No. 209. The Geology of Ascutney Mountain, Vermont, by Reginald Aldworth Daly, pp. 122, fig. 1, pls. i–vii, 1903.

Bulletin No. 210. The correlation of Geological Faunas, a contribution to Devonian Paleontology by Henry Shaler Williams, pp. 1–147, pl. i, 1903.

2. *On Batrachian and other footprints from the Coal Measures of Joggins, N. S.;* by G. F. Matthew. Bull. Nat. Hist. Soc. of New Brunswick, vol. v, No. 21 (1903).—Dr. Matthew has described certain footprints in the collections of the Natural History Society of New Brunswick. They pertain to three different types of Batrachian footprints which have received generic names from King and Marsh. The first is of a type common in the Coal Measure sandstones and the other two have been referred to the genera Baropus and Dromopus, respectively. The following are the names of these species: *Thenaropus* (?) *McNaughton*, *Baropus imguifer*, *Dromopus agilis*, *Myriapodites*, sp.

3. *Ueber Artinit, ein Neues Mineral der Asbestgruben von Val Lanterna;* Luigi Brugnatelli.—Under the name artinite is described a new hydrous magnesium carbonate. It is white in color and occurs in spherical aggregates made up of radiating fibers. Its formula was determined to be $MgCO_3.Mg(OH)_2.3H_2O$.

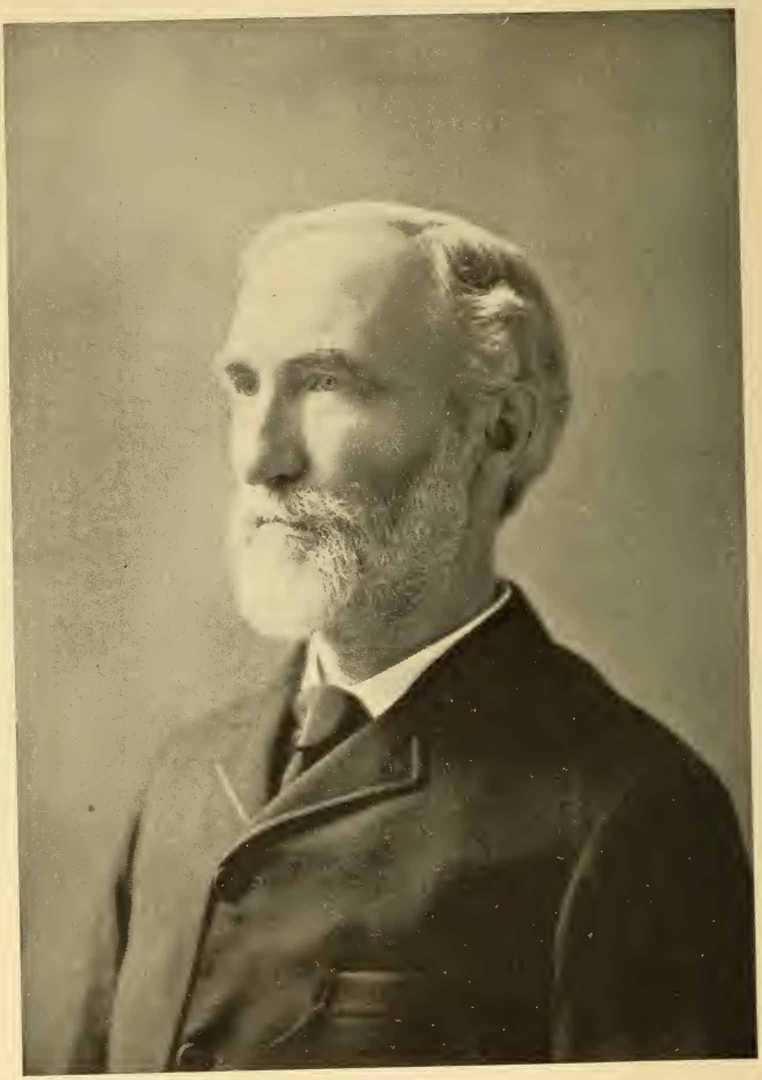
Sp.G. = 2·028.H = 2. Named after Dr. Ettore Artini, director of the mineralogical collection of the State Museum of Milan.—*Cent. f. Min., Geol. u. Palaeon.* 1903. No. 5.

4. *Minerals from Leona Heights, Alameda Co., California.*—The Leona Heights locality has been mined for some years for sulphuric acid ; the ore body consisting of pyrite with some chalcopyrite and their oxidation products. The latter include the new species BOOTHITE, also crystallized melanterite, pisanite and chalcanthite, and further copiopite, epsomite and alunogen. Boothite occurs massive with crystalline structure, also fibrous and rarely in incomplete crystals. The crystallization is monoclinic and the form related to that of melanterite and of pisanite, with which it may be regarded as forming an isomorphous series. Analyses of the fibrous and massive mineral, after deduction of the insoluble portion, gave concordant results and led to the formula $CuSO_4.7H_2O$ or, since six-sevenths of the water goes off above 105°, $H_2O.CuSO_4+6H_2O$. This species is named by W. T. SCHALLER after Edward Booth, Department of Chemistry, Univ. of California.—*Univ. California, Bull. Geol.*, iii, 191, 1903.

5. *Palacherite, a new mineral.*—A. S. EAKLE has named, after Dr. Charles Palache, a new hydrous basic sulphate of iron and magnesia from the Redington mercury mine, Knoxville, California. It occurs in loosely coherent aggregates of minute monoclinic crystals of a deep brick-red color. The hardness is 1·5–2, specific gravity 2·075, luster vitreous, streak pale yellow. The formula given is $Fe_2O_3.2MgO.4SO_3+15H_2O$, deduced from the following average of several analyses :

SO_3 38·37, Fe_2O_3 19·51, MgO 9·35, H_2O (above 100°) 12·75, H_2O (100°) 19·53 = 99·51

—*Univ. California, Bull. Geol.*, iii, 231, 1903.



THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

JOSIAH WILLARD GIBBS.

Josiah Willard Gibbs was born in New Haven, Connecticut, February 11, 1839, and died in the same city, April 28, 1903. He was descended from Robert Gibbs, the fourth son of Sir Henry Gibbs of Honington, Warwickshire, who came to Boston about 1658. One of Robert Gibbs's grandsons, Henry Gibbs, in 1747 married Katherine, daughter of the Hon. Josiah Willard, Secretary of the Province of Massachusetts, and of the descendants of this couple, in various parts of the country, no fewer than six have borne the name Josiah Willard Gibbs.

The subject of this memorial was the fourth child and only son of Josiah Willard Gibbs, Professor of Sacred Literature in the Yale Divinity School from 1824 to 1861, and of his wife, Mary Anna, daughter of Dr. Van Cleve of Princeton, N. J. The elder Professor Gibbs was remarkable among his contemporaries for profound scholarship, for unusual modesty, and for the conscientious and painstaking accuracy which characterized all of his published work. The following brief extracts from a discourse commemorative of his life, by Professor George P. Fisher, can hardly fail to be of interest to those who are familiar with the work of his distinguished son: "One who should look simply at the writings of Mr. Gibbs, where we meet only with naked, laboriously classified, skeleton-like statements of scientific truth, might judge him to be devoid of zeal even in his favorite pursuit. But there was a deep fountain of feeling that did not appear in these curiously elaborated essays . . . . . Of the science of comparative grammar, as I am informed by those most competent to judge, he is to be considered in relation to the scholars of this country as the leader." Again, in speaking of his unfinished translation of Gesenius's Hebrew Lexicon: "But with his wonted thoroughness, he could not leave a word until he had made the article upon it perfect, sifting what the author had written by independent investigations of his own."

His son entered Yale College in 1854 and was graduated in 1858, receiving during his college course several prizes for excellence in Latin and Mathematics; during the next five years he continued his studies in New Haven, and in 1863 received the degree of doctor of philosophy and was appointed a tutor in the college for a term of three years. During the first two years of his tutorship he taught Latin and in the third year Natural Philosophy, in both of which subjects he had gained marked distinction as an undergraduate. At the end of his term as tutor he went abroad with his sisters, spending the winter of 1866–67 in Paris and the following year in Berlin, where he heard the lectures of Magnus and other teachers of physics and of mathematics. In 1868 he went to Heidelberg, where Kirchhoff and Helmholtz were then stationed, returning to New Haven in June, 1869. Two years later he was appointed Professor of Mathematical Physics in Yale College, a position which he held until the time of his death.

It was not until 1873, when he was thirty-four years old, that he gave to the world, by publication, evidence of his extraordinary powers as an investigator in mathematical physics. In that year two papers appeared in the Transactions of the Connecticut Academy, the first being entitled "Graphical Methods in the Thermodynamics of Fluids," and the second "A Method of Geometrical Representation of the Thermodynamic Properties of Substances by Means of Surfaces." These were followed in 1876 and 1878 by the two parts of the great paper "On the Equilibrium of Heterogeneous Substances," which is generally, and probably rightly, considered his most important contribution to physical science, and which is unquestionably among the greatest and most enduring monuments of the wonderful scientific activity of the nineteenth century. The first two papers of this series, although somewhat overshadowed by the third, are themselves very remarkable and valuable contributions to the theory of thermodynamics; they have proved useful and fertile in many direct ways and, in addition, it is difficult to see how, without them, the third could have been written. In logical development the three are very closely connected, and methods first brought forward in the earlier papers are used continually in the third.

Professor Gibbs was much inclined to the use of geometrical illustrations, which he employed as symbols and aids to the imagination, rather than the mechanical models which have served so many great investigators; such models are seldom in complete correspondence with the phenomena they represent, and Professor Gibbs's tendency toward rigorous logic was such that the discrepancies apparently destroyed for him the usefulness of the model. Accordingly he usually had recourse to the geometrical representation of his equations, and this method he used with great ease and power. With this inclination, it is probable that he made much use, in his study of thermodynamics, of the volume-pressure diagram, the only one which, up to that time, had been used extensively. To those who are acquainted with the completeness of his investigation of any subject which interested him, it is not surprising that his first published paper should have been a careful study of all the different diagrams which seemed to have any chance of being useful. Of the new diagrams which he first described in this paper, the simplest, in some respects, is that in which entropy and temperative are taken as coördinates; in this, as in the familiar volume-pressure diagram, the work or heat of any cycle is proportional to its area in any part of the plane; for many purposes it is far more perspicuous than the older diagram, and it has found most important practical applications in the study of the steam engine. The diagram, however, to which Professor Gibbs gave most attention was the volume-entropy diagram, which presents many advantages when the properties of bodies are to be studied, rather than the work they do or the heat they give out. The chief reason for this superiority is that volume and entropy are both proportional to the quantity of substance, while pressure and temperature are not; the representation of coexistent states is thus especially clear, and for many purposes the gain in this direction more than counterbalances the loss due to the variability of the scale of work and heat. No diagram of constant scale can, for example, adequately represent the triple state where solid, liquid and vapor are all present; nor, without confusion, can it represent the states of a substance which, like water, has a maximum density; in these and in many other cases the volume-entropy diagram is superior in distinctness and convenience.

In the second paper the consideration of graphical methods in thermodynamics was extended to diagrams in three dimensions. James Thomson had already made this extension to the volume-pressure diagram by erecting the temperature as the third coördinate, these three immediately cognizable quantities giving a surface whose interpretation is most simple from elementary considerations, but which, for several reasons, is far less convenient and fertile of results than one in which the coördinates are thermodynamic quantities less directly known. In fact, if the general relation between the volume, entropy and energy of any body is known, the relation between the volume, pressure and temperature may be immediately deduced by differentiation; but the converse is not true, and thus a knowledge of the former relation gives more complete information of the properties of a substance than a knowledge of the latter. Accordingly Gibbs chooses as the three coördinates the volume, entropy and energy and, in a masterly manner, proceeds to develop the properties of the resulting surface, the geometrical conditions for equilibrium, the criteria for its stability or instability, the conditions for coexistent states and for the critical state; and he points out, in several examples, the great power of this method for the solution of thermodynamic problems. The exceptional importance and beauty of this work by a hitherto unknown writer was immediately recognized by Maxwell, who, in the last years of his life, spent considerable time in carefully constructing, with his own hands, a model of this surface, a cast of which, very shortly before his death, he sent to Professor Gibbs.

One property of this three dimensional diagram (analogous to that mentioned in the case of the plane volume-entropy diagram) proved to be of capital importance in the development of Gibbs's future work in thermodynamics; the volume, entropy and energy of a mixture of portions of a substance in different states (whether in equilibrium or not), are the sums of the volumes, entropies and energies of the separate parts, and, in the diagram, the mixture is represented by a single point which may be found from the separate points, representing the different portions, by a process like that of finding centers of gravity. In general this point is not in the surface representing the stable states of the substance, but within the solid bounded by this surface, and its distance from the surface, taken parallel to the axis of energy, represents the available energy of the mixture. This possibility of representing the properties of mixtures of different states of the same substance immediately suggested that mixtures of substances differing in chemical composition, as well as in physical state, might be treated in a similar manner; in a note at the end of the second paper the author clearly indicates the possibility of doing so, and there can be little doubt that this was the path by which he approached the task of investigating the conditions of chemical equilibrium, a task which he was destined to achieve in such a magnificent manner and with such advantage to physical science.

In the discussion of chemically homogeneous substances in the first two papers, frequent use had been made of the principle that such a substance will be in equilibrium if, when its energy is kept constant, its entropy cannot increase; at the head of the third paper the author puts the famous statement of Clausius: "Die Energie der Welt ist constant. Die Entropie der Welt strebt einem Maximum zu." He proceeds to show that the above condition for equilibrium, derived from the two laws of thermodynamics, is of universal application, carefully removing one restriction after another, the first to go being that the substance shall be chemically homogeneous. The important analytical step is taken of introducing, as variables in the fundamental differential equation, the masses of the constituents of the heterogeneous body; the differential coefficients of the energy with respect to these masses are shown to enter the conditions of equilibrium in a manner entirely analogous to the "intensities," pressure and temperature, and these coefficients are called potentials. Constant use is made of the analogies with the equations for homogeneous substances, and the analytical processes are like those which a geometer would use in extending to n-dimensions the geometry of three.

It is quite out of the question to give, in brief compass, anything approaching an adequate outline of this remarkable work. It is universally recognized that its publication was an event of the first importance in the history of chemistry, that in fact it founded a new department of chemical science which, in the words of M. Le Chatelier, is becoming comparable in importance with that created by Lavoisier. Nevertheless it was a number of years before its value was generally known; this delay was due largely to the fact that its mathematical form and rigorous deductive processes make it difficult reading for any one, and especially so for students of experimental chemistry whom it most concerns; twenty-five years ago there was relatively only a small number of chemists who possessed sufficient mathematical knowledge to read easily even the simpler portions of the paper. Thus it came about that a number of natural laws of great importance which were, for the first time, clearly stated in this paper were subsequently, during its period of neglect, discovered by others, sometimes from theoretical considerations, but more often by experiment. At the present time, however, the great value of its methods and results are fully recognized by all students of physical chemistry. It was translated into German in 1891 by Professor Ostwald and into French in 1899 by Professor Le Chatelier; and, although so many years had passed since its original publication, in both cases the distinguished translators give, as their principal reason for undertaking the task, not the historical interest of the memoir, but the many important questions which it discusses and which have not even yet been worked out experimentally. Many of its theorems have already served as starting points or guides for experimental researches of fundamental consequence; others, such as that which goes under the name of the "Phase Rule," have served to classify and explain, in a simple and logical manner, experimental facts of much apparent complexity; while still others, such as the theories of catalysis, of solid solutions, and of the action of semi-permeable diaphragms and osmotic pressure, showed that many facts, which had previously seemed mysterious and scarcely capable of explanation, are in fact simple, direct and necessary consequences of the fundamental laws of thermodynamics. In the discussion of mixtures in which some of the components are present only in very small quantity (of which the most interesting cases at present are dilute solutions) the theory is carried as far as is possible from *à priori* considerations; at the time the paper was written the lack of experimental facts did not permit the statement, in all its generality, of the celebrated law which was afterward discovered by van't Hoff; but the law is distinctly stated for solutions of gases as a direct consequence of Henry's law and, while the facts at the author's disposal did not permit a further extension, he remarks that there are many indications "that the law expressed by these equations has a very general application."

It is not surprising that a work containing results of such consequence should have excited the profoundest admiration among students of the physical sciences; but even more remarkable than the results, and perhaps of even greater service to science, are the methods by which they were attained; these do not depend upon special hypotheses as to the constitution of matter or any similar assumption, but the whole system rests directly upon the truth of certain experiential laws which possess a very high degree of probability. To have obtained the results embodied in these papers in any manner would have been a great achievement; that they were reached by a method of such logical austerity is a still greater cause for wonder and admiration. And it gives to the work a degree of certainty and an assurance of permanence, in form and matter, which is not often found in investigations so original in character.

In lecturing to students upon mathematical physics, especially in the theory of electricity and magnetism, Professor Gibbs felt, as so many other physicists in recent years have done, the desirability of a vector algebra by which the more or less complicated space relations, dealt with in many departments of physics, could be conveniently and perspicuously expressed; and this desire was especially active in him on account of his natural tendency toward elegance and conciseness of mathematical method. He did not, however, find in Hamilton's system of quaternions an instrument altogether suited to his needs, in this respect sharing the experience of other investigators who have, of late years, seemed more and more inclined, for practical purposes, to reject the quaternionic analysis, notwithstanding its beauty and logical completeness, in favor of a simpler and more direct treatment of the subject. For the use of his students, Professor Gibbs privately printed in 1881 and 1884 a very concise account of the vector analysis which he had developed, and this pamphlet was to some extent circulated among those especially interested in the subject. In the development of this system the author had been led to study deeply the Ausdehnungslehre of Grassmann, and the subject of multiple algebra in general; these investigations interested him greatly up to the time of his death, and he has often remarked that he had more pleasure in the study of multiple algebra than in any other of his intellectual activities. His rejection of quaternions, and his championship of Grassmann's claim to be considered the founder of modern algebra, led to some papers of a somewhat controversial character, most of which appeared in the columns of "Nature." When the utility of his system as an instrument for physical research had been proved by twenty years experience of himself and of his pupils, Professor Gibbs consented, though somewhat reluctantly, to its formal publication in much more extended form than in the original pamphlet. As he was at that time wholly occupied with another work, the task of preparing this treatise for publication was entrusted to one of his students, Dr. E. B. Wilson, whose very successful accomplishment of the work entitles him to the gratitude of all who are interested in the subject.

The reluctance of Professor Gibbs to publish his system of vector analysis certainly did not arise from any doubt in his own mind as to its utility, or the desirability of its being more widely employed; it seemed rather to be due to the feeling that it was not an original contribution to mathematics, but was rather an adaptation for special purposes of the work of others. Of many portions of the work this is of course necessarily true, and it is rather by the selection of methods and by systematization of the presentation that the author has served the cause of vector analysis. But in the treatment of the linear vector function and the theory of dyadics to which this leads, a distinct advance was made which was of consequence not only in the more restricted field of vector analysis, but also in the broader theory of multiple algebra in general.

The theory of dyadics * as developed in the vector analysis of 1884 must be regarded as the most important published contribution of Professor Gibbs to pure mathematics. For the vector analysis as an *algebra* does not fulfill the definition of the linear associative algebras of Benjamin Peirce, since the scalar product of vectors lies outside the vector domain; nor is it a geometrical analysis in the sense of Grassmann, the vector product satisfying the combinatorial law, but yielding a vector instead of a magnitude of the second order. While these departures from the systems mentioned testify to the great ingenuity and originality of the author, and do not impair the utility of the system as a tool for the use of students of physics, they nevertheless expose the discipline to the criticism of the pure algebraist. Such objection falls to the ground, however, in the case of the theory mentioned, for dyadics yield, for $n = 3$, a linear associative algebra of nine units, namely nonions, the general nonion satisfying an identical equation of the third degree, the Hamilton-Cayley equation.

It is easy to make clear the precise point of view adopted by Professor Gibbs in this matter. This is well expounded in his vice-presidential address on multiple algebra, before the American Association for the Advancement of Science, in 1886, and also in his warm defense of Grassmann's priority rights, as against Hamilton's, in his article in Nature, "Quarternions and the Ausdehnungslehre." He points out that the key to matricular algebras is to be found in the open (or indeterminate) product (i. e. a product in which no equations subsist between the factors) and, after calling attention to the brief development of this product in Grassmann's work of 1844, affirms that Sylvester's assignment of the date 1858 to the "second birth of Algebra" (this being the year of Cayley's Memoir on Matrices) must be changed to 1844. Grassmann, however, ascribes very little importance to the open product, regarding it as offering no useful applications. On the contrary, Professor Gibbs assigns to it the first place in the three kinds of multiplication considered in the Ausdehnungslehre, since from it may be derived the algebraic and the combinatorial products, and shows in fact that both of them may be expressed in terms of indeterminate products. Thus the multiplication rejected by Grassmann becomes, from the standpoint of Professor Gibbs, the key to all others. The originality of the latter's treatment of the algebra of dyadics, as contrasted with the methods of other authors in the allied theory of matrices, consists exactly in this, that Professor Gibbs regards a matrix of order n as a multiple quantity in n^2

* For the following account of the mathematical relations of this theory the writer is indebted to Professor Percey F. Smith.

units, each of which is an indeterminate product of two factors. On the other hand, C. S. Peirce, who was the first to recognize (1870) the quadrate linear associative algebras identical with matrices, uses for the units a *letter pair*, but does not regard this combination as a product. In addition, Professor Gibbs, following the spirit of Grassmann's system, does not confine himself to one kind of multiplication of dyadics, as do Hamilton and Peirce, but considers two sorts, both originating with Grassmann. Thus it may be said that quadrate, or matricular algebras, are brought entirely within the wonderful system expounded by Grassmann in 1844.

As already remarked, the exposition of the theory of dyadics given in the vector analysis is not in accord with Grassmann's system. In a footnote to the address referred to above, Professor Gibbs shows the slight modification necessary for this purpose, while the subject has been treated in detail and in all generality in his lectures on multiple algebra delivered for some years past at Yale University.

Professor Gibbs was much interested in the applications of vector analysis to some of the problems of astronomy, and more than once he called attention to the great saving of labor which the use of this method would cause in such subjects as the determination of an orbit from three observations, the differential equations which are used in determining the best orbit from an indefinite number of observations by the method of least squares, or those which give the perturbations when the elements are treated as variable.

Between the years 1882 and 1889, five papers appeared in this Journal upon certain points in the electromagnetic theory of light and its relations to the various elastic theories. These are remarkable for the entire absence of special hypotheses as to the connection between ether and matter, the only supposition made as to the constitution of matter being that it is fine-grained with reference to the wave-length of light, but not infinitely fine-grained, and that it does disturb in some manner the electrical fluxes in the ether. By methods whose simplicity and directness recall his thermodynamic investigations, the author shows in the first of these articles that, in the case of perfectly transparent media, the theory not only accounts for the dispersion of colors (including the "dispersion of the optic axes" in doubly refracting media), but also leads to Fresnel's laws of double refraction for any particular wave-length without neglect of the small quantities which determine the dispersion of colors. He proceeds in the second paper to show that circular and elliptical polarization are explained by taking into account quantities of a still higher order, and that these in turn do not disturb the explanation of any of the other known phenomena; and in the third paper he deduces, in a very rigorous manner, the general equations of monochromatic light in media of every degree of transparency, arriving at equations somewhat different from those of Maxwell in that they do not contain explicitly the dielectric constant and conductivity as measured electrically, thus avoiding certain difficulties (especially in regard to metallic reflection) which the theory as originally stated had encountered; and it is made clear that "a point of view more in accordance with what we know of the molecular constitution of bodies will give that part of the ordinary theory which is verified by experiment, without including that part which is in opposition to observed facts." Some experiments of Professor C. S. Hastings in 1888 (which showed that the double refraction in Iceland spar conformed to Huyghens's law to a degree of precision far exceeding that of any previous verification) again led Professor Gibbs to take up the subject of optical theories in a paper which shows, in a remarkably simple manner, from elementary considerations, that this result and also the general character of the facts of dispersion are in strict accord with the electrical theory, while no one of the elastic theories which had, at that time, been proposed could be reconciled with these experimental results. A few months later upon the publication of Sir William Thomson's theory of an infinitely compressible ether, it became necessary to supplement the comparison by taking account of this theory also. It is not subject to the insuperable difficulties which beset the other elastic theories, since its equations and surface conditions for perfectly homogeneous and transparent media are identical in form with those of the electrical theory, and lead in an equally direct manner to Fresnel's construction for doubly-refracting media, and to the proper values for the intensities of the reflected and refracted light. But Gibbs shows that, in the case of a fine-grained medium, Thomson's theory does not lead to the known facts of dispersion without unnatural and forced hypotheses, and that in the case of metallic reflection it is subject to similar difficulties; while, on the other hand, "it may be said for the electrical theory that it is not obliged to invent hypotheses, but only to apply the laws furnished by the science of electricity, and that it is difficult to account for the coincidences between the electrical and optical properties of media unless we regard the motions of light as electrical." Of all the arguments (from theoretical grounds alone) for excluding all other theories of light except the electrical, these papers furnish the simplest, most philosophical, and most conclusive with which the present writer is acquainted; and it seems likely that the considerations advanced in them would have sufficed to firmly establish this theory even if the experimental discoveries of Hertz had not rendered such discussions forever unnecessary.

In his last work, "Elementary Principles in Statistical Mechanics," Professor Gibbs returned to a theme closely connected with the subjects of his earliest publications. In these he had been concerned with the development of the consequences of the laws of thermodynamics which are accepted as given by experience; in this empirical form of the science, heat and mechanical energy are regarded as two distinct entities, mutually convertible of course with certain limitations, but essentially different in many important ways. In accordance with the strong tendency toward unification of causes, there have been many attempts to bring these two things under the same category; to show, in fact, that heat is nothing more than the purely mechanical energy of the minute particles of which all sensible matter is supposed to be made up, and that the extra-dynamical laws of heat are consequences of the immense number of independent mechanical systems in any body,—a number so great that, to human observation, only certain averages and most probable effects are perceptible. Yet in spite of dogmatic assertions, in many elementary books and popular expositions, that "heat is a mode of molecular motion," these attempts have not been entirely successful, and the failure has been signalized by Lord Kelvin as one of the clouds upon the history of science in the nineteenth century. Such investigations must deal with the mechanics of systems of an immense number of degrees of freedom and (since we are quite unable in our experiments to identify or follow individual particles), in order to compare the results of the dynamical reasoning with observation, the processes must be statistical in character. The difficulties of such processes have been pointed out more than once by Maxwell, who, in a passage which Professor Gibbs often quoted, says that serious errors have been made in such inquiries by men whose competency in other branches of mathematics was unquestioned.

On account, then, of the difficulties of the subject and of the profound importance of results which can be reached by no other known method, it is of the utmost consequence that the principles and processes of statistical mechanics should be put upon a firm and certain foundation. That this has now been accomplished there can be no doubt, and there will be little excuse in the future for a repetition of the errors of which Maxwell speaks; moreover, theorems have been discovered and processes devised which will render easier the task of every future student of this subject, as the work of Lagrange did in the case of ordinary mechanics.

The greater part of the book is taken up with this general development of the subject without special reference to the problems of rational thermodynamics. At the end of the twelfth chapter the author has in his hands a far more perfect weapon for attacking such problems than any previous investigator has possessed, and its triumphant use in the last three chapters shows that such purely mechanical systems as he has been considering will exhibit, to human perception, properties in all respects analogous to those which we actually meet with in thermodynamics. No one can understandingly read the thirteenth chapter without the keenest delight, as one after another of the familiar formulæ of thermodynamics appear almost spontaneously, as it seems, from the consideration of purely mechanical systems. But it is characteristic of the author that he should be more impressed with the limitations and imperfections of his work than with its successes; and he is careful to say (p. 166): "But it should be distinctly stated that, if the results obtained when the numbers of degrees of freedom are enormous coincide sensibly with the general laws of thermodynamics, however interesting and significant this coincidence may be, we are still far from having explained the phenomena of nature with respect to these laws. For, as compared with the case of nature, the systems which we have considered are of an ideal simplicity. Although our only assumption is that we are considering conservative systems of a finite number of degrees of freedom, it would seem that this is assuming far too much, so far as the bodies of nature are concerned. The phenomena of radiant heat, which certainly should not be neglected in any complete system of thermodynamics, and the electrical phenomena associated with the combination of atoms, seem to show that the hypothesis of a finite number of degrees of freedom is inadequate for the explanation of the properties of bodies." While this is undoubtedly true, it should also be remembered that, in no department of physics, have the phenomena of nature been explained with the completeness that is here indicated as desirable. In the theories of electricity, of light, even in mechanics itself, only certain phenomena are considered which really never occur alone. In the present state of knowledge, such partial explanations are the best that can be got, and, in addition, the problem of rational thermodynamics has, historically, always been regarded in this way. In a matter of such difficulty no positive statement should be made, but it is the firm belief of the present writer that the problem, as it has always been understood, has been successfully solved in this work; and if this belief is correct, one of the great deficiencies in the scientific record of the nineteenth century has been supplied in the first year of the twentieth.

In method and results, this part of the work is more general than any preceding treatment of the subject; it is in no sense a treatise on the kinetic theory of gases, and the results obtained are not the properties of any one form of matter, but the general equations of thermodynamics which belong to all forms alike. This corresponds to the generality of the hypotheses in which nothing is assumed as to the mechanical nature of the systems considered, except that they are mechanical and obey Lagrange's or Hamilton's equations. In this respect it may be considered to have done for thermodynamics what Maxwell's treatise did for electromagnetism, and we may say (as Poincaré has said of Maxwell) that Gibbs has not sought to give a mechanical explanation of heat, but has limited his task to demonstrating that such an explanation is possible. And this achievement forms a fitting culmination of his life's work.

The value to science of Professor Gibbs's work has been formally recognized by many learned societies and universities both in this country and abroad. The list of societies and academies of which he was a member or correspondent includes the Connecticut Academy of Arts and Sciences, the National Academy of Sciences, the American Academy of Arts and Sciences, the Dutch Society of Sciences, Haarlem, the Royal Society of Sciences, Göttingen, the Royal Institution of Great Britain, the Cambridge Philosophical Society, the London Mathematical Society, the Manchester Literary and Philosophical Society, the Royal Academy of Amsterdam, the Royal Society of London, the Royal Prussian Academy of Berlin, the French Institute, the Physical Society of London, the Bavarian Academy of Sciences and the American Mathematical Society. He was the recipient of honorary degrees from Williams College, and from the universities of Erlangen, Princeton, and Christiania. In 1881 he received the Rumford Medal from the American Academy of Boston, and in 1901 the Copley Medal from the Royal Society of London.

Outside of his scientific activities, Professor Gibbs's life was uneventful; he made but one visit to Europe and with the exception of those three years, and of summer vacations in the mountains, his whole life was spent in New Haven, and all but his earlier years in the same house, which his father had built only a few rods from the school where he prepared for college and from the university in the service of which his life was spent. He never married, but made his home with his sister and her family. Of a retiring disposition, he went little into general society and was known to few outside the university; but by those who were honored by his friendship, and by his students, he was greatly beloved. His modesty with regard to his work was proverbial among all who knew him, and it was entirely real and unaffected. There was never any doubt in his mind, however, as to the accuracy of anything which he published, nor indeed did he underestimate its importance; but he seemed to regard it in an entirely impersonal way and never doubted, apparently, that what he had accomplished could have been done equally well by almost any one who might have happened to give his attention to the same problems. Those nearest him for many years are constrained to believe that he never realized that he was endowed with most unusual powers of mind; there was never any tendency to make the importance of his work an excuse for neglecting even the most trivial of his duties as an officer of the college, and he was never too busy to devote, at once, as much time and energy as might be necessary to any of his students who privately sought his assistance.

Although long intervals sometimes elapsed between his publications, his habits of work were steady and systematic; but he worked alone and, apparently, without need of the stimulus of personal conversation upon the subject, or of criticism from others, which is often helpful even when the critic is intellectually an inferior. So far from publishing partial results, he seldom, if ever, spoke of what he was doing until it was practically in its final and complete form. This was his chief limitation as a teacher of advanced students; he did not take them into his confidence with regard to his current work, and even when he lectured upon a subject in advance of its publication (as was the case for a number of years before the appearance of the Statistical Mechanics) the work was really complete except for a few finishing touches. Thus his students were deprived of the advantage of seeing his great structures in process of building, of helping him in the details, and of being in such ways encouraged to make for themselves attempts similar in character, however small their scale. But on the other hand, they owe to him a debt of gratitude for an introduction into the profounder regions of natural philosophy such as they could have obtained from few other living teachers. Always carefully prepared, his lectures were marked by the same great qualities as his published papers and were, in addition, enriched by many apt and simple illustrations which can never be forgotten by those who heard them. No necessary qualification to a statement was ever omitted and, on the other hand, it seldom failed to receive the most general application of which it was capable; his students had ample opportunity to learn what may be regarded as known, what is guessed at, what a proof is, and how far it goes. Although he disregarded many of the shibboleths of the mathematical rigorists, his logical processes were really of the most severe type; in power of deduction, of generalization, in insight into hidden relations, in critical acumen, utter lack of prejudice, and in the philosophical breadth of his view of the object and aim of physics, he has probably had no superiors in the history of the science; and no student could come in contact with this serene and impartial mind without feeling profoundly its influence in all his future studies of nature.

In his personal character the same great qualities were apparent. Unassuming in manner, genial and kindly in his intercourse with his fellow-men, never showing impatience or irritation, devoid of personal ambition of the baser sort or of the slightest desire to exalt himself, he went far toward realizing the ideal of the unselfish, Christian gentleman. In the minds of those who knew him, the greatness of his intellectual achievements will never overshadow the beauty and dignity of his life.

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Art. XIX.—*The Origin of Coral Reefs as shown by the Maldives;** by J. Stanley Gardiner, M.A.

It was with very mixed feelings that I received some months ago a request from the editor of this Journal, for some account of my work on the formation of Coral Reefs, more particularly as exemplified by the Maldive Group of islands. The question involved is an extremely complicated one, especially since the conditions in the various parts of the world where coral reefs are found appear, superficially at least, to be widely different. We have evidence in the fact of reefs, built by the same lime-secreting organisms, actually occurring over broad areas of the oceans, that the same animals and plants can adapt themselves to the different conditions such as they are. At the same time the reefs in widely separated areas of the Pacific and Indian oceans, at any rate bear to one another a remarkable family, even generic likeness, so that there would seem to be certain factors of general occurrence. Indeed, it would appear that we should look to such conditions as are constant for an adequate explanation of the main features of the topography of the existing reefs as well as for an account of their original formation. Premising the fact that it is only profound knowledge and vast experience that can tell how much of the present appearance of any set of reefs is due to factors of universal distribution and how much is due to purely local conditions, I pass to my more immediate subject, the origin of coral reefs.

The question under consideration divides itself into two chief heads, (1) the nature of the foundations on which the lime-secreting organisms have built up their superstructure, and (2) the mode of building and later history of their erections. My work of the past eight years in the Pacific Ocean (Funafuti, Rotuma and the Fiji Islands) and in the Maldive and Laccadive Groups, has dealt principally with the second of these two heads, and in the latter islands can do no more than throw an indirect light on the first question. Yet, a knowledge of the physical conditions of the sea, and of their effects, is not without importance in indicating the possible and even probable methods of formation of these foundations.

* For a full account of the Maldives see "The Maldive and Laccadive Groups with Notes on other Coral Formations in the Indian Ocean," *Fauna and Geography of the Maldive and Laccadive Archipelagoes*, vol. i, pp. 12–50, 146–183, 313–346, 376–423 (1901–3).

The Maldive and Laccadive Groups lie to the southwest of India, extending in a broad belt almost from Bombay to lat. 1° S. Sufficiently good charts for the purposes of this article will be found in Dana and Darwin's well-known works on coral islands.

It is not my intention to discuss the formation of coral reefs at any length, or to give precise references to the great pioneer work of Charles Darwin and James D. Dana, so greatly in advance of its time, to the fresh considerations and opinions ably put forward by Murray, to the views of Semper, Louis Agassiz and Wharton, and finally to the determined work of Alexander Agassiz during the last twenty years. Such references will be found in that beautiful series of publications, which the latter authority has given to the world, from the Museum of Comparative Zoology of Harvard College. It suffices to remark that, while it may be that some reefs really owe their existence to the subsidence of the land round which they originally formed only a fringe, the great mass of facts, that has been collected in the last twenty years, points out clearly and decidedly that such a method of formation can never have been anything else but rare and altogether exceptional. Elevated reefs, which have proved to be extremely numerous in coral reef regions, give no evidence of the very considerable thickness which such a view postulates, and the examination of the existing atolls and reefs has shown that such a conception is unnecessary to explain any of their conditions and is absolutely opposed to many. In some places, notably some reefs of Fiji, the formations in progress are as yet mere skins on the surfaces of older elevated limestone and volcanic rocks, which have been cut down by denudation and erosion to the level of the sea. Elsewhere, no doubt, and this more particularly in the less open seas, reef foundations have been built up to the requisite depths by the accretion of the remains of organisms, both pelagic and other, on submarine mountains and elevations, or where the currents are such as to especially bring about a deposition of material. Again, submarine eruptions have thrown up mounds on the ocean floor, perhaps to be built up further by organisms, perhaps of the requisite depth, or perhaps to form islands, the latter of loose cinders and ash, themselves to be cut down and form wide plateaus on which reefs have subsequently arisen. A *prima facie* example of this method is seen in that line of coral atolls, the Gilbert and Ellice Groups, which seems to indicate a line of weakness of the earth's crust.

It is improbable, considering the diversified conditions of the earth along the coral reef belt, that any one explanation will be found to be of general applicability. Certainly no one, nor indeed all of the above views, taken together, can serve to explain the method by which the foundations of the Maldive reefs were formed. The greater part of the Maldive Group arises on an immense plateau lying at a depth of about 200 fathoms in a sea of over 2000 fathoms. At the same time this plateau itself, together with the atolls and reefs of the Laccadive Group, all spring from a second wider table at a depth of about 1100 fathoms, which connects with that on which the continent of India arises, and which may further extend down to and include the Chagos Archipelago to the south. Of what material and by what means these plateaus were formed is a question to which we can as yet give no adequate answer. As evidence has accumulated, it has become more and more certain that India was formerly connected with Madagascar. This connection continued up to the commencement, at least, of the Tertiary period, when a great depression must have extended over the whole of the belt. Probably the contour of the deeper plateau, which should be much larger than the charts indicate, represents nearly the outline of the original land before this subsidence occurred. If this be so, the deepest foundations not only of the Maldives and Laccadives but also of the Chagos and many reef areas near the Seychelles, owe their origin to this source. This depression is not the same as the slow and long continued subsidence, postulated by the upholders of the Darwinian theory, for it is quite obvious that the reefs of the present day are so placed that they can have little or no close relation to such a depression.

The problem now passes to the question of the formation of the shallower plateau, which in the Maldives is roughly 300 miles in length by 65 miles in breadth. This plateau is peculiar in that its area is remarkably sharply defined, sloping off evenly in two to four miles outside the lines of reefs to over a thousand fathoms. It is scarcely possible considering its position, swept by the monsoon currents, that it owes its origin to an upgrowth of organisms and deposition of sediment on the original line of sinking. Consequently one is driven to the conclusion that it represents an island or line of peaks left after the great depression took place. Again its topography equally precludes the idea of a slowly progressing, long continued subsidence to form the existing reefs. How and by what means could this plateau be formed from the isolated series of mounds or mountains that were left after the great depression took place? The answer is supplied by the Fiji Group in which the erosive and denuding action is well seen on hard volcanic as well as on raised limestone rocks. Additional evidence is afforded by the East Indies in which Professor Max Weber has constant occasion to refer to former land connections and the very remarkable effects of tides and currents down to several hundreds of fathoms in depth. Indeed, it is not too much to say that Professor Max Weber's Introduction to the Siboga Expedition Results, taken altogether and in its entirety, points to a levelling of the East Indian area down to a depth of over two hundred fathoms. The study of the charts and of the survey work of the last thirty years gives much additional evidence, and the Maldives themselves give clear indications. Lastly, a depth of about 150 fathoms is that at which the steep slope of most coral reefs passes into a more gradual slope, and would seem to be the critical depth to which the main oceanic and tidal currents act, this depth decreasing off the smaller reefs and increasing off the larger. At the same time it is scarcely necessary to suppose that the whole area was cut down to 200 fathoms before reefs commenced to build up, though such a depth would seem to be critical for a bank of about this size, so situated in a fully exposed area. Seeing the absolute impossibility of subsidence affording any explanation, examining all considerations and taking the indications that the area itself gives, I conclude that an almost flat plateau at a depth of 140 to 170 fathoms was at one time formed by the erosion and denudation of an original land mass or more probably series of masses.

We have now to examine the means by which the existing reefs have been built up on this plateau to the surface. Here I am on firmer ground. Of course, as already mentioned, certain parts may from the first have been higher and have served as foundations for lime-secreting organisms, but such elevations are not necessary for the foundations of our reefs. In the first place the observations of my expedition from upwards of 300 dredgings, largely made to settle this point, prove that the regular reef-building corals do not live below 30 fathoms in any such luxuriance as would be requisite if a reef were to be built up. Reef corals feed mainly or almost entirely by their commensal algae. Hence their limit in depth depends on the penetrability of sunlight through sea water, and this, judging from marine algae, must be about 150 fathoms in the tropics. In all probability, however, the light is not of sufficient intensity for any of these organisms to actually live below 75 fathoms, to upwards of which depth flourishing banks of *Lithothamnion* have been found in the East Indies.

The question in reality is not one presenting any real difficulty. Given an upstanding bank, on which the movement of mud and sand be not too great to choke the animal larvæ, we know from the examination of many such that it would soon be covered by animal life. Every part even of our immense bank at 150 fathoms would be thus overgrown, since a relatively strong current would be passing over it and thoroughly churning up and mixing the pelagic life on which the sedentary organisms so largely feed. This state could not, however, continue as the bank grew up towards the surface. The current over it would increase in proportion to its upward growth. Less and less food would tend to reach the organisms on its center, and channels due in the first place to lesser growth would tend to be formed, along which the currents would more particularly rush off, doubtless carrying with them a certain amount of material in suspension. The result at about 75 fathoms would be that we would have a great broad rim cut by channels of 100 or 120 fathoms, in other words a series of banks all round a plateau, reaching a depth of 75 fathoms from the surface of the ocean.

Up to 75 fathoms the chief organisms that formed our bank were those which approximate to the deep sea type in being essentially holozoic forms. Now, however, we are approaching the minimum depth to which experience shows us that these forms can survive, perhaps owing to physical causes, perhaps owing to competition. At any rate a fresh series of organisms comes into account, and gradually becomes more and more dominant, reaching its maximum at about 45 fathoms but continuing to exist on to 25 or 30 fathoms, at which depth in the tropics reef corals obtain full sway over all other sedentary forms of life. This medium depth group of organisms is a most varied one. It includes in the first place many corals such as *Goniopora*, *Alveopora*, *Dendrophyllia*, *Heliopora*, *Millepora* and many solitary *Madreporaria*. *Polytrema* is not unimportant from its consolidating (binding) growth. Sponges are few but molluscs of all sorts are very abundant. *Lithothamnion* is known to completely cover banks at 66 fathoms, and not improbably has had a considerable share in building them up to this height; various forms of *Halimeda* and similar algae no doubt also exist.

There is no upward limit to the growth of these medium depth forms. Most enter into competition with the actual organisms of the reef, but apparently few are able to compete with the reef corals. The larvae of the latter settle in some numbers at about 40 fathoms, and commence a struggle with the possessors of the ground for supremacy. The reef corals feed almost entirely by means of their commensal algae, and, as the depth decreases, the light becomes more powerful so that at about 25 fathoms they finally obtain the upper hand and only a few of the deeper organisms (notably *Millepora* and *Heliopora*) manage to maintain their position. Our bank, in effect, soon becomes crowned with a surface reef.

It is scarcely necessary to point out that the smaller a bank the greater the relative circumference it presents, and the more the water over it will be mixed together; and that the shallower the bank, irrespective of its size, the less will such admixture be. The smaller the bank the more will the current be divaricated on either side of it, and the less will its rate be increased. The larger the bank the more will the rate of the current around it be enhanced, and more water will consequently have to pass over it. The Maldive plateau is an extreme case both from its size, particularly its length, and from the fact of its being situated practically at right angles to the main currents of the Indian Ocean; viz., those of the monsoons. Even at 75 to 150 fathoms there would have been, I believe, a considerably lesser supply of food to its edges than to its center so that on the former more growth would have been seen, and gutters, having been formed as shown above, the foundations would have been laid for the present banks. Still more definitely would these conditions have become established as the banks grew up, and in the second phase of growth the separation of the banks would have been still more marked.

It follows from the above considerations that, as the banks approached the surface, there would naturally have tended to be a rim formed to each. Each again would have tended to split up into separate reefs in the same manner as the whole plateau had previously itself been severed into separate banks. The depth at which this cleavage took place is of some importance as bearing on the depths of the lagoons of the various banks as well as on the depths of the passages into these lagoons. It is not until the rim becomes moderately perfect that the atoll lagoon begins to be hollowed out by solution, and its depth in the first place would to a large extent depend on that of the original shoal before the rim became definitely determined. Now, as the depth at which the growth of the rim commenced would necessarily vary by decreasing with the reduction in size of the original bank, the lagoons of larger banks would from the start have had a greater depth than those of smaller. Tiladumati-Miladumadulu and Mahlos give the depth of 25–30 fathoms for large, linearly extended banks, but in Suvadiva, Kolumadulu and Haddumati, large, rounded and somewhat isolated banks, the depth would naturally be expected to be greater. Our present knowledge allows only a guess at the original depth and the amount which it has increased owing to various causes. In any case the Maldives clearly give a series from an immense atoll 50 fathoms deep on the one hand to open banks studded with isolated reefs; and on the other through atolls of various sizes to separate reefs of a mile or two across, not as yet of atoll form and rising directly from the common plateau. Lastly, even on an open bank it is obvions from the foregoing considerations that some parts of the rim might again be still further broken up and form atolls of a secondary order, a condition which seems to be clearly shown in Mahlos and the other northern banks.

Having shown how the banks may have, and, considering our evidence, probably have grown up, I pass to the consideration of the changes in progress and here I have a firmer basis of fact. First, it is obvious that change depends largely on the rate of growth of reef-corals. Estimates of all sorts had been made previous to my expedition, but none were founded on other than isolated growths. I was, however, fortunate enough to obtain forty coral colonies weighing 21,961 grams and measuring 13,026 cubic cms. from an area of four square yards, which had been *absolutely* cleared less than three years before. The area being considerably enclosed was by no means a rich one, and the corals had each to become affixed and to start from a larva, but against this the position was in shallow water where the full effect of sunlight would have been felt. According to one method of estimating I conclude that the growth of a reef would be upwards of 15 fathoms in 1,000 years, whilst according to another method, which assumes all conditions to be good, such as on the seaward side of a reef or on an open bank, it would be upwards of 25 fathoms. Whatever estimate may be correct, the facts show that the rate of growth of a reef is relatively rapid, and that, unless checked in some way, any coral-covered bank at a suitable depth would soon reach the surface.

The facts relating to the solution of carbonate of lime in sea water are well known and require no recapitulation. Generally, the bottom within the lagoons of the larger atolls and banks was covered between the surface and 10 fathoms with corals, between 10 and 20 fathoms with rubble, and between 20 and 25 fathoms with coarse sand passing to fine sand and finally mud at about 40 fathoms. Most of the lagoons are amply provided with passages through their rim reefs, the depths in which seem to bear some relation to the depths within the lagoons, and there is in all an ample circulation of water. Coral sand from the island shores or such as collects on the surface reefs in hollows, contains about ·03 per cent of silica, rock on the land which has suffered rain water denudation ·06 per cent, whilst mud from Suvadiva lagoon 40 to 50 fathoms has 2·4 per cent. The difference is remarkable. Fourteen thoroughly representative surface sands and rocks gave an average of ·047 per cent of silica, and muds from three different parts of Suvadiva lagoon all over 40 fathoms gave 2·441 per cent, or fifty times as much. Some of this enormous difference no doubt may be due to Radiolaria and sponge spicules collecting rather in the lagoon, but no explanation seems to me to be thoroughly adequate that does not consider solution as well.

Other important factors enter into and undoubtedly assist in the formation of the lagoons, or at the least prevent them from being filled up. Even within their areas an enormous bulk of carbonate of lime is laid down by the corals and other marine animals, but this at once, except in particularly favorable, i. e. quite open situations, is very rapidly acted upon by various organisms and reduced to the finest mud. In the first place boring algae of the genus *Achyla* penetrate the lime skeletons in every direction, extending almost up to touch their living tissues. They are soon followed by boring sponges, the ramifications of some of which are as fine as those of *Achyla* while the growths of others hollow out cavities of a square cm. or so in the skeletons. A way is paved by these for various Polychaeta, of which worms of the family Eunicidae are by far the most numerous both in numbers and species. Again, these are succeeded by sipunculids such as *Aspidosiphon*, *Phascolosoma*, etc., while numerous Crustacea and Polychaeta take up their abode in any holes. *Lithodomus*, *Lithotrya* and other forms complete the destruction, and the largest coral skeleton crumbles down into small fragments. But then a fresh class of organisms, which feed on such organic matter as coarse sand or small rubble may retain, comes into play and, while often keeping the coarser fragments in their guts for long periods of time, finally pass the whole out in the form of fine mud. Of this class of animal, by far the most important on account of their great abundance in every position, are the Holothurians. Sipunculids, various Echinids and *Thalassema* are often very numerous, while *Ptychodera* is abundant everywhere but only dwells where there is a considerable thickness of sand.

As already remarked, there is an ample circulation of water within the lagoons of most of the Maldive atolls and banks. The encircling reefs are seldom crowned for more than the half of their length by land, and the passages into the lagoons are generally deep. It is only in a few protected situations, where the depth is as great as 40 fathoms or more, that the lagoon bottom appears not to be churned up by the currents and waves. In heavy weather the lagoon water is almost milky, and floating surface nets are almost useless on account of the enormous amount of mud in suspension. The total amount of mud that passes out of the lagoon in the water is enormous, and must be of wide reaching importance. On the other hand the destructive effects outside the atolls within the same limits, i. e. down to 40 fathoms, are relatively small, and the vast quantity of coral mud, that covers 400,000 square miles of the Indian Ocean as compared with the 25,000 square miles occupied by the reefs and banks, is almost entirely formed by the fine material which is in this way carried out of the lagoons and off the coral banks. Solution is probably more constant than this action, but the two combined undoubtedly serve not only to prevent the lagoons from being filled up but also to enlarge them. Both to some degree increase as the atoll-form, i. e. the ring of reef round a bank, becomes more perfect. Neither action can proceed through the bodies of living organisms, and on an open bank the whole slope of any reef is often practically completely covered by fixed and living animal and plant life, so that both this action and solution are impossible. The movement of fine mud tends to choke and kill the organisms on the lower slope of any reef on a bank or within a lagoon. Since more mud is deposited as a bank becomes enclosed, sedentary life in this position must be seriously affected, and then the boring animals enter, weakening the coral masses so that they topple over, giving fresh openings for the entrance of a new series of boring forms. The effect is well seen in the practically perpendicular lagoon slopes of the reefs, that fringe or lie within the lagoons of the Maldive atolls, from three fathoms or so to within a few fathoms of the bottom.*

With this gradual but sure increase in the size of any lagoon it is necessary for the life of any atoll that its rim reefs should be growing outwards at least as rapidly as destruction is taking place inside. All conditions point clearly to this being the case. From the outer edge of an encircling reef-flat there is generally to seaward a gradual slope to 30–50 fathoms in 200–400 yards, succeeded by the steep already referred to. This slope is essentially the growing area, being covered almost completely by living organisms, great spreading and branching colonies of all kinds of corals, which are being bound together and fixed by *Lithothamnion*, *Polytrema* and many other kinds of encrusting organisms. At the edge great masses are constantly reaching the surface, and at the same time being bound by the same organisms on to the reef flat behind. Fissures remain for some time in the edge of the reef for the escape of the water, but these subsequently become bridged across, and finally built into the solid reef. At the same time the outwash of detritus, largely due to the under-currents, causes a raining down of coral masses and sand over the edge of the steep, carrying it out and allowing the extension of the whole outwards as a fairy ring.

The whole mode of growth sounds most simple, while in reality it is produced by a series of nicely correlated actions, which result in the atoll shape, undoubtedly the dominant and characteristic form of oceanic reefs. Should the encircling reef become too narrow, the conditions within it will become more open, and more of its lagoon will be covered by coral

* This perpendicular slope is not consistent with the possibility of the lagoons having been filled in by detritus washed over their encircling reefs.

growth. The effect will be absolutely opposite, if the outward growth of the atoll causes a considerable broadening of the rim. Much land on the encircling reef, by preventing the rush of tidal water into the lagoon, by protecting the lagoon from wind, etc., may prevent a free circulation of the water for solution and erosion, and so produce a stillness and calmness in its waters, eminently favorable for a vigorous growth of corals which may to a greater or less extent fill it up, a condition perhaps found in the lagoon of Addu atoll.

Lastly, land in the Maldives appears to have been formed by three means, (1) a small elevation, (2) the washing back and piling up of loose coral masses on a reef flat, and (3) the washing and blowing up of sand on a flat from the lagoon. Most of the islands on the rim reefs, which show any definite signs of their origin appear to have been formed in their earliest stage by the first means, but they have frequently been very greatly added to and increased in size by the last. At the present time the islands show in one place increase and in another loss, the latter on the whole predominating.

The various changes and modes of growth, as sketched above, may be seen in the different banks and atolls of the Maldive Group. The open banks show numerous small flat reefs, arising from 25–30 fathoms, and even complete little atolls studding their surfaces. A flat reef may become completely covered with land, or a small depression may appear in its center due to the impossibility of organisms growing in that position, to solution and the outwash of sand and mud. This may deepen, and, the whole meantime spreading, our bank may turn into a small atoll (atollon or *faro*), while other neighboring *faro* may perhaps have grown up as such. Our atollons will still go on broadening, and this will especially be the case with those towards the edges of the bank, since they will be bathed by the freshest water. As growth proceeds, the reefs of these atollons will meet and fuse with one another, forming a double rim to our bank, which, by this means, will be turned into an atoll (*vide* Suvadiva Atoll). Finally the inner parts of the same little atolls will be removed by solution and the action of the currents, so that their little lagoons will be thrown into the big central lagoon, and thus will be brought about the formation of our typical atoll. The distribution, the slopes and topography of these small faro and banks of the Maldives, and the distribution of sedentary and other life in the group are explicable on such a view alone, though there is not wanting evidence also from the comparison of the present condition of the banks with that shown in Moresby's charts of 1836. The latter evidence is in any case quite subsidiary and much of it of doubtful value on account of the small scale of the original charts and my lack of time, means and experience for a thorough survey. Yet, the fact that the great bulk of the evidence points in precisely the same direction lends considerable support to the views put forward above, which I have attempted to graphically represent in the annexed figure.

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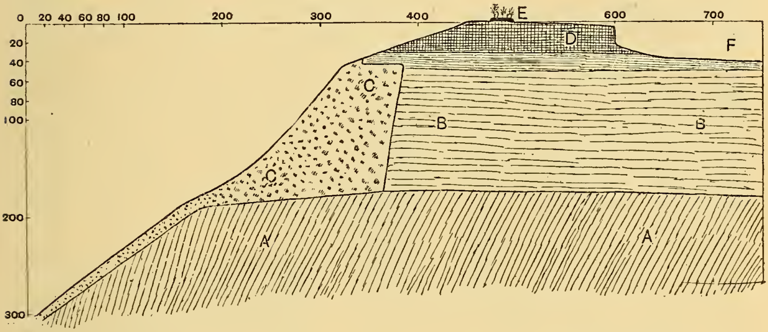

FIG. 1.—Diagram showing some points in the formation of the Maldives. The figure represents a supposed section through the rim of one of the atolls (scale in fathoms).

A. Basis of primitive rock, cut down by the action of the currents, etc.

B. Upgrowth of a shoal by means of deep-sea corals assisted by other organisms. The more densely shaded area between B and D shows the depth at which the deep corals cease to grow and the reef forms commence. The reef, however, in this part is mainly formed by the medium depth corals and other organisms.

C. Outward extension of the reef by means of detritus, swept off the reef above by the currents.

D. Surface reef, formed by corals, etc.

E. Land, formed by elevation or a piling up of sand and rubble on the reef.

F. Lagoon, formed partially by the more rapid growth of the organisms on the edge of the original bank, building up an encircling reef, and partially by the solution and erosion of the central parts.

In conclusion, it may be observed that the above remarks apply mainly to the Maldive Group, but it is not unlikely that many of the dominant conditions there will be found to be dominant all over the coral reef area of the Indo-Pacific region. I have done no more above than touch on a few of the newest, most important and general points relating to the subject. For a full and detailed account of the coral formations and biological conditions of the Maldives, I must refer to "The Fauna and Geography of the Maldive and Laccadive Groups" already cited.

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Art. XX.—*On the Heat of Combustion of Hydrogen;* by W. G. Mixter.

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

The constant for the heat of combustion of hydrogen is fundamental in thermal chemistry and its values found in the more recent investigations differ by nearly two per cent. While the results of Thomsen, Schüller and Wartha, and Than, agreeing closely, may be regarded as quite accurate, it appeared desirable to obtain additional data, and also to make a critical investigation of the bomb method of calorimetry now in general use. Andrews made good determinations of the heats of combustion of hydrogen and carbonic oxide with a copper bomb in 1848 but his method does not appear to have been used again until Berthellot perfected it.

The calorimeter, fig. 1, consists of the bomb B, the calorimeter vessel C, supported by the wooden ring W in the tin vessel A which is surrounded by the double-walled copper tank containing 20 liters of water. The water in the calorimeter is stirred by two small propellers. The bomb is fine silver except the stem of sterling silver. Its capacity was found by filling it with boiling water, allowing to cool, best in a tank of water in a room of constant temperature, and weighing with the usual precautions. Determinations were made at 4° and common temperature and the difference in volume observed accorded well with that calculated with the coefficient of expansion of silver. The internal volume of the bomb was found to diminish $0{\cdot}15^{cc}$ when the internal pressure was made 737^{mm} less than the external, and to recover its original volume when the internal pressure was restored. No correction was made for this change in volume in the exhausted bomb. After several explosions the capacity of the bomb was found to have increased $0{\cdot}25^{cc}$ by each explosion. An internal pressure of 16 atmospheres for 18 hours expanded it $0{\cdot}3^{cc}$ and the internal volume was then $1110{\cdot}56^{cc}$ at 18°. After lying unused eight months it was found to be $1110{\cdot}58^{cc}$. The capacity of the stem of the bomb is $0{\cdot}3^{cc}$. E is an insulated platinum electrode for sparking the gas. The calorimeter vessel C is german silver and is nickel plated on the outside. The water equivalent of it and the bomb was derived from the specific heats given in Landolt and Bernstein's Physikalish-Chemische Tabellen, using Naccari's numbers for copper at 17°, zinc at 18°, silver at 23°, and Regnault's for nickel between 14° and 97°.

		grams.	Specific heat.	Water equivalent. grams.
Vessel C	Copper	318·8	0·09245	29·5
	Nickel	95·7	0·1092	10·4
	Zinc	116·9	0·0915	10·7
		531·4		50·6
Silver bomb		1342·	0·05498	73·8
				124·4

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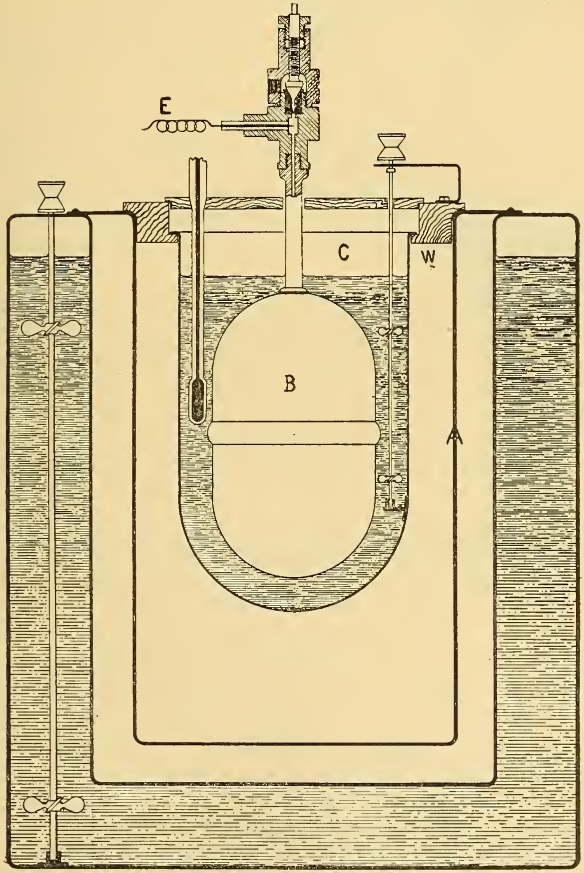

Two differential thermometers graduated to hundredths and numbered 1 and 172,683 respectively were used in the work. They were calibrated and compared with a standard thermometer graduated to tenths. This was also calibrated and its 0° and 100° points determined and the results agreed well with the certificate of the Reichsanstalt. The correction for No. 1 is +0·003° and for No. 172,683+0·038° for an interval of 5° on the scale of each.

By way of control comparisons were made with an air thermometer consisting of the silver bomb connected with a constant volume pressure gauge. As the air thermometer was in fact the calorimeter the differences in temperature observed with the mercurial thermometers were subject to the same source of error as the temperature observations of the calorimetric work. The following are the results:

	Interval.	Standard.	Air thermometer.
No. 1	5°	5·003°	5·004°
" 172,683	5°	5·038°	5·036°

The error in the value of 1·8°, the interval in the calorimetric work, probably does not exceed 0·001°. Thermometer No. 3, used for finding the temperature of the gas measured, is graduated to tenths. It was calibrated, and compared with the standard, and the 0° point was from time to time taken in ice.

The temperature interval of the calorimetric work was determined as follows: The temperature observed at the instant of an explosion was taken as the initial temperature. It was assumed during the first minute after an explosion that the gain and loss of heat from external causes were equal. To the maximum temperature observed was added the average fall noted subsequently for the number of minutes less one intervening between the explosion and the highest temperature. The errors due to the time required for the thermometers to come to an equilibrium with the water are small, since No. 1 changed the last 0·01° in 20 seconds and No. 172,683 in 30.

The barometer used was one made by Green. The scale is $0·7^{mm}$ less than 760^{mm} on the standard meter of the Physical Laboratory, and the correction for the meniscus is $0·72^{mm}$. Three sets of weights used in the investigation were tested and found to be sufficiently in accord for the purpose. The balance is an old 5^{k} one in an ordinary glass case. It indicates a difference of one milligram with a load of 2^{k} on each arm. During the third series of experiments it was enclosed in a large hood. The weighing of gas required much time, and proved to be sufficiently accurate for the purpose. The weight of the water used in the calorimeter was reduced to weight in vacuo.

The mass of one liter of hydrogen in the latitude of New Haven, 41·3°, is taken as 0·089844 gram and is derived from Morley's figure 0·089873 gram for latitude 45°. The mass of

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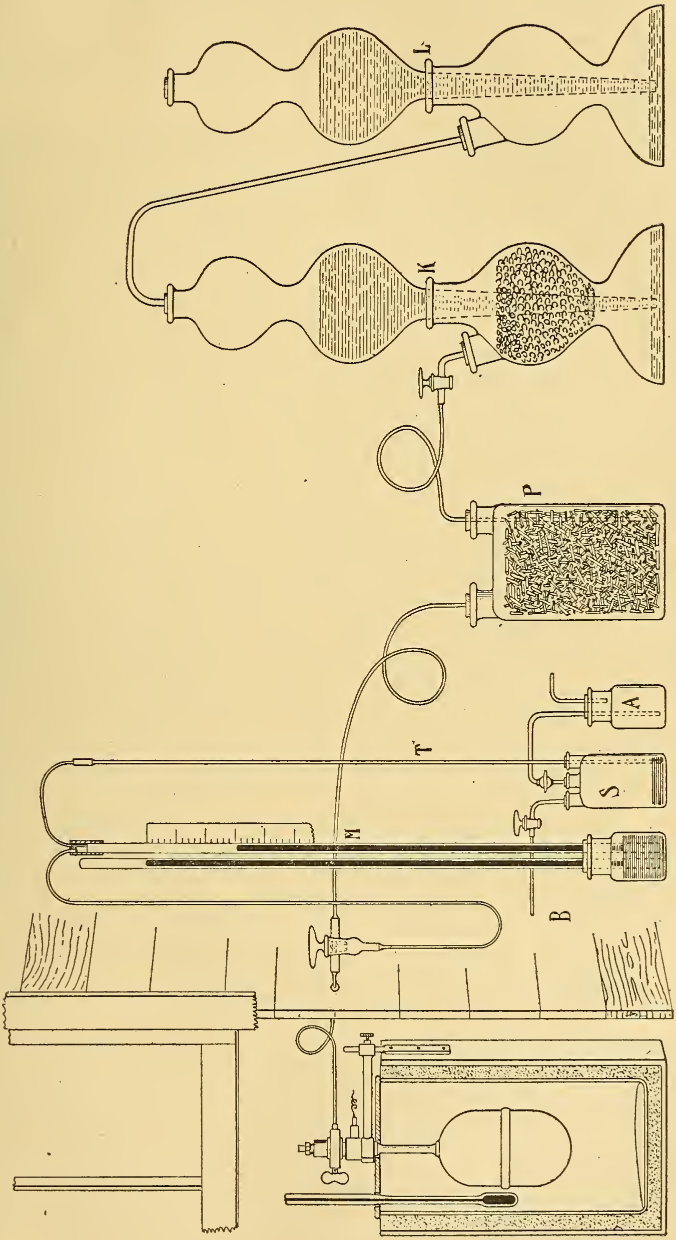


one liter of air is 1·293 gram in latitude 45° and in New Haven it is 1·2926 gram. No correction was made for the small elevation of the laboratory above the sea level. The coefficient of expansion of both hydrogen and air used in the calculations is 0·00366.

The apparatus employed in filling the bomb with hydrogen is shown in fig. 2, page 217. The generator K was charged with 250 grams of sheet aluminium and a solution of sodium hydroxide of density 1·1. Owing to the alkali held by the bulky sediment which formed on the metal the gas was evolved for hours and often for days after the stop cock was closed, thus expelling the air from K and L. The latter vessel contained water to keep air from contact with the solution in K. Each series of experiments was made with one charging of the generator. For the last series zinc was substituted for aluminium. The hydrogen was tested for arsenic by the Marsh method, though if present none was likely to escape the alkali; for carbon compounds by passing it over glowing copper oxide and then into lime water; and for ammonia by the Nessler test. None of these impurities was detected. The jar P contained 2½ kilos of potassium hydroxide, in sticks. Hydrogen or air after passing through this drying jar yielded to phosphorus pentoxide only 0·2 milligram of water per liter, an amount too small to affect the results. The method is well suited to drying rapidly large volumes of gas. The manometer M is a barometer and tube as shown. The apparatus was exhausted by means of large water-aspirator pump connected at B. To prevent moisture or air passing into the apparatus mercury was placed in S so that the end of T dipped into it. The bottle A with its tubes is for removing the mercury from S when necessary. The small brass tubing of the connections was tinned and varnished. The bomb was protected from changes of temperature by a glass jar packed in cotton wool in a wooden box, which stood in the hood with the balance.

The relative mass of the bomb was obtained as follows: It was repeatedly filled with air dried by potassium hydroxide and finally closed after noting the temperature and pressure. It was then counterpoised on the balance by a silver plated copper bomb of like shape and size. Next the air was exhausted to 15 or 20^{mm} pressure and the loss in weight noted. The bomb was next filled with hydrogen at a known temperature and low pressure and weighed again. The relative mass of the bomb in the first case is the mass of the counterpoise less the calculated mass of contained air. In the second and third instances it is less the weight required to counterpoise it again plus the calculated weights of the contained gases. The mean of the three results was taken as the mass of the bomb.

The bomb was then filled with hydrogen and exhausted to a pressure of 15 to 20^{mm} and the process was repeated a number of times. This method of filling the bomb was adopted with the idea that there was less danger of air leaking into the bomb than if the exhaustion was made more nearly complete by long pumping with a mercury pump. The close agreement between the calculated and observed weight of the hydrogen shows that the errors from impurity of the gas were negligible except in four experiments of the first series. The apparatus used in filling the bomb in this series was similar to the one described with the exception that some rubber tubing was used in the connections. After the final filling of the bomb with hydrogen the mercury was removed from S so that the gas in the bomb which was under more than atmospheric pressure might escape through the long small tubing until it attained the pressure of the atmosphere and without danger of air diffusing into the bomb. The temperature, pressure and weight of the gas were noted. The hydrogen was weighed in order to have evidence of its purity but the mass calculated from the volume was used in the calculation of a calorimetric result. The oxygen required was made from potassium chlorate, and was passed through a cylinder filled with sticks of potassium hydroxide and condensed in an iron flask containing solid potassium hydroxide. It was free from compounds of carbon and contained 2·7 per cent of nitrogen. With this amount of nitrogen present the quantity of nitric acid which was formed by an explosion was too small to be taken into account. The bomb was rinsed after an explosion with about 100^{cc} of water. The wash water was neutral to ordinary litmus paper, gave a slight turbidity on addition of hydrochloric acid, and contained only a milligram of silver. The oxygen was passed by means of a tube 2^{mm} in diameter into the bomb and the valve of the latter was closed when the gauge indicated rather more than half an atmosphere. There was, therefore, no danger of loss of hydrogen by diffusion. The quantity of oxygen in the bomb was also found by weighing.

To Dr. H. A. Bumstead of the Physical Laboratory the writer is indebted for the following method of reducing the results.

The general formula for reducing the heat of combination, found under the condition of constant volume, and between the temperatures t_1 and t, to that found at 0° and under constant pressure, is easily obtained by imagining the mixed gases to be carried through two different processes from the same initial state to the same final state, and equating the losses of energy in the two processes.

(1) Suppose m grams of the mixed gases, originally in the state p, v, t_1, is first cooled and expanded or compressed until its state is P, v_0, 0°; by Joule's law, the total loss of energy will be mC_vt_1 calories, where C_v is the specific heat at constant volume of the combined gases. Let the gases now combine at constant pressure, giving out Q calories, in the form of heat, and receiving $\frac{Pv_0}{J}$ calories, in the form of work done by the outside pressure (the final volume of the water being negligible in comparison with v_0). The total loss of energy by this process is thus

$$Q-\frac{Pv_0}{J}+mC_vt_1.$$

(2) In the second process, starting with the same conditions, let the mixture be burned at constant volume, v, the final temperature of the calorimeter being t; let the observed heat be Q′. If σ_t is the density of steam at t and p_t its pressure, the mass of uncondensed vapor will be $\sigma_t v$ (again neglecting the volume of the water); let this be compressed, at constant temperature, t, until all is condensed. The energy given to it in the form of work will be $\frac{p_t v}{J}$ calories, and the energy lost will be $\sigma_t v L_t$, where L_t is the latent heat of steam at the temperature t. Let the resulting water be then cooled from t to 0°, giving out mt calories. We now have water in the same final state as by the first process, so that the losses of energy in the two cases are equal.

Thus

$$Q-\frac{Pv_0}{J}+mC_vt_1=Q'+\sigma_t vL_t-\frac{p_t v}{J}+mt$$

or

$$Q=Q'+\sigma_t vL_t+\frac{Pv_0}{J}+mt-mC_vt_1-\frac{p_t v}{J}.$$

The product $\sigma_t L_t$ may be got most conveniently from the formula of Clapeyron which, when we neglect the volume of water in comparison with the volume of steam, becomes

$$\sigma_t L_t=\frac{1}{J}(273+t)\frac{dp}{dt},$$

$\frac{dp}{dt}$ being obtained from a table giving the pressure of steam at different temperatures.

If one gram of hydrogen is burned, and P is the standard pressure, 760^{mm} of mercury, at latitude 45°

$$\frac{Pv_0}{J}=\frac{76\cdot\times13\cdot6\times980\cdot6\times16680\cdot}{4\cdot181\times10^7}=404\cdot \text{ calories.}$$

$mC_v = 3{\cdot}6$, $m = 9$ grams and $\frac{p_t v}{J}$ is a small correction amounting to about 6· calories when t is 18°. Thus

$$Q = Q' + \sigma_t v L_t + 404 + 9\,t - 3{\cdot}6 t_1 - \frac{p_t v}{J}\,. \qquad (1)$$

If Q'' is the heat given out when m grams of the mixed gases are burned to liquid water between t_1 and t, at the constant pressure P, precisely similar reasoning shows that we have

$$Q = Q'' + mt - mC_p t_1 \qquad (2)$$

where C_p is the specific heat, at constant pressure, of the mixed gases.

First Series.

Experiment 1.—Hydrogen, 1107·6^{cc} at 17·6° and 767·4^{mm}; calculated weight 0·0944, observed 0·0945 gram. Water and water equivalent of calorimeter 1761·2 grams.

Minutes.	Temperature.	Temperature interval.	
0	15·73	17·498 − 15·73 + 0·005 = 1·773°	
1	15·73		
2	15·73	Observed heat, 1761·2 × 1·773 =	3122·6^c
3	17·50	Correction to calorie at 20°	2·2^c
4	17·498		———
5	17·495		3124·8^c
6	17·488		
7	17·485		
8	17·477		

Substituting numerical values in equation 1 we have

$$Q' = \frac{3124{\cdot}8}{0{\cdot}0944} = 33102$$
$$\sigma_t v L_t = 102$$
$$\frac{Pv_0}{J} = 404$$
$$9t = 157$$
$$-3{\cdot}6 t_1 = -\ 57$$
$$-\frac{p_t v}{J} = -\ 6$$
$$Q = 33702^c$$

Experiment 2.—Gas, 1108^{cc} at 18·3° and 756·8^{mm}, weighing 0·0965 gram; weight of like volume of hydrogen 0·09289 gram. Calculated amount of hydrogen present 0·09266 gram. Water and water equivalent of calorimeter 1720·4 grams.

Minutes.	Temperature.	Temperature interval.
0	15·074	17·903 − 15·082 + 0·002 = 1·823°
1	15·078	
2	15·082	Observed heat, 1720·4 × 1·823 = 3136·3^c
3	17·883	Correction to calorie at 20° 2·3^c
4	17·903	———
5	17·901	3138·6^c
6	17·899	From these data we have for the value
7	17·897	of Q = 34483^c.

Experiment 3.—Gas, 1108·3^cc at 17·9° and 773·2^mm, weighing 0·1004 gram; weight of like volume of hydrogen 0·09507 gram. Calculated amount of hydrogen present 0·09469 gram. Water and water equivalent of calorimeter 1765·4 grams.

Minutes.	Temperature.	Temperature interval.
0	16·631	18·454 − 16·643 = 1·811°
1	16·637	
2	16·643	Observed heat, 1765·4 × 1·811 = 3197·3^c
3	18·454	Correction to calorie at 20° 1·6^c
4	18·454	———
5	18·454	3198·9^c
6	18·456	Q = 34395^c

Experiment 4.—Gas, 1108·6^cc at 18·5° and 751·3^mm, weighing 0·095 gram; weight of like volume of hydrogen 0·09221 gram. Calculated amount of hydrogen present 0·09202 gram. Water and water equivalent of calorimeter 1733·3 grams.

Minutes.	Temperature.	Temperature interval.
0	17·109	18·896 − 17·115 + 0·004 = 1·785°
1	17·112	
2	17·115	
3	18·896	Observed heat, 1733·3 × 1·785 = 3093·9^c
4	18·896	Correction to calorie at 20° 1·2^c
5	18·892	———
6	18·889	3095·1^c
7	18·884	Q = 34254^c

Experiment 5.—Hydrogen, 1108·8^cc at 19·3° and 767·8^mm; calculated weight 0·09399, observed 0·095 gram. Water and water equivalent of calorimeter 1716 grams.

Minutes.	Temperature.	Temperature interval.
0	16·427	18·244 − 16·429 + 0·005 = 1·820°
1	16·428	
2	16·429	
3	18·244	Observed heat, 1716 × 1·82 = 3123·1^c
4	18·244	Correction to calorie at 20° 1·5^c
5	18·234	———
6	18·234	3124·6^c
7	18·225	Q = 33854^c
8	18·225	
9	18·217	

Experiment 6.—Gas, 1109^{cc} at 16·2° and 768·4^{mm}, weighing 0·098 gram; weight of like volume of hydrogen 0·09511 gram. Calculated amount of hydrogen present 0·09489 gram. Water and water equivalent of calorimeter 1706·2 gram.

Minutes.	Temperature.	Temperature interval.	
0	15·330	17·180 − 15·332 + 0·005 = 1·853°	
1	15·331		
2	15·332	Observed heat, 1706·2 × 1·853 =	3161·6^c
3	17·166	Correction to calorie at 20°	2·5^c
4	17·180		———
5	17·174		3164·1^c
6	17·170	Q = 33942^c	
7	17·163		
8	17·157		

Experiment 7.—Hydrogen, 1109·3^{cc} at 21·5° and 761·1^{mm}; calculated weight 0·09251, observed 0·089 gram. (There was evidently an error in weighing the hydrogen.) Water and water equivalent of calorimeter 1728·8 grams.

Minutes.	Temperature.	Temperature interval.	
0	17·201	18·967 − 17·203 + 0·007 = 1·771°	
1	17·202		
2	17·203	Observed heat, 1728·8 × 1·771 =	3061·8^c
3	18·967	Correction for calorie at 20°	1·2^c
4	18·967		———
5	18·959		3063·0^c
6	18·952	Q = 33727^c	
7	18·945		
8	18·937		

Second Series.

Experiment 8.—Hydrogen, 1109·3^{cc} at 17·05 and 752·9^{mm}; calculated weight 0·09294, observed 0·0933 gram. Water and water equivalent of calorimeter 1688·8 grams.

Minutes.	Temperature.	Temperature interval.	
0	15·291	17·129 − 15·301 + 0·005 = 1·833°	
1	15·296		
2	15·301	Observed heat, 1688·8 × 1·833 =	3095·5^c
3	17·113	Correction to calorie at 20°	2·5^c
4	17·127		———
5	17·129		3098·0^c
6	17·126	Q = 33932	
7	17·123		
8	17·121		
9	17·119		

Experiment 9.—Hydrogen 1109·5^{cc} at 15·9° and 770^{mm}; calculated weight 0·09544, observed 0·0953 gram. Water and water equivalent of calorimeter 1710·4 grams.

Minutes.	Temperature.	Temperature interval.	
0	15·071	16·940 − 15·081 + 0·004 = 1·863°	
1	15·076		
2	15·081	Heat observed, 1710·4 × 1·863 =	3186·5^{c}
3	16·903	Correction to calorie at 20°	2·5^{c}
4	16·939		
5	16·940		3189·0^{c}
6	16·938	Q = 34008^{c}	
7	16·936		
8	16·935		
9	16·933		

Experiment 10.—Hydrogen, 1109·8^{cc} at 15·6° and 755·4^{mm}; calculated weight 0·09376, observed 0·0933 gram. Water and water equivalent of calorimeter 1765·7 grams.

Minutes.	Temperature.	Temperature interval.	
0	15·044	16·814 − 15·048 + 0·003 = 1·769°	
1	15·046		
2	15·048	Heat observed, 1765·7 × 1·769 =	3123·6^{c}
3	16·813	Correction to calorie at 20°	2·5^{c}
4	16·814		
5	16·812		3126·1^{c}
6	16·808	Q = 33934^{c}	
7	16·805		
8	16·802		

Experiment 11.—Hydrogen 1110·2^{cc} at 18·4^{cc} and 767·1^{mm}; calculated weight 0·09432, observed 0·0947 gram. Water and water equivalent of calorimeter, 1711·9 grams.

Minutes.	Temperature.	Temperature interval.	
0	16·049	17·904 − 16·067 + 0·004 = 1·841°	
1	16·054		
2	16·062	Heat observed, 1711·9 × 1·841 =	3151·6^{c}
3	16·067	Correction to calorie at 20°	1·9^{c}
4	17·874		
5	17·904		3153·5^{c}
6	17·904	Q = 34039^{c}	
7	17·902		
8	17·900		
9	17·898		

Third Series.

Experiment 12.—Hydrogen, 1110·6^{cc} at 17·3° and 761^{mm}; calculated weight 0·09395, observed 0·0934 gram. Water and water equivalent of calorimeter, 1633·3 grams.

Minutes.	Temperature.	Temperature interval.
0	16·140	18·050 − 16·142 + 0·014 = 1·922°
1	16·141	
2	16·142	Heat observed, 1633·3 × 1·922 = 3139·2^c
4	18·049	Correction to calorie at 20° 1·9^c
5	18·050	
6	18·043	Q = 34041^c 3141·1^c
7	18·036	
8	18·029	

Experiment 13.—Hydrogen, 1110·7^cc at 15·9° and 767·25^mm; calculated weight 0·09519, observed 0·0953 gram. Water and water equivalent of calorimeter, 1683·3 grams.

Minutes.	Temperature.	Temperature interval.
0	15·771	17·656 − 15·78 + 0·008 = 1·884°
1	15·776	
2	15·780	Heat observed, 1683·3 × 1·884 = 3171·3^c
4	17·616	Correction to calorie at 20° 2·6^c
5	17·656	
6	17·656	3173·9^c
7	17·653	Q = 33945^c
8	17·651	
9	17·648	
10	17·645	

Experiment 14.—Hydrogen, 1111·1^cc at 20·1° and 754·15^mm; calculated weight 0·09227, observed 0·0924 gram. Water and water equivalent of calorimeter, 1731·2 grams.

Minutes.	Temperature.	Temperature interval.
0	16·410	18·209 − 16·423 = 1·786°
1	16·416	
2	16·423	Heat observed, 1731·2 × 1·786 = 3091·9^c
4	18·204	Correction to calorie at 20° 1·5^c
5	18·209	
6	18·209	3093·4^c
1	18·209	Q = 34136^c

The following table contains the result of every thermal experiment made with hydrogen:

	First series. Thermometer No. 1.		Second series. Thermometer No. 1.		Third series. Thermometer No. 172,863.
No. of exp.	Calories.	No. of exp.	Calories.	No. of exp.	Calories.
1	33702	8	33932	12	34041
2	34483	9	34008	13	33945
3	34395	10	33934	15	34136
4	34254	11	34039		
5	33854				
6	33942				
7	33727				
Mean	34051		33978		34041
Probable error	± 80		± 18		± 38

Weighting these means inversely as the squares of their probable errors, we have for the mean of the three series 33993±16 calories for the heat of combustion of one gram of hydrogen at constant pressure and formation of liquid water at 0°, and in terms of the calorie at 20°.

It may be stated that the aim has been to present an outline of the work sufficient to show the character of it, omitting a vast amount of detail. Every precaution was taken to ensure accuracy and much time was spent in testing the thermometers and in finding the most favorable room temperature for the work. The investigation was the more laborious because a room of fairly constant temperature was not available, and it was often necessary to wait for hours or a day for the conditions requisite for thermometric and barometric observations.

Results of other Investigators.

In the following table the results of different investigators are given in chronological order and for constant pressure. Andrew's published result of 33808[c] at constant volume is increased 438[c] for constant pressure. Likewise Than's observed heat of 33822[c] at constant volume is 404[c] greater for constant pressure.

Calories.						Temperature.
34473	Dulong.	Heat of formation of 9 grams of water.				
34792	Hess.	"	"	"	"	
34666	Grassi.	"	"	"	"	
34246	Andrews.*	"	combustion 1	"	hydrogen	20°—22°
34462	Favre and Silbermann.†	"	formation of 9	"	water	6°—12°
34178	Thomsen.‡	"	" 9	"	"	16°—20°
34126	Schüller and Wartha.§	"	" 8·98	"	"	0°
34226	Than.‖	"	" 8·98	"	"	0°
34495	Berthellot.¶	"	combustion of 1	"	hydrogen	9°—10°

Calculating the heat of combustion of one gram of hydrogen from the heat of formation of the stated amounts of water on the basis of the accepted ratios of 2·016 to 16 of hydrogen to oxygen in water, we have

* Phil. Mag. [3], xxxii, 321, 1848.
† Ann. Chem. et Phys. [3], xxxiv, 349, 1852.
‡ Thermochemischen Untersuchungen, ii, 52.
§ Ann. Phys. u. Chem. N. F., ii, 371, 1877.
‖ Ann. Phys. u. Chem. N. F., xiv, 393, 1881.
¶ Ann. Chem. et Phys. [6], xxx, 553, 1893.

Calories.		Calories.	
34498 D.		33937 Thom.	16° to 20°
34547 H.		33961 S. & W.	0°
34414 G.			
34246 A.	20° to 22°	34061 Than	0°
34219 F. & S.	6° to 12°	34495 B.	9° to 10°

The most recent investigation of the specific heat of water is that of Callendar and Barnes.* They regard the specific heat at 20° as unity, and 1·0010 at 15°, 1·0022 at 10° and 10037 at 5° and the mean between 0° and 100° as 1·0014. These data are used in reducing the calorimetric results to the water calorie at 20°. Adding 14 to Thomsen's figures for reduction to the calorie at 20° gives 33951. Allowing for the correction he made for the interval between 18° and 20° and reducing by formula 2, p. 221, $Q = Q'' + mt - mCpt_1$ in which Q'' is 33951 and t_1 is 16° and t 18° we have Q = 34031. Schüller and Wartha calibrated their ice calorimeter in terms of the mean specific heat of water between 0° and 100°. Their figures are, therefore, multiplied by 1·0014. Than calibrated his ice calorimeter with silver and lead, using Regnault's specific heats of these metals and also with water. His calibration is possibly high. Omitting the figures of Dulong, Hess, Grassi and Berthellot, which are obviously high, the results in the preceding table reduced give the figures in the next table for the heat of combustion of one gram of hydrogen at constant pressure and formation of liquid water at 0° and in terms of the calorie at 20°. The writer's result, p. 226, is included.

Andrews	34336	calories.
Favre and Silbermann	34378	"
Thomsen	34031	"
Schüller and Wartha	34009	"
Than	34061	"
Mixter	33993	"

The first two are evidently high and should not be included in the final value. Thomsen's value is the result of seven experiments in which a total of 18 grams of water were formed by burning hydrogen at constant pressure. Schüller and Wartha's value is the mean of five closely accordant experiments and in each one about 1·3 gram of water was produced. They burned electrolytic gases in a Bunsen ice calorimeter, weighed the water formed and measured the heat, not with the aid of a thermometer, but by the specific heat of water, Than's value is the mean of the result of four experiments in

* The Electrician, xliii, 775, 1899.

which he exploded electrolytic gases in a Bunsen calorimeter. His method is good but perhaps more liable to error because of the small volume of gas taken, than the methods of Thomsen and S. and W. The writer used the bomb method.

The mean of the last four results in the table is 34023c. If Thomsen's and S. and W.'s be weighted twice the last two, the result is essentially the same, namely 34022c. It is highly probable that this value is accurate in the third figure and that the total error is not more than one-tenth of one per cent. It is the mean of closely agreeing results of different investigators who used four different methods not subject to the same constant error, excepting that of the specific heat of water at different temperatures, and this error is small. This value, 34020 calories, is the heat of combustion of one gram of hydrogen at constant pressure with formation of liquid water at 0° and in terms of the calorie at 20°. For a gram-molecule it is

	H=1.	H=1·008.
At 0°	68040c	68580c
" 18°	67900c	68440c

In conclusion the writer desires to express his indebtedness to Professors Hastings and Bumstead for their valuable suggestions and assistance.

ART. XXI.—*The Determination of Uranium and Uranyl Phosphate by the Zinc Reductor;* by O. S. PULMAN, JR.

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

E. F. KERN* has recently proposed a method for determining uranium in which the uranyl salt is reduced to the uranous condition by allowing a warm solution of uranyl sulphate to pass through a long Jones reductor, made by putting in the bottom of a 50^{cm^3} burette, a layer of broken glass an inch thick, and then placing on this an 18-inch column of 20-mesh amalgamated zinc. The sulphate solution, in volume from 100 to 150^{cm^3}, and containing free sulphuric acid (1·84) between the ratios of 1 to 6 and 1 to 5 to the total solution, was poured through the reductor and caught in a large Erlenmeyer flask, the titration flask, which was closed by a small funnel and contained about a gram of dry sodium carbonate. According to Kern, the solution, which was quite acid, upon coming in contact with the dry sodium carbonate liberated carbon dioxide, which filled the flask and prevented the oxidation of the uranous solutions. After all the solution had been emptied into the reductor it was followed by about 250^{cm^3} of distilled water. The solution was then diluted to 500^{cm^3} and titrated with a "0·01 normal potassium permanganate solution," containing 3·16 grams of the salt per liter, to a faint red end-reaction.

The time required for 100^{cm^3} of uranyl solution and 250^{cm^3} of water to pass through the reductor was about ten minutes; for 150^{cm^3} of uranyl solution and 250^{cm^3} of water, about twenty minutes.

From his experiments Kern concluded that the reduction went exactly to the uranous stage of oxidation, the reduction being in all cases complete and proceeding no further when the solutions were twice passed through the column of zinc than when passed through once. The results obtained were concordant with those obtained gravimetrically. In making some tests of this process my experience has been somewhat different from that of Kern.

For carrying out the tests an uranium solution containing about six grams of uranic oxide per liter was made from uranyl nitrate which had been purified according to the directions of Richards and Merigold.† Twenty-five cubic centimeters of nitric acid were added per liter to keep basic salts from separating out. It was standardized in the usual gravimetric way by precipitating the uranium by ammonia and weighing it as U_3O_8.

* Jour. Am. Chem. Soc., xxiii, 716.

† Proc. Am. Acad., vol. xxxvii, No. 14, p. 385.

The potassium permanganate solution, approximately $\frac{n}{10}$ (containing about 3·16 grams of the crystals to the liter), was standardized against an exactly $\frac{n}{10}$ arsenite solution by allowing a measured amount of the permanganate to act upon an acidified solution of potassium iodide (containing enough of the salt to hold the iodine set free in solution), the iodine thus set free being taken up by adding an excess of the arsenite and neutralizing with acid potassium carbonate, the excess of the arsenite then being titrated by standard iodine, with starch as an indicator. The total amount of arsenite employed, less the excess which is indicated by the iodine, corresponds to the amount of permanganate taken.

For each experiment a measured amount of the standard uranyl nitrate solution was converted into the sulphate by evaporating it with 10^{cm^3} of sulphuric acid (1·84) in a 300^{cm^3} flask, placed in a slanting position on an iron radiator to prevent any loss by spattering, until dense white fumes were formed. The liquid was then cooled, and water and more sulphuric acid were added in sufficient amount to make the volume of the solution up to that desired (generally from 100 to 150^{cm^3}), and the proportion of the free sulphuric acid to the total volume to between the ratios of 1 to 5 and 1 to 7. Before passing the solution through the reductor, a small amount of warm acid was sent through, and, in order that the proportion of the acid in the uranium solution might not be changed by the liquid thus left in the reductor, care was taken to have the dilute acid of the same strength of acidity as in the uranium solution. The warm acid was followed by the uranium solution, and this was washed through by a little of the acid and by 250^{cm^3} of hot water. The solution was collected in the flask, diluted, and titrated with potassium permanganate. This was the general procedure in preparing and treating the uranium solution.

It was found that it required about an hour, instead of ten minutes, as Kern said, for 100^{cm^3} of a solution, containing sulphuric acid even in the ratio of 1 to 7, and 250^{cm^3} of water to pass through a reductor prepared exactly according to Kern's directions. The apparatus, therefore, was arranged so that suction could be applied, but with suction the carbon dioxide generated by a gram of sodium carbonate would be very quickly exhausted. In view of this fact, it was thought best to connect the apparatus with a carbon dioxide generator, to pass a current of gas through the apparatus before starting the operation, and then after the operation to fill up the partial vacuum formed by the suction with carbon dioxide before disconnecting the receiving flask and titrating the solution with permanganate. For this purpose there was joined to the stopcock of the burette by a rubber connector a straight glass tube running down through a three-hole stopper into a receiving flask of about a liter capacity. Through the other two holes of the stopper passed pieces of glass tubing bent at right angles, of which one served for introducing the carbon dioxide and the other for applying the suction.* A layer of glass wool about 5^{mm} in thickness was placed between the broken glass in the bottom of the burette and the column of zinc so that any particles of zinc might not be drawn into the receiving flask by the suction. The results were constantly very high when operating in this manner.

Zimmermann† found that uranous salts are fairly stable in the air, an exposure of the dilute solution in a porcelain dish for two hours making a difference of only two milligrams and a half on 0·1568 grams UO_3, and also that the same results were obtained whether he poured his reduced solution into a porcelain dish, diluted it with water, and titrated it with permanganate, or poured the reduced solution into a porcelain dish containing an excess of permanganate diluted and acidified with sulphuric acid, then destroyed the excess of permanganate by a slight excess of ferrous sulphate, and finally took the end-point with permanganate.

Since Zimmermann did not find it necessary to keep his reduced solution of uranium from exposure to the air, the idea occurred that possibly the presence of carbon dioxide, as suggested by Kern, might be unnecessary. Some experiments were therefore tried in which the solution was passed through the reductor, caught in a flask in which no carbon dioxide was present, and after dilution was titrated directly in the receiving flask with the permanganate. Even this procedure gave positive errors, although not so great as when the carbon dioxide was present, thus seeming, together with the experiments with the carbon dioxide, to point to the fact that the uranyl salts were actually reduced below the uranous state by zinc and sulphuric acid, and that they tended to oxidize back again when exposed to the air.

It was thought that if the contents of the flask after passing the reductor were poured through the air into a porcelain dish, any over-reduction might be corrected, and the uranium thus brought exactly to the uranous stage. In each of a set of experiments performed in this manner it was found that the results were sharp and concordant, and the presumption that the uranium salt is actually reduced below the uranous stage by

* Compare figure p. 234.

† Ann. Chem. (Liebig), ccxiii, 303.

the action of the reductor, and reoxidized on exposure to the air seems to be justified.

The details of the procedure were as follows: The uranium sulphate solution, obtained from the standard solution of uranium nitrate by evaporating with 10^{cm^3} of strong sulphuric acid, as previously described, ranging in volume from 100 to 150^{cm^3}, and containing a proportion of free sulphuric acid varying between the limits of 1 to 7 and 1 to 5, was heated nearly to the boiling point, and, preceded by a few cubic centimeters of the same strength of acid, was passed slowly through the reductor, using gentle suction. The flask which had contained the solution was washed thoroughly with sulphuric acid of the same strength as was in the solution. This was added to the reductor after the uranium and was followed by 250^{cm^3} of hot water. The contents of the receiving flask were poured into a porcelain dish, diluted with about 200^{cm^3} of hot water, and titrated with a $\frac{n}{10}$ potassium permanganate solution to a faint pink end-reaction.

In most of the determinations the proportion of the free sulphuric acid in the solution was kept nearly at 1 to 6, since this was found to be the most satisfactory, although the determinations in which the ratio was between the limits of 1 to 5 and 1 to 7 gave accurate results. When the ratio was at 1 to 5 or greater, however, the acid attacked the zinc so rapidly that there was too great an evolution of hydrogen for convenience, so much so that if for any reason the operation had to be interrupted the rapidity of the evolution caused the solution to rise in the tube and to be in danger of flowing over the top of the reductor. The ratio of 1 to 7 required more time than that of 1 to 6. With acid in the ratio of 1 to 6, it was found that amounts of uranium sulphate equivalent to 0.2 gram of uranic oxide were not reduced completely in eight to ten minutes, so that for this amount about fifteen minutes or more should be taken for passing the uranium solution and water through the reductor. For 0.3 gram of uranic oxide it was found that eighteen to twenty minutes were not sufficient for complete reduction, so that half an hour or more was allowed for reducing and washing with this amount. With the stronger acid, in the ratio of 1 to 5, it was found that the uranium could be reduced in about two-thirds of the time required by the acid in the ratio of 1 to 6, but the use of the weaker acid was preferred on account of the rapid evolution of hydrogen and the consequent danger of loss connected with using the stronger acid, as above mentioned.

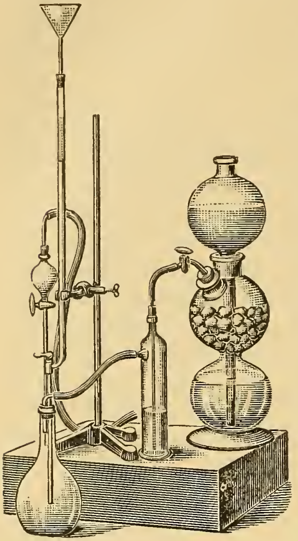
In using the reductor for estimating the molybdic acid in ammonium phospho-molybdate, Blair states that the solution should always be kept above the level of the zinc, so that no air will pass into the reductor. This precaution was carefully observed, for, by the action of nascent hydrogen, hydrogen peroxide might be formed, and this would cause high results in the process.

The contents of the receiving flask after the operation were of an olive-green color, but upon exposure to the air by pouring into a porcelain dish the color changed immediately to the sea-green color always possessed by uranous salts, and this change of color is of itself evidence of oxidation. In the titration of the hot solution of uranous sulphate with permanganate the solution gradually became more and more of a yellowish green color as it approached the highest condition of oxidation. With small amounts of uranium the addition of a single drop of permanganate in excess caused the whole solution to change to a very faint pink color, but with larger amounts the solution became a yellowish pink upon adding the excess of permanganate, and the end-point was harder to read.

The results obtained are shown in the table:

Uranyl sulphate taken, in terms of UO_3. grm.	H_2SO_4 (1·84). cm^3.	Dilution at time of reduction. cm^3.	Time, minutes.	$KMnO_4$. cm^3.	$KMnO_4$. grm. UO_3.	Error in terms of UO_3. grm.
0·1336	18	117	15	9·32	0·1334	−0·0002
0·1337	20	120	15	9·37	0·1341	+0·0004
0·1336	25	125	17	9·40	0·1345	+0·0009
0·2005	18	117	20	14·02	0·2006	+0·0001
0·2003	25	125	17	14·01	0·2005	+0·0002
0·2671	23	150	20	18·67	0·2671	±0·0000
0·2673	20	140	18	18·65	0·2669	−0·0004
0·1001	25	125	22	7·06	0·1010	+0·0009
0·1002	20	140	17	7·02	0·1004	+0·0002
0·1002	20	140	14	7·01	0·1003	+0·0001
0·0668	18	117	17	4·70	0·0673	+0·0005
0·0994	20	100	16	6·96	0·0995	+0·0001
0·1988	20	120	18	13·90	0·1988	±0·0000
0·1988	25	150	18	13·88	0·1985	−0·0003
0·3314	25	150	27	23·14	0·3309	−0·0005
0·3314	30	150	36	23·19	0·3316	+0·0002
0·3314	25	145	33	23·17	0·3313	−0·0001

Since the uranium, by contact with the air, is oxidized exactly to the stage of oxidation represented by UO_2, and since in a few preliminary experiments carried out in the presence of carbon dioxide it apparently remained reduced below that stage, it appeared that it might be interesting to investigate that point a little more fully. The apparatus that was used is shown in the accompanying figure.



The same form of apparatus was used in the preliminary experiments just mentioned, except that in the place of the stoppered funnel there was a piece of glass tubing bent at right angles. In the process finally worked out for the determination of the uranium a two-hole stopper was used, instead of the one having three holes, of which one served for carrying the inlet tube connected with the stopcock of the burette and the other for carrying a bent glass tube, by which the suction was applied.

In the experiments carried out with this form of the apparatus carbon dioxide was passed through the receiving flask until, by testing the escaping current with a solution of sodium hydroxide, it was proved that only carbon dioxide was present. The uranium sulphate solution was then passed through the reductor with gentle suction, just as when no carbon dioxide was used, and was followed by the dilute sulphuric acid used to wash out the flask, 250^{cm^3} of hot water, and finally by 200^{cm^3} of water at the ordinary temperature of the room, to cool down the solution somewhat and to bring up the volume to the dilution at which it was ordinarily titrated. A strong current of carbon dioxide was then turned on until the partial vacuum caused by the suction had been entirely filled, and, by testing again, it was found that carbon dioxide entirely filled the flask. An excess of a $\frac{n}{10}$ potassium permanganate solution was next introduced into the receiving flask by means of the stoppered funnel without admitting any air. After the flask had been gently shaken so that the permanganate was diffused through the liquid, the apparatus was disconnected from the reductor and the excess of permanganate destroyed by a small excess of a $\frac{n}{10}$ solution of ammonium oxalate. The solution was still so warm that it was possible to tell fairly well when an excess of the ammonium oxalate had been added. The mixture was then heated to about 60° and the final end-point taken with a $\frac{n}{10}$ potassium permanganate solution.

The following results were obtained:

Uranyl sulphate taken, in terms of UO_3. grm.	H_2SO_4 (1·84). cm³.	Dilution at time of reduction. cm³.	Time, minutes.	$KMnO_4$ used after deducting cm³. of oxalate. cm³.	grm. UO_3.	Amount of UO_3 more than theory. grm.
0·1336	20	120	13	10·41	0·1490	+0·0154
0·1337	20	120	17	10·54	0·1508	+0·0171
0·2004	20	120	15	15·71	0·2247	+0·0243
0·2003	25	125	19	15·68	0·2242	+0·0239
0·1002	20	120	18	7·56	0·1081	+0·0079
0·0668	18	90	18	5·12	0·0732	+0·0064
0·2658	25	125	16	20·60	0·2946	+0·0288
0·2672	20	120	15	21·11	0·3019	+0·0347
0·1002	18	90	15	8·01	0·1145	+0·0143

In order to be certain that the cause for this apparent over-reduction was not partially due to the setting free of oxygen during the interaction of the permanganate and the oxalic acid in the strongly acid solution of sulphuric acid, it was decided to investigate the point. In an article from this laboratory,* it is shown that in the presence of 20 per cent of sulphuric acid (1:1) there is no appreciable loss of the permanganate at the ordinary temperature under an exposure of a few hours only. The results, however, were obtained with small volumes and at the ordinary room temperature, while in the uranium process there was a much larger volume at a temperature of from 30° to 40° when the permanganate and oxalic acid were added. Some blanks, therefore, were carried out as follows: Approximately 550^{cm^3} of distilled water were placed in a flask, 25^{cm^3} of strong sulphuric acid added, the mixture heated to about 40°, and 19^{cm^3} of a $\frac{n}{10}$ solution of permanganate run in. A slight excess of a $\frac{n}{10}$ ammonium oxalate solution was then added, the mixture warmed to about 60°, and the final end-point taken with permanganate. It was found that there was no loss of the permanganate, the same results being given in this way as when the ammonium oxalate was diluted to 600^{cm^3} and after adding 25^{cm^3} of sulphuric acid was heated to 60° and titrated directly with permanganate.

Since there was no loss between the permanganate and the oxalic acid (and there is no other apparent cause for error), the

* Danner and Gooch, this Journal, vol. xliv (1892), 304.

natural inference to be drawn is, that when an uranium sulphate solution is reduced with zinc and sulphuric acid out of contact with the air, a compound of uranium lower than that corresponding to the uranous condition may be formed. Zimmermann* opposed this view, but his mode of operation would give this very unstable body the chance to be oxidized back to the uranous condition before coming in contact with the permanganate. His method was to pour through the air his reduced solution into an excess of permanganate previously diluted and acidulated, then to destroy this excess by a slight excess of ferrous sulphate, and to titrate the excess of ferrous sulphate with more permanganate. Zimmermann, furthermore, in reducing his solution in a small flask, with a comparatively small amount of zinc, did not give the uranyl salt as great a chance to be reduced below the uranous stage as is given by the greater exposure of zinc surface when the solution passes through the reductor. As has been shown in the table, the results do not run together constantly for the same amounts of uranium used, and it appears that the amount of lower oxide formed depends upon the manner of action upon the zinc, and that it is so unstable that the least trace of oxygen may change it very materially. In fact, when the olive-green solution is poured through the air, the change to the sea-green color of the uranous salt is immediate.

The results establish pretty conclusively that it is not advisable to pass the solution through the reductor into a flask full of carbon dioxide. This would appear to be what Kern tried to do by dropping his solution into a funnel, and so into his "titration flask," but during this operation the solution must have been exposed to the air enough to oxidize the lower oxide to the uranous state (Kern thought that the uranyl sulphate was not reduced below uranous sulphate by passing through the reductor), and the protection offered afterward by the carbon dioxide generated from a gram of sodium carbonate would hardly be significant. The conditions under which Kern operated could not be repeated exactly, since the uranium sulphate would not, without suction, pass through a reductor consisting of an 18-inch column of 20-mesh amalgamated zinc set up according to directions, in less than five times as long a period as Kern's table called for. When operating, however, as nearly as possible according to Kern's prescription, that is, by gentle suction into a flask, no carbon dioxide was needed. In fact, as previously stated, high results were obtained. In thinking it necessary to have carbon dioxide present because Zimmermann poured his reduced uranium solution directly into permanga-

* Ann. Chem. (Liebig), ccxiii, 302–304.

nate in a few experiments, to avoid exposure to the air, Kern undoubtedly misunderstood Zimmermann, since the latter ordinarily emptied his reduced solution into a porcelain dish, diluted it with water, and then titrated it with permanganate. Zimmermann did try some experiments, as previously described, by pouring the reduced solution directly into an excess of permanganate, but that was only in the few cases when he was trying to prove that the uranyl salt was not reduced below the uranous condition by zinc and sulphuric acid. Ordinarily, however, Zimmermann's operation was not conducted in that way.

It would appear, therefore, that Kern labored under a misapprehension in regard to the use of carbon dioxide in his "titration flask," that the zinc employed in his own work must have been larger than that which is called for in his directions for setting up the reductor, and that his statement is wrong that uranyl sulphate is not reduced below the uranous condition of oxidation by passing through a long Jones reductor made as above described.

After completing these experiments with carbon dioxide, a few trials were made to see whether, by running air through the solutions reduced in the ordinary way as worked out for the determination of uranium, the solutions would be oxidized above the stage represented by UO_2. It was found that by bubbling air rapidly through the solution for ten minutes it was oxidized to an amount equal to about 0·0020 gram of UO_3 for 0·1336 gram UO_3 used.

The process, then, for the determination of uranium by the reductor depends upon the fact that any reduction of uranium lower than uranous oxide—and such reduction undoubtedly takes place in the reductor—is corrected by exposure to the air, the lower oxide being rapidly oxidized to exactly the uranous state, while the uranous salts are stable enough to permit of being estimated before they are oxidized.

Kern also stated, in the same article, that the filtering of a precipitate of ammonium uranyl phosphate through a Gooch crucible could not be accomplished on account of the fineness of the precipitate. In trying to work out a method for determining phosphoric acid by precipitating the phosphoric acid in the presence of ammonium salts by uranium, filtering off the ammonium uranyl phosphate thus obtained, determining the uranium in the precipitate according to the method just described, and then, from the amount of uranium so found, estimating the phosphoric present, much experience was obtained in filtering off the precipitate, which, as Kern said, is very finely divided and tends to pass through the filter very easily. It was found that the precipitate went through two ashless filter papers (Schleicher & Schüll, No. 589), and also that an asbestos felt of ordinary tightness in a Gooch crucible would not entirely retain the precipitate. By shaking up the flask containing the asbestos, however, allowing it to settle a minute and then pouring off the particles still in suspension, a very finely-divided asbestos was obtained, which, when poured upon the felt made in the ordinary way, was found to give a pad of such tightness that the filtrate obtained from the ammonium uranyl phosphate was perfectly clear. The tightness of the felt, however, together with the gelatinous character of the precipitate, caused the process of filtering and washing to be rather slow.

The process as worked out for the determination of the phosphoric acid was as follows: A measured amount of a standard phosphate solution (containing about 4·7 grams of microcosmic salt per liter) was drawn into a beaker, and a mixture of about twelve grams of ammonium acetate, formed by neutralizing about 10^{cm^3} of ammonium hydroxide (0·90 sp. gr.) with acetic acid (50 per cent), and from 2 to 4^{cm^3} of free acetic acid was added. The total volume was made up to about 150^{cm^3} and the solution heated nearly to boiling. The ammonium uranyl phosphate was then precipitated by slowly adding an excess of uranium nitrate, with stirring, and the precipitate was boiled gently for about twenty minutes, allowed to settle, and filtered on a tight felt of asbestos. The precipitating beaker and the precipitate were washed thoroughly with a dilute solution of ammonium acetate containing a little free acetic acid (to overcome the tendency of the precipitate to pass through the filter) and the crucible containing the precipitate was placed in a glass funnel. Enough dilute sulphuric acid, in the ratio of 1 to 6, was then added to dissolve the precipitate and thoroughly wash out all the soluble uranium salt from the asbestos, the solution being caught below as it passed through the crucible and funnel in the same beaker that was used for the precipitation. The solution was then made up to a volume of from 100 to 150^{cm^3} with dilute sulphuric acid, in the ratio of 1 to 6, heated to boiling, and treated just as has been described for a solution of uranyl sulphate—that is, a few cubic centimeters of warm dilute sulphuric acid, in the ratio of 1 to 6, were passed through the reductor and were followed by the uranium solution, a few cubic centimeters more of the dilute sulphuric acid, and 250^{cm^3} of hot water. The contents of the flask were then poured into a porcelain dish, diluted with 200^{cm^3} of hot water, and titrated with a $\frac{n}{10}$ solution of potassium permanganate to a faint pink end-reaction.

The results obtained are shown in the following table :

P_2O_5 taken. grm.	UO_3 corresponding to P_2O_5 taken. grm.	H_2SO_4 (1·84). cm³.	Dilution at reduction. cm³.	$KMnO_4$. cm³.	UO_3 found. grm.	Error on UO_3. grm.	Error on P_2O_5. grm.
0·0404	0·1630	25	150	11·06	0·1632	+0·0002	+0·00005
0·0404	0·1630	25	150	11·03	0·1628	−0·0002	−0·00005
0·0226	0·0912	20	120	6·14	0·0906	−0·0006	−0·00015
0·0226	0·0912	20	120	6·17	0·0911	−0·0001	−0·00002
0·0719	0·2902	25	150	19.62	0.2896	−0·0006	−0·00015
0·0719	0·2902	25	150	19·61	0·2894	−0·0008	−0·00020

The results are all that can be desired as far as accuracy is concerned. The only objection to the process is that the filtering and washing of the precipitate are apt to be slow, especially when large amounts of the material are being treated.

In conclusion the author wishes to thank Professor F. A. Gooch for many helpful suggestions given during the course of this work.

Art. XXII.—*Certain River Terraces of the Klamath Region, California;* By Oscar H. Hershey.

Remnants of terraces occur in all the principal valleys of the Klamath Mountains. Heretofore, the writer has not considered them of any particular significance as they appeared not to constitute a definite system. In the down-cutting of the deep Pleistocene valleys, remnants of the old valley floor were left at various levels above the present streams and do not necessarily indicate an uplift of the region by stages. On a recent trip between the coast at Humboldt Bay and the high mountains near the head of the South Fork of Salmon River, the writer had the opportunity of observing a more definite system of river terraces than are developed farther east in the Klamath region and they seem to tell a story worthy of consideration, especially through its bearing on the problem of the cause of glaciation of the high mountains.

These terraces are situated on the Trinity River below the mouth of New River, on the Klamath River below the mouth of Salmon River, and on the Salmon River and its South Fork as far up as Summerville. These streams in this region flow in Pleistocene cañons which have an average depth of 3,000 feet. They are trenched into comparatively resistant metamorphic rocks such as schists and slates, intruded by batholites and dikes of gabbro, diabase, diorite and allied igneous rocks. There is considerable diversity in the resistant properties of the different formations and in consequence the cañons vary greatly in width. Throughout the greater portion of their courses they are extremely narrow at the bottom, usually no wider than the streams, and for miles in places are practically impassable except high up on the slopes. The rivers are superimposed on the structure and traverse indifferently hard and soft belts. The downward progression of the valley floor is controlled by the rate of erosion of the hard rock barriers in the gorges. In the soft belts, the streams exert their energies on the walls of the valley rather than its floor and excavate small basin-like valleys with flat floors from ten to twenty-five times as wide as the gorges in the hard rocks.

Through the gorges the streams flow straight and swift and hurry along the gravel and boulders. In the basins, the streams until recently wound about in meanders, here and there touching and undermining the valley walls. The gravel carried out of the gorges was spread over the flat floors of the basins in sheets from 5 to 20 feet in depth, constituting ordinary gravelly alluvial plains. As the rock barriers in the gorges were eroded, the basin floors were cut down, remnants of the alluvial plains left as terraces, and a new gravel plain formed. That is the explanation of the terraces but it is not by any means the whole of the story.

The terraces are confined almost exclusively to the basins. The system is chiefly developed below a height of three or four hundred feet above the streams. Occasional alluvial remnants occur higher but there is nothing definite about them. Three fairly persistent levels may be traced out in the different basins, although intermediate terraces are occasionally detected. The lower is the most prominent, stands from 20 to 75 feet above the present streams at low water, and in reality forms the flat floor of the basins. After a terrace level is abandoned by the streams, the rock debris from the neighboring steep mountain slopes works down and builds up talus deposits, giving the older terraces a sloping surface. Hydraulic mining demonstrates that the river deposits extend to the inner edge of the terraces under the talus debris. The lower terrace level has been abandoned so recently that talus deposits and alluvial fans on it are not conspicuous, so that its evenness of surface is a marked feature.

Above Hawkin's Bar, the Trinity River issues from a gorge cut largely in gabbro, and enters upon a belt of Bragdon slate, the least resistant of all the pre-Cretaceous formations of the Klamath region, and has eroded in it a valley from one-fourth to over one-half mile in width. The stream now flows in a narrow cañon trenched from 50 to 75 feet below the flat valley floor. The walls of the cañon consist of highly inclined slates capped by gravel.

From the mouth of Willow Creek to Waterman, three miles, the valley is wide and the terrace system well developed. Several hills of rock rise like islands, centrally on the valley floor. The stream flows in its usual very narrow cañon trenched 30 to 40 feet below the lower terrace which forms the flat valley floor.

The river passes out of the Bragdon slate belt, for several miles traverses a narrow gorge and then returns to the slate belt and enters Hoopa valley. This is about seven miles in length and one mile in average width. Its altitude is about 350 feet above sea level.* The floor is even enough to constitute a fine body of agricultural land. The river traverses it in a meandering course, touching each side alternately, but the meanders are trenched 20 to 30 feet below the flat valley floor.

* Altitudes given in this paper are derived largely from aneroid determinations by J. S. Diller. The figures of the height of terraces are mainly estimates drawn from memory, but are sufficiently accurate not to vitiate the arguments.

The tiny cañon is no wider than the stream and is cut into the rock below the gravel. The valley also preserves splendid remnants of the higher terraces up to several hundred feet, especially at the upper end where there is a beautiful display of three sharp terraces, each a rock bench capped with gravel. Opposite the village of Hoopa, each side of the valley has a well marked remnant of the principal upper terrace, several hundred feet above the stream and other remnants indicate strongly that at that level the valley once had a flat floor of similar shape and size as the present.

At the lower end of Hoopa valley, the river leaves the Bragdon slate belt and to its mouth traverses a gorge in Paleozoic schists. In ascending the Klamath River from Weitchpec, traces of the terrace system are observed in the cañon at various places, particularly at the mouths of Bluff and Red Cap Creeks, but there is no prominent development of them until Orleans is reached. Here for several miles the river is traversing a comparatively soft belt of schist and has eroded a basin over one-fourth mile in average width, the slopes of which are finely terraced. The broad lower terrace, on which is built the village of Orleans, is the valley floor proper and has a level about 30 feet above the ordinary stage of the river. The stream flows through the basin in a rock cañon no wider than the river. Gravel-capped rock benches rise behind each other to a level of 400 or 500 feet above the river and are extensively mined. The main one at several hundred feet seems to correspond in degree of preservation with the main upper terrace on the Trinity River. The altitude of Orleans is nearly 800 feet.

Continuing up the Klamath River and then up the Salmon River traces of the terrace system are encountered at many places in the cañon, particularly at the mouths of tributary streams, but there is no pronounced development of them until Nordheimer is reached. From here to the Forks of Salmon, the valley is wide enough to have a well-marked flat bottom, which is traversed by the river in a narrow rock cañon cut down from 30 to 60 feet. Discontinuous remnants of the higher terraces up to several hundred feet are present all along the river for many miles. The altitude of the river at the Forks of Salmon is about 1700 feet.

Up the South Fork of Salmon River, traces of the lower terrace are hardly anywhere absent, except in a few of the narrowest gorges. Wherever the rocks are soft this lower terrace spreads out to a broad, flat gravel bar, always elevated above the present river level. It is well developed at Cecilville, altitude about 2650 feet, where the village is built on it. The present cañon has a depth of about 25 feet and its usual extreme narrowness. At several points from here upstream there are in the small cañon, where the rock is excessively soft, traces of a lower terrace whose rock floor is usually 5 to 10 feet above the stream. They are indefinite, are due to a shifting of the stream meanders and do not necessarily indicate renewed uplift. From Cecilville downstream they are weakly developed at a number of points, but nowhere are conspicuous and will be ignored in the following discussion.

In the vicinity of the old town-site of Petersburg, several miles above Cecilville, the river was able to excavate a basin in the area of the Salmon hornblende schist because of its local shearing and partial alteration into chlorite schist. Here the terrace system is typically developed with three main levels, the lower trenched by the river to a depth of 30 to 40 feet. The lower terrace may be traced through the next gorge upstream. At its level there is a slight bench with gravel deposits along both sides of the gorge, and the present cañon, with nearly perpendicular rock walls, has a depth below them of 30 to 50 feet. This leads us into the Summerville basin, excavated largely into an area of non-resistant granite.

The altitude of the river at Summerville is about 3100 feet above the sea. It flows in a rather wide cañon (because the rock is unusually soft), and 30 to 40 feet deep. From its edges, before mining operations were begun, a gravel terrace extended back several hundred feet and then the basin floor rose in successive benches to a level of 300 feet above the stream. Indeed, the entire terrace system was developed here in unmistakable form. This is the farthest point up the river at which it reaches a prominent development, as above here the rocks are nearly uniformly hard, the cañon narrow, and the stream very high grade. Glacial deposits occur within five miles upstream. Within the cañon at many points there are benches, by which the terrace system may be traced into connection with the glacial series. This has been done. However, it deserves treatment as a separate subject, but some of the conclusions will be used in this paper.

The most important features described in the preceding paragraphs are, that each basin throughout the area discussed contains a broad, flat, gravel floor, and that the streams no longer flow at this level, but in a tiny cañon trenched mostly from 30 to 50 feet beneath it into the hard rock below. The contrast between the broad valley floor and the narrow cañon winding about in it is extremely prominent and certainly indicates a change of conditions. The size of the cañons relative to that of the streams is everywhere so nearly alike as to point indubitably to a like age for the flat valley floor in each basin. Now, the development of the flat valley floor required a long period of comparative stability during which down-cutting in the basins was practically nothing and the streams devoted their attention to widening their valleys. The streams were low grade, at least in the basins, and had meandering courses. Suddenly conditions changed and the streams universally in this area began to trench the valley floor, in many cases retaining the meandering courses. Several hypotheses as to the nature of this change in conditions will be examined briefly:

1. That the down-cutting of the barriers in the gorges was intermittent because of some peculiarity in their structure. This position is untenable. The hypothesis would be worthy of serious consideration if the strata were at a low angle and hard and soft layers alternated. The strata throughout the region are practically vertical and the igneous rocks rise vertically through them. Each barrier belt is essentially uniform in structure and resistant properties in any given 500 feet of depth. All other conditions remaining equal, the down-cutting in the gorges will be practically uniform and the lowering of the basin floors equally as regular. The tiny cañons in the basins are rarely any wider than the streams. Down-cutting in the gorges must proceed as rapidly as in these cañons in the basins. There is not nearly the contrast in the size of the cañons in the basins and the equivalent portion of the gorges, as between the broad valleys and their equivalent portion of the gorges. In this I see evidence that the broad valley floors are not due solely to the barriers, but to the barriers in combination with a past general low-grade condition of the main streams of the entire area. Further it appears evident that the down-cutting from the level of each main terrace, and especially from the last, was due to causes independent of the structure of the barriers.

2. In some regions, particularly those of semi-arid climatic conditions, an increased and better distributed rainfall sometimes causes a dissection of alluvial plains. In this region precipitation is now, and apparently always has been abundant. The streams have been able to remove the rock debris to the sea about as fast as weathering produced it, so that it nowhere accumulated to great depth. Therefore, widening of the valleys occurred only under low-grade conditions of the main streams. Suddenly increased rainfall would hardly result in dissection, but rather, for a time at least, in aggradation. I am going to connect the lower terrace with the later stages of glaciation in the high mountains, and on the generally accepted principle that the Glacial Period was one of excessive precipitation, we must presume that the rainfall is now less than when the broad valley floors were formed.

3. That decreased rainfall caused the erosion of the tiny cañons has in its favor the probability as derived from other sources of such a lessening in the precipitation during their development, but hardly explains the sudden trenching without even destroying the meanders. Further, a lessened precipitation would yield smaller streams which would be less able to carry away the products of weathering and would reach a stable grade with a higher angle of slope and aggradation would result.

4. That the tiny cañons are the result of a general uplift, without tilting, of the entire region is vitally defective for the reason that dissection should begin at the coast line and advance inland. The cañons would be older and consequently larger near the sea than far up on the streams. Now, it is a characteristic of these cañons that they are equally developed proportionate to the streams far up on Salmon River as low down on the Trinity and Klamath Rivers. The recency of the beginning of the cañon erosion low down on the streams as clearly shown by their small size, implies that with uplift without tilting, in order to abrade the stream-bed at all, there should be such an increase of grade near the coast that the cañons would soon run out and the middle and upper courses of the streams retain their low-grade condition.

5. The hypothesis which I can unreservedly accept, is that along with general uplift there has been a tilting of the region toward the coast. The main rivers have been converted from low-grade to high-grade streams. They began to erode their beds at the same time throughout the area and the cañons resulting are everywhere approximately equal. The present high-grade character of the streams is evident. They flow swiftly in the cañons within the basins as well as in the gorges. They move considerable bowlders with ease and there is little more tendency for the debris to lodge in the cañons in the basins than in the gorges. The bottoms of these cañons will be reduced far below their present level before the energy of the streams will be largely devoted to widening of the basins as it once was. Indeed, I am of the impression that this uplift and tilting of the region was one of the most pronounced which has effected it in Quaternary time, but has been so recent that its products are yet insignificant and likely to be overlooked.

In the absence of accurate surveys, distances on these rivers may be roughly determined by the trails. The Klamath River at Weitchpec, about 45 miles from the sea, has an altitude of scarcely 300 feet. Taking this point as a base, the Salmon and Klamath Rivers fall from Summerville to Weitchpec (a distance of about 80 miles), 2,800 feet or 35 feet per mile.

The upper Trinity River between Trinity Center and Bragdon falls about 10 feet per mile. This is so nearly a stable grade for that stream that it has not in recent times materially trenched the floor of its comparatively broad valley, but, on the contrary, it is able to build alluvial plains of coarse gravel which it floods nearly every year. This portion of the Trinity River is a larger stream than the Salmon River above Forks of Salmon, and a smaller stream than the Klamath River from the mouth of the Salmon River to Weitchpec, but it is about the equivalent of the average of those two streams. It is encumbered with gravel of similar coarseness to that on the Salmon and Klamath Rivers. I wish to derive from this comparison the suggestion that while the streams were forming the flat valley floor in the basins, the fall from Summerville to Weitchpec was probably no greater than 10 feet per mile. Indeed, on the lower Trinity where the tiny cañon is well developed, the fall now scarcely exceeds that amount and at the time of the development of the broad valley floor must have been considerably less.

The difference between the theoretical 10 feet per mile and the present fall of 35 feet per mile or 25 feet per mile, may be the differential amount of the uplift, which would mean an absolute elevation of the Summerville basin exceeding 2,000 feet (which, in reality, is probably a minimum). This implies that the central portion of the Klamath region, particularly that area which is occupied by the high mountains which were once extensively glaciated, has suffered an elevation relative to the present coast-line, late in the Quaternary Era, of several thousand feet.

The higher terraces seem also to indicate uplift, but not of such a pronounced differential character, as a stable grade was resumed without great depth of cutting. This series of disturbances occurred within the last one-fifth and probably the last one-tenth of the Quaternary Era. Similar uplifts may have occurred earlier in the era, but their effects inland have been mostly destroyed.

The terrace system is developed on Redwood Creek and on the lower Mad River, where it connects with the lower marine terraces along the coast. Opposite Korbel the flat-topped hills mark the floor of an ancient valley a number of miles wide, as described by Mr. J. S. Diller.* It is traceable as the principal upper terrace to the mouth of the valley where the latter enters on the lowland of the Humboldt Bay region. The river has trenched it to the depth of several hundred feet, excavating a broad valley in soft Tertiary strata but a narrow gorge

* "Topographic Development of the Klamath Mountains." U. S. Geol. Sur. Bull., No. 196, p. 54.

in the hard Franciscan sandstone just below Korbel. The degree of preservation of this terrace, and its relation to lower terraces in the same valley, constrain me to consider it practically the equivalent of the main upper terrace (that occurring so persistently at several hundred feet above the streams) on the Trinity, Klamath and Salmon Rivers. The Mad River terrace seems to slope toward the sea at a rate which was certainly not original. It may connect with a marine terrace back of Eureka.

Near Bay View station, on the railway between Eureka and Arcata, there is a much eroded terrace rising probably 75 or 100 feet above the bay. An extensive railway cutting exposes false-bedded brown sand and silt, evidently marine. This terrace I consider the equivalent of one of the upper river terraces inland. It is developed in the town of Arcata where it consists largely of a yellowish, non-pebbly silt resembling weathered loess. North of Arcata there is developed a lower terrace which consists of a bed of irregularly stratified gravel overlaid by silt. Its outer edge rises probably 15 to 20 feet above the Humboldt Bay lowland or alluvial plain. This terrace I correlate with the lower terrace (the broad valley floors) of the Trinity, Klamath and Salmon Rivers. The town of Eureka is largely built on a low, flat terrace of brown sand, whose outer edge rises probably 15 to 20 feet above the bay and may be of the same age as the lower river terrace inland.

The main upper terrace, occurring so persistently at several hundred feet above the Trinity, Klamath and Salmon Rivers in the area herein discussed, seems to be approximately of the age of the Red Bluff formation. The cañons excavated by the Sacramento River and Clear Creek since the uplift of the Red Bluff formation, are fairly comparable with those eroded on the western slope of the Klamath Mountains since the streams began to cut below the main upper terrace. I should say that throughout the Klamath region the post-Red Bluff erosion nowhere exceeded a depth of 500 feet, unless in a few limited areas which were exceptionally tilted, areas which have not yet come to light. It has been prevailingly from 200 to 300 feet in depth, reaching 400 feet locally. The post-Red Bluff erosion constitutes at least the last one-fifth and probably the last one-tenth of the erosion of the Sierran or Pleistocene cañons.

The low terrace at Eureka and the low gravel terrace at Arcata I attribute to the San Pedran subsidence which seems to have been quite persistent along the coast of California. The development of the broad valley floor, constituting the lower terrace on the Trinity, Klamath and Salmon Rivers, I also consider to have been approximately San Pedran in age. At the close of the San Pedran epoch there seems to have been a land disturbance practically co-extensive with the State. The coast line and Great Valley were slightly uplifted and some of the main mountain masses, as the Klamath, were distinctly bowed. In the incoherent strata of the Great Valley, broad, shallow cañon-shaped valleys were excavated, but in the hard rocks of the Klamath region tiny cañons were eroded. With the exception of a more recent local subsidence on the coast and west of the center of the Great Valley, this first post-San Pedran orogenic activity is the last of which we have any record in California.

After studying the small present cañon of the lower Trinity, Klamath and Salmon Rivers as far up as Summerville, one is able to arrive at a fairly definite conclusion as to what would be the character and amount of the erosion of the same period in the glaciated valleys had not glaciation intervened to complicate matters. Recently the writer has recognized evidence of glacial deposits earlier in age than those usually described from the California mountains. Part of the evidence of age consists of certain rock gorges on Coffee Creek and the South Fork of Salmon River. Higher in the glaciated valleys are much smaller rock gorges (tiny cañons) which have been eroded practically since the complete disappearance of the Quaternary glaciers. It is not possible at the present time to accurately fix upon the time relation of the erosion of the cañon from Summerville downstream and the different stages of the glaciation. But comparison, and the connection by direct tracing of one of the upper terraces in the Summerville basin with the product of one of the earlier stages of the glaciation, make it fairly certain that the inception of the cañon cutting from Summerville downstream considerably antedated the close of the glaciation, but certainly did not occur earlier than its beginning. If there were no inter-glacial stages, the uplift which inaugurated the last cañon cutting from Summerville downstream, was contemporary with some stage of the glaciation, probably a later one. At any rate, it is safe to assert that the uplift did not occur before the beginning of glaciation and apparently has not occurred since its close.

The axis of deformation or line of greatest elevation, is somewhere centrally situated between Summerville in the Salmon River valley and Trinity Center in the upper Trinity valley. Between these points is the group of high mountains which were most extensively glaciated. These mountains apparently rose to the extent of between 2,000 and 3,000 feet at some time between the beginning and close of the glaciation. The elevation may have contributed to the glaciation, but to accepting it as the sole cause of the glaciation there is one serious objection. That is that the glaciated areas in these mountains are now probably as high above sea-level as they ever have been, yet the existing glaciers, three in number, are insignificant.

The supposed submerged river valleys in the border of the continental plateau off the coast of California have been accepted by certain writers as evidence of a former much higher elevation of the California mountains, a probable cause of Quaternary glaciation. For some time, the writer has doubted the pertinence of the argument. In the first place, it is not certain, as pointed out by Lawson,* that all or any of these long, narrow depressions are submerged valleys of erosion. But, accepting the general opinion that they are such, it is not certain that they were eroded as late as any part of the Glacial Period. Further, it is not certain that they indicate an uplift of the mountains of California above their present altitudes.

The sub-marine border of the continental plateau west of the Klamath region was depressed, not by a general epeirogenic subsidence but by a sea-ward tilting of the land. Such differential movements of this region have characterized it throughout the late Tertiary and Quaternary times, an opinion fully accepted and enlarged on by Mr. Diller in the paper before cited. The land has been swinging on an axis approximately corresponding to the present shore-line. By its not exactly coinciding with the present shore-line have been produced the various elevations and subsidences along the coast. But west of this axis the dominating movements were depressions, sinking the plateau border deeper and deeper beneath the sea. East of the axis we have evidence chiefly of a succession of differential uplifts. The supposed submerged river valleys off shore are probably an extension of the upper portion of the deep Pleistocene cañons. They were first submerged by a sea-ward tilting of the country long before the earliest glaciation of which we have any record in the California mountains. This statement I base on the fact that, since the submergence, the sea near the present shore-line has cut away so much of the land as that it must have been at work long before the earliest glaciation in the California mountains. The larger topographic features of the present coast line had been developed before the close of the Red Bluff epoch. The present coast line yields no evidence whatever of a marked elevation above the present at any time as late as the Red Bluff epoch.

In short, it is in the submergence and not the erosion of the

* Bull. Dept. Geol., Univ. Calif., vol. i, pp. 57–59.

supposed sub-marine river channels that I see corroborate evidence of elevation inland. Each tilting to which is due the river terraces described in this paper, served only the more effectually to depress the drowned valleys. Even the recent drowning of the mouths of the modern rivers west of the Klamath region tells the story of tilting, as the tide runs up them only a few miles.

The writer long accepted elevation as the direct cause of the great Quaternary glaciations, but that theory of late has seemed very questionable. The uplifts and the glaciations should connect more closely than they do. Further, the disappearance of the glaciers should have been brought about by depression of the land. In the Klamath region, the glaciated valleys, as already mentioned, appear to be at present as high above sea-level as they were at any time during the Glacial Period; therefore, the theory of elevation as the sole cause of glaciation seems inadequate.

Berkeley, California.

Art. XXIII.—*The Occurrence of the Texas Mercury Minerals;* by Benj. F. Hill.

The mercury deposits of Terlingua, Brewster County, Texas,* are found in both the Upper and Lower Cretaceous rocks, which in this locality are exposed in a section of more than two thousand feet. In general the Lower Cretaceous is made up of heavy thick-bedded limestones that are practically free from foreign material. The Upper Series, however, is composed largely of thin-bedded marls, shales and impure limestone with extensive clay beds. Both series are cut in many places by old rocks, plugs and dikes of volcanic material, the most common type of which are phonolite, andesite, and basalt. The ore deposits are invariably within a short distance of these igneous manifestations.

The deposits of the Lower Cretaceous, which in the present stage of development are the most important, occur in a variety of forms in the Edwards and Washita limestones. The most common method of occurrence is in decomposed and brecciated zones in the limestone. These zones are in many instances contiguous to fissure veins, and it is probable that the ore-bearing solutions were let into the broken and therefore receptive zones through these channels.

The fissures themselves often carry ore. They are invariably calcite-filled. In no case in the whole Terlingua district have quartz crystals in association with the ore been observed. Besides the calcite are gypsum, iron oxides, manganese, and in some localities much aragonite.

The principal mercury-yielding mineral is cinnabar, which occurs in a number of forms. Beautiful crystals of a ruby red color, often three-quarters of an inch long, have been found, intimately associated with calcite and native mercury. The crystals are usually acicular prismatic, but at times have a tabular habit, the prismatic condition being found only in association with the calcite. Large quantities of cinnabar that is crystalline occurs in granular masses, often of a large size. These masses show distinct grains and under the microscope exhibit crystal faces. The color of these granular aggregates varies from bright vermilion to dark reddish-brown. The cinnabar occurs also in large amorphous masses which present the same variation in color as do the granular masses.

The native quicksilver is present in a number of openings in the field, sometimes in considerable quantities. It is

* Bulletin 4 of University of Texas Mineral Survey, Terlingua Quicksilver Deposits of Brewster Co., by B. F. Hill.

generally intimately mixed with crystalline masses of calcite, occurring in the interstices between them in the form of globules. Some of these cavities have yielded over twenty pounds of the native metal. This metal is also present in the clay fillings of seams and in one instance in a close-grained cream-colored limestone.

Calomel, which is present in small quantities, is found in crystalline masses with practically the same association as the native mercury. The calomel has generally a few crystals of "terlinguaite" associated with it.

The new minerals eglestonite and montroydite, described by Prof. Moses from material sent to him by the writer, have been found in only one locality, which was a vugg in a calcite vein. The material was associated with considerable native mercury and what is locally known as amalgam, a mixture of cinnabar and native mercury. Here also was found the crystallized terlinguaite described in the following paper.

The deposits in the Upper Cretaceous are found in veins in the Eagle Ford shales. The ore is not associated with calcite to such an extent as is that of the Lower Cretaceous. The veins are of the fissure type and are filled with clay and gypsum, with subordinate quantities of iron oxides and calcite. A considerable quantity of iron pyrites occurs with the ore, in this respect furnishing a contrast to the deposits of the Lower Cretaceous.

The only mercury minerals found in the Upper Cretaceous are cinnabar and native mercury.

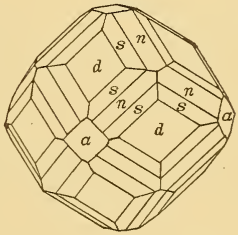
Art. XXIV.—*Eglestonite, Terlinguaite and Montroydite, New Mercury Minerals from Terlingua, Texas;* by Alfred J. Moses.

1. *Eglestonite, an Isometric Oxychloride of Mercury.*

The most abundant material in the specimens received from Mr. B. F. Hill so resembled minute crystals of sphalerite that the first test made was for a zinc coating. The material occurs, so far as observed, only as crystals which rarely exceed one millimeter in diameter and are sometimes isolated and at other times united loosely in a crust which readily crumbles under pressure into separate well developed crystals, evidently isometric and with the dodecahedron the predominating form. The associated minerals are the later described terlinguaite and montroydite, calomel, native mercury and calcite.

Crystalline Form of Eglestonite.—The crystals are usually sharply and beautifully developed, but in some specimens are pitted and the cavities filled with metallic mercury. The system is isometric and the class hexoctahedral. With the two-circle goniometer the forms identified were *a* {100}; *d* {110} *n* {112} and *s* {123} as shown in fig. 1. The dodecahedral planes are the largest.

1



The following table gives the angles obtained from twenty-nine faces on one-half of a crystal, one mm. in diameter. The calculated angles are also given.

Form.		Faces Reflecting.	φ Measured.	φ Calculated.	ρ Measured.	ρ Calculated.
a	001	1			0°	
	010	4	0°		90°	
d	110	4	45° 0½′	45°	90°	
	011	4	0°	0°	44° 58′	45°
n	112	4	45° 02′	45°	35° 17′	35° 16′
	121	7	26° 30′	26° 34′	65° 50′	65° 54′
s	123	2	26° 32′	26° 34′	36° 45½′	36° 42′
	132	2	18° 26½′	18° 26′	57° 40′	57° 41′
	231	1	33° 35′	33° 41′	74° 22′	74° 30′

Chemical Analysis of Eglestonite.—The analyses here recorded were made by Mr. J. S. McCord, Assistant in Mineralogy at Columbia University. The method used was chosen after an attempt to obtain an electrolytic determination of the mercury by dissolving ·2465 gms. of very carefully picked material in nitro-hydrochloric acid, precipitating as sulphide and dissolving in hot solution of sodium sulphide. This solution in a dish of platinum was subjected for five hours to a current of about two volts. Two separate weighings of the dish and mercury showed a loss between the times of weighing corresponding to over two per cent. (·0055 gms.). It was therefore decided that with the large dish surface and the small amount of available material the method was not safe.

By trial Mr. McCord found that in a narrow closed tube of hard glass 75^{mm} by 6^{mm} external diameter and with low red heat, mercuric chloride volatilized and was redeposited with a loss of less than two-tenths of one per cent. Mercuric oxide yielded metallic mercury with a loss almost exactly that of the oxygen.

Analyses I and II were therefore made by heating carefully picked crystals in such a weighed tube and determining the loss, which in the proved absence of water and carbonic acid was assumed to be oxygen. The sublimates of mercury and chloride of mercury were then dissolved from the tube by nitric acid, the chlorine determined as silver chloride and the difference between the weight of the chlorine and the weight of the sublimates was taken as mercury.

In analyses III, IV and V the method was varied. The weighed powdered crystals were mixed with dried soda free from chlorine and heated in one of the closed tubes described until the mass was bright red and all sublimate had been driven clear of the fused mass. When cool the tube was cut just above the fused mass and the piece containing the sublimate carefully weighed. The sublimate was then dissolved in nitric acid and the dried tube again weighed. The difference was mercury. For safety the solution was tested for chlorine and in one analysis a small amount was found and added to the rest.

From the other piece of the cut tube the soda fusion was dissolved in hot water acidified with nitric acid and the chlorine determined as silver chloride. Each sample was separately picked.

	I.	II.	III.	IV.	V.
Grams taken	·0768	·0618	·2048	·1404	·1097
Per cent oxygen	2·60	2·26	----	----	----
" chlorine	8·72	7·24	7·81	7·68	8·20
" mercury	88·67	90·45	90·72	88·25	89·70

The average of these determinations corresponds closely to the empirical formula $Hg_6Cl_3O_2$.

	Percentages in $Hg_6Cl_3O_2$.	Percentages by analysis.		Group proportion.
O	2·391	2·43	÷ 15·88 =	·1530 or 2·036
Cl	7·946	7·93	÷ 35·18 =	·2254 " 3·000
Hg	89·666	89·56	÷ 198·49 =	·4512 " 6·005
	100·003	99·92		

Other Characters of Eglestonite.—Luster, brilliant adamantine to resinous. Color, varying between brownish yellow and yellowish brown but darkening quickly on exposure to sunlight and becoming nearly black but retaining a high luster. In powder, greenish yellow to canary yellow, becoming quickly green and finally black on exposure to light. Transparent if smooth-faced. Brittle and without observed cleavage. Hardness between 2 and 3. Specific gravity by direct weight of two carefully picked samples 8·327, as follows:

	I.	II.
Grams taken	·2576	·4548
Loss in water.........	·0310	·0545
Specific gravity	8·309	8·345

Heated on charcoal, volatilizes completely without fusion and forms a slight grayish sublimate.

Heated in the closed tube, decrepitates, becomes orange-red, evolves dense white fumes and deposits a white non-crystalline sublimate which is slightly yellow hot, drives without fusing, is soluble in nitric acid and gives the chlorine tests with copper oxide. Later the orange-red residue volatilizes completely, forming a mercury mirror beyond the ring of chloride.

In dilute nitric acid the crystals become opaque and pinkish white but retain their shape and there is a visible formation of metallic mercury. On heating, the mercury dissolves with effervescence and the pinkish white residue is also slowly but completely dissolved.

In cold hydrochloric acid the crystals do not whiten but in hot acid the surface becomes gray from metallic mercury, which dissolves with a very slight effervescence. The greater portion of the crystal is insoluble even in concentrated cold acid.

If hydrochloric acid is added during the dissolving in nitric acid there is a heavy precipitate formed, but on heating this and the opaque white residue dissolve quickly and completely.

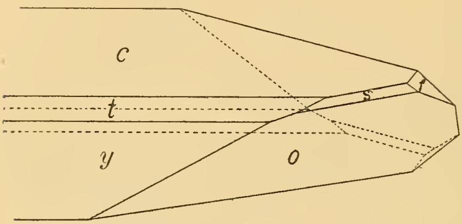
Name of Eglestonite.—For this substance, an isometric and hexoctahedral oxychloride of mercury, the name Eglestonite is proposed in honor of the late Prof. Thomas Egleston, founder of the Columbia School of Mines and for many years professor of mineralogy and metallurgy in Columbia University.

2. *Terlinguaite, a Monoclinic Oxychloride of Mercury.*

On the specimens which show the eglestonite there is generally found a bright sulphur-yellow material usually as an agglomeration of imperfect striated crystals and less frequently as doubly terminated crystals of not over one millimeter in length. This material on examination is found to be quite distinct from the eglestonite with which it is associated. In one of the specimens the central portion was a mass of this yellow substance and outside of this was a thick crust of eglestonite crystals, while scattered through the crust were globular masses of native mercury coated with the oxide montroydite.

Crystalline Forms of Terlinguaite.—Few crystals were satisfactory for measurement. Four were measured which may be briefly described as follows:

2



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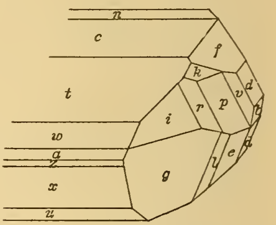

Crystal 1.—Very minute and complex, yielding reflections from about twenty definite polygonal faces. No figure was drawn because of the difficulty of judging relative development of forms. a, c, m, y, h, g, a, λ were the most prominent forms.

Crystal 2.—Larger and simpler than crystal 1, and elongated parallel to the axis $\bar{b}$. The principal forms are shown in fig 2 in approximately the relative size.

Crystal 3.—Short and relatively thick and complex crystal. The principal forms are shown in fig. 3.

Crystal 4.—Tabular parallel a {100}. Showing prominently also e, γ and π and less prominently δ, d, t, u, x, i, s, g, λ. No drawing was made of this crystal.

The crystals were mounted with their most prominent zone normal to the vertical circle. The axis of this zone proved to be the only axis of symmetry and therefore was the axis of $\bar{b}$ of the monoclinic system. By trial in the stereographic projection the forms denoted by c and a were found to be the most prominent zone centers and were chosen as {001} and {100}.

The angles obtained by measuring with the axis $\bar{b}$ normal to the vertical circle were transformed to the conventional ϕ and ρ angles referred to a pole plane at right angles to the $\dot{c}$ axis and to a meridian through {010}. These angles are here tabulated and with them the calculated angles for the particular indices and calculated axial elements.

Forms.		Measured Coordinate Angles.		Calculated Coordinate Angles.		Remarks.
		φ	ρ	φ	ρ	
c	{001}	90° 00′	15° 44′	------	-----	Well developed on 1, 2 and 3.
b	{010}	0 00	90 00	------	------	Minute face on 3.
a	{100}	90 00	"	------	------	Large on 4, small on 1 and 3.
θ	{130}	33 07	"	33° 08′	------	Microscopic on 3.
δ	{230}	52 21	"	52 33	------	Microscopic on 4.
d	{011}	7 48	64 13	7 53	64° 02′	Well developed on 3, poorly on 4.
f	{013}	22 28	36 20	22 34	36 17	Fair on 3, minute on 1 and 2.
h	{015}	34 50	26 12	34 43	26 19	Minute face on 1.
t	{106}	90 00	43 14	90 00	42 56	On all four crystals, prominent on 3.
y	{103}	"	57 57	"	57 39	Prominent on 2, small on 1.
w	{101}	"	76 25	"	76 31	Striated face on 3.
n	$\{\bar{1}06\}$	$\overline{90}$ 00	20 30½	$\overline{90}$ 00	20 09	Minute faces on 3.
u	$\{\bar{1}03\}$	"	45 40	"	45 26	Indistinct on 3 and 4.
m	$\{\bar{5}08\}$	"	65 25	"	65 37	Large dull face on 1.
x	$\{\bar{7}, 0, 10\}$	"	67 40	"	67 43	Striations on 100 of No. 4, large face on 3.
z	$\{\bar{1}01\}$	"	74 08	"	74 30	Fine edge on 3.
v	{155}	27 31	66 19	27 55	66 31	Narrow minute face on 3.
p	{133}	38 11	68 42	38 21	68 54	" " "
r	{11, 25, 25}	45 08	70 58	45 00	70 50	Minute triangular face on 3,
i	{7, 11, 11}	53 59	74 30	54 10	73 56	Minute faces on 3 and 4.
s	{111}	64 22	78 04	64 30	78 03	" 2 and 4.
λ	{1, 3, 15}	53 16	34 15	53 23	34 17	" 1 and 4.
π	{136}	42 26	53 59	42 55	54 13	Distinct on 4.
k	{134}	39 17	63 20	39 57	63 12	Distinct triangular on 3.
e	$\{\bar{1}33\}$	$\overline{26}$ 54	66 14	$\overline{27}$ 13	66 22	Prominent on 3 and 4.
l	$\{\bar{1}1, 25, 25\}$	$\overline{36}$ 12	68 22	$\overline{35}$ 52	68 16	Large striated face on 3.
g	$\{\bar{1}3, 20, 20\}$	$\overline{48}$ 37	72 02	$\overline{48}$ 36	71 59	Very prominent on 3, visible on 4.
o	$\{\bar{1}11\}$	$\overline{61}$ 02	76 32	$\overline{61}$ 12	76 40	Very prominent on 2, visible on 1 and 3.
γ	$\{\bar{9}77\}$	$\overline{67}$ 42	79 28	$\overline{67}$ 16	79 15	Prominent on 4.
β	$\{\bar{1}. 3, 15\}$	$\bar{2}$ 40	22 03½	$\bar{2}$ 18	22 08	Minute face on 1.
q	$\{\bar{1}15\}$	$\overline{51}$ 21	32 51	$\overline{51}$ 41	33 16	Small but distinct on 1.
a	$\{\bar{1}13\}$	$\overline{56}$ 34	51 00	$\overline{57}$ 02	51 14	Minute faces on 1 and 2.

The value of *β* was determined to be 74° 16′, the average of determinations from the angles of *c*, *f* and *h*.

The ratio between the axes was determined to be

$$\grave{a} : \bar{b} : \acute{c} = 0{\cdot}5306 : 1 : 2{\cdot}0335$$

the average of eleven determinations for each axis from the angles of *p*, *s*, *m*, *k*, *e*, *l*, *g*, *o*, γ, *q* and *a*, two for $\grave{a}$ from the *t* and *x* angles and two for $\acute{c}$ from the *f* and *h* angles. The maximum deviations from the average were for $\grave{a}$ ·0139, for $\acute{c}$ = 0·0214. Much more complex indices could be chosen for some of the forms which would check more accurately the measured angles, but as a certain error is undoubtedly due to a blurring of the images from the microscopic faces, it is believed the simpler indices chosen are generally correct.

Chemical Analyses of Terlinguaite.—Analyses I, II and III were made by Mr. McCord by fusion with soda in a closed tube as described under eglestonite. Analysis IV was made to determine the loss by heating. All samples were separately picked. The results tabulate as follows:

	I	II	III	IV
Grams taken	·1960	·1078	·0874	·06635
Per cent oxygen				3·47
" chlorine	7·78		8·00	
" mercury	88·67	87·38	88·64	

These determinations lead to the simple empirical formula of Hg_2ClO as follows:

	Percentages in Hg_2ClO.	Percentages by analysis.	Group proportions.
O	3·544	3·47 ÷ 15·88 =	·2185 or ·974
Cl	7·852	7·89 ÷ 35·18 =	·2242 " 1·000
Hg	88·604	88·24 ÷ 198·49 =	·4445 " 1·983
	100·000	99·60	

Other characters of Terlinguaite.—Luster, brilliant adamantine. Color, sulphur-yellow with a slightly greenish tinge, very slowly darkening on exposure to an olive green. Color of powder lemon-yellow, also slowly becoming olive-green. Transparent or nearly so. Hardness between 2 and 3. Brittle or sub-sectile.

Specific gravity on very carefully picked samples 8·725, higher than eglestonite by 0·316.

	I	II
Quantity taken	·4443	·4545
Weight in water	·3934	·4024
Specific gravity	8·728	8·723

Between crossed nicols there is distinct double refraction. The crystals can be viewed only normal to the $\bar{b}$ axis and show extinction parallel to this.

Heated on charcoal and in the closed tube, behaves like eglestonite except that a little oxide appears to be formed, giving a pinkish tinge to the white sublimate.

In nitric acid behaves like eglestonite but dissolves more rapidly. In hydrochloric acid becomes white but does not appear to dissolve.

Distinctions from Eglestonite.—The most convenient distinctions are the yellow color and the very slow change of color to olive-green as compared to the brownish color and rapid change to black with eglestonite. The eglestonite crystals are usually easily recognized. In testing, the double refraction and the more rapid solution of the terlinguaite are characteristic.

The name Terlinguaite.—This name should be limited to the yellow monoclinic oxychloride of mercury here described in order to remove the confusion at present existing. Mr. W. H. Turner* first used the name terlinguaite in the following words: "In addition to cinnabar, mercury occurs in the native form and as a white coating and *as yellow-green* crystals. Prof. S. L. Penfield has identified the . . . greenish crystals as an oxychloride of mercury forming a new mineral species for which I have suggested the name terlinguaite."

To the miners in the Terlingua district terlinguaite is "a heavy soft† cadmium yellow substance in masses or powder with a distinct green shade. It blackens on exposure and gives by rough retort tests 60 to 70 per cent of mercury." Some of this material has been recently sent to me and will be examined; the description, however, suggests a mixture of eglestonite and terlinguaite.

Prof. Penfield sent me by request the best two of the specimens received from Mr. Turner and at the same time wrote that "I have never given these minerals more than superficial examination and they may not be oxychlorides; I simply suggested that they might be." One of these specimens received from Prof. Penfield was undoubtedly the material here described as terlinguaite, crystal 4 having been taken from the specimen and the color change to olive-green on exposure being very pronounced. The other specimen, although apparently an oxychloride, was evidently the undetermined mineral spoken of in No. 5 of this article.

Of the three possibly different substances to which the name terlinguaite has hitherto been applied we have therefore

1st. The mineral here described.

2d. The undetermined rough yellow crystals mentioned in No. 5.

3d. The pulverulent yellow masses.

It is therefore proposed that the name terlinguaite be definitely limited to the mineral here described.

3. *Montroydite, Mercuric Oxide in Orthorhombic Crystals.*

Associated sparingly with the eglestonite and terlinguaite and in one or two instances occurring as masses of an inch or more on a side there was found a third new mineral. The most frequent occurrence was as a velvety incrustation of orange-red needles projecting from the surface of little hollow spheres and hollow pipe-like stems. The supporting material forming the sphere or pipe was metallic in luster, white to

* The Terlingua Quicksilver Mining District, Brewster Co., Texas, by W. H. Turner, Mining and Scientific Press, San Francisco, July 21, 1900.

† From a letter by W. P. Jenney.

gray in color, and although possessing very much the solidity of a soft amalgam and spoken of by Mr. Hill as a mixture of cinnabar and mercury, was nevertheless entirely volatile and so far as qualitative tests went was simply metallic mercury.

In addition to the minute needles forming the velvety crusts there were numerous larger transparent needles of darker red color and of a length often exceeding one mm. These were in most instances poorly terminated, striated and composite, but occasional crystals showed terminations and the best of these crystals was carefully measured in the two-circle goniometer.

Crystalline Form of Montroydite.—A very perfect doubly terminated and highly modified crystal exceeding slightly one mm. in length by one-third mm. in breadth, and suggesting under the hand glass a general resemblance in habit to some crystals of topaz, was mounted with its longest direction normal to the vertical circle and the orthorhombic symmetry being soon made evident, this direction was retained as that of the vertical axis. The most prominent pyramidal form *x*, fig. 4, being very acute, the pyramid *o* in the same vertical zone was chosen as the unit form. The more prominent forms shown in fig. 4 are *a* {100}; *b* {010}; *m* {110}; *d* {101}; *x* {331}; *o* {111}; *s* {112}; *r* {211} and *e* {132}. In addition to these, faint reflections were obtained from faces of microscopic dimensions corresponding to *w* {311} and *t* {122}.

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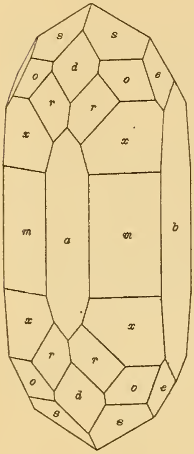

The faces *s* are less prominent in the real crystal than in the drawing from the presence of indeterminate truncating faces.

In the calculation of the elements $\dot{c}$ and $\breve{a}$ most of the occurring forms were considered and in proportion to the sharpness of the signals yielded by their faces. The results were as follows:

Form.	Factor.	Value of $\breve{a}$.	Value of $\dot{c}$.
m	3	·63625	
o	2	·63707	1·1918
x	8	·63748	1·1894
w	2	·64406	1·1960
t	1	·63729	1·1985
r	2	·63956	1·2037
e	3	·63670	1·1941
Average		$\breve{a}$ = ·63797	$\dot{c}$ = 1·1931

The form *s* {112} was not used in this calculation because although two evident faces were found their signals were very faint and their angles not sure.

The comparison between the measured angles and the angles calculated to the determined indices and axial elements is as follows:

Form.	Faces Reflecting.	ϕ Measured.	ϕ Calculated.	ρ Measured.	ρ Calculated.
a{100}	2	90°		90°	
b{010}	2	0°		90°	
m{110}	4	57° 32′	57° 28′	90°	90°
d{101}	1	89° 56′	90°	61° 58′	61° 52′
o{111}	3	57° 30′	57° 28′	65° 44′	65° 44′
x{331}	4	57° 29′	57° 28′	81° 26′	81° 27′
s{112}	2	58° 20′	57° 28′	48° 53′	47° 54′
r{211}	1	72° 16′	72° 18′	75° 48′	75° 42′
e{132}	3	27° 38′	27° 25′	63° 41′	63° 37′
Also,					
w{311}	2	77° 53′	77° 59′	80° 02′	80° 06′
t{122}	2	38° 07′	38° 05′	56° 43′	56° 35′

Chemical Analysis of Montroydite.—With great difficulty, picking crystal by crystal, ·0506 grams of pure material was obtained and very carefully heated alone in one of the small closed tubes described under eglestonite. The sublimate formed appeared to be entirely metallic. The dissolved sublimate gave no test for chlorine. It was therefore assumed, for want of further material, that the sublimate was mercury and the loss oxygen. The percentages are very close to those of mercuric oxide HgO.

	Percentages Analysis.		Percentages HgO.
Loss on heating	7·13	O	7·408
Sublimate	92·87	Hg	92·592

Other Characters of Montroydite.—Luster, adamantine to vitreous. Transparent. Color of larger crystals, a red darker than crocoite and nearer realgar; minute crystals orange-red. Color of the powder a little lighter than color of crystals. Not noticeably affected by sunlight. Brittle. Hardness less than 2. Specific gravity not determined.

Under the microscope there are indications of cleavage oblique to the length and with crossed nicols there is extinction parallel to the length.

Heated in the closed tube volatilizes completely and forms a sublimate of metallic mercury.

Dissolves easily and quietly in cold nitric or cold hydrochloric acid.

The name Montroydite.—The name Montroydite is suggested in honor of Mr. Montroyd Sharpe, one of the owners of the mines at Terlingua.

4. *Crystallized Calomel.*

One of the specimens from the cavity which yielded the minerals just described consisted of tabular crystals of calomel not suitable for measurement. Some specimens obtained by Mr. W. P. Jenney, from the district but not from the cavity however, yielded measurable crystals of two types:

1. Square prismatic crystals, fig. 5, sometimes 4 to 5^{mm} in length by 1 to $1\frac{1}{2}$ in breadth.

2. Tabular crystals flattened parallel to one of the faces of *a* {010}. Fig. 6 shows, in orthographic projection, two such individual crystals in parallel position with the α {113} planes relatively large.

The forms are the same in both types and consist of:

c {001} somewhat rough; *a* {010} slightly curved; *r* {111} dull; α {113} bright and *z* {013} minute.

Between the two individuals, as shown in fig. 6, and in the pris-

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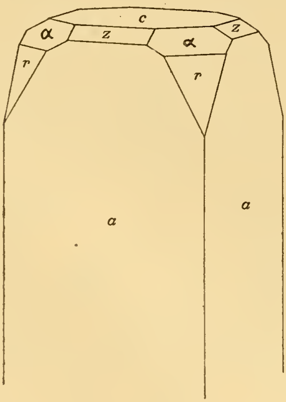

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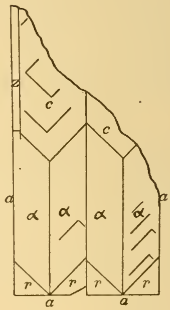


matic zone a single reflection was obtained corresponding very closely to a face of a new form {120}.

The essential measured and calculated angles were

	Measured.	Calculated.
cr	67° 50′	67° 41′
ca	38 45	39 05
cz	30 14	29 52

5. *An undetermined yellow mercury mineral.*

The second specimen received from Prof. Penfield and one received from Mr. W. P. Jenney show small yellow needles and short prismatic crystals which suggest hexagonal prisms and a basal cleavage. There was not sufficient material for analysis but the closed tube test showed mercury and apparent mercurous chloride suggesting an oxychloride, and the fact that the color did not noticeably change on long exposure indicated a different species from those described. An optical test made by carefully rubbing a basal cleavage down to transparency showed an indistinct biaxial brush in convergent light and double refraction in parallel light. The symmetry is therefore not higher than that of an orthorhombic class.

Two crystals were measured but the results were entirely unsatisfactory, the apparent faces being irregular and frequently yielding two reflections several degrees apart. The only suggestion resulting from the measurements was a very acute orthorhombic or monoclinic form, the faces making an angle with the apparent basal cleavage of about 85½ degrees. Pending the obtaining of more material the substance can not be described definitely.

ART. XXV.—*On a New Lilac-Colored Transparent Spodumene;* by GEORGE FREDERICK KUNZ. (With Plate X.)

A MOST remarkable discovery of unaltered lilac-colored spodumene has lately been made in California. The crystals were obtained fifty feet from a deposit of colored tourmaline, itself of notable interest, a mile and a half northeast from Pala, in San Diego County. This new discovery is but half a mile northeast from the celebrated rubellite and lepidolite locality at that place, where recent developments have brought to light immense quantities of amblygonite,—this latter species occurring by the ton, while the lepidolite is estimated by the thousand tons. The locality is thus unequalled in the world for its abundance of lithia minerals. The rubellite crystals found here are entirely embedded in lepidolite, and until recently it was found impossible to remove them to show their complete form. They were, however, often polished with the lepidolite,—the rubellite appearing as pink radiations in a darker gangue of lilac-colored lepidolite. Recently, however, the crystals of rubellite have been rubbed out, as it were,—made to stand out by removing the lepidolite matrix by means of brushes and cleaning-tools,—forming most beautiful groups of crystals.

At the new locality, colored tourmaline crystals have been found that are remarkable in size and beauty, although they are much broken in taking them out. Some are a foot long and three inches in diameter, with a red central core (rubellite) and a blue exterior (indicolite) separated by a pale intervening zone. Other pink crystals have a blue cap or termination; the blue color in these specimens is a deep shade, inclining toward purple. One very remarkable large crystal is like a hollow cylinder, apparently composed of a group of prisms surrounding an open central space at the axis of the cluster; this is entirely of a rather dull blue, verging toward reddish in the interior.

The spodumene crystals are beautiful in their color tones, varying from deep rosy lilac at some depth to pale or almost colorless, doubtless due to weathering or to the action of sunlight,—in striking contrast to the rich deep pink-purple found at a greater depth.

These spodumene crystals are of extraordinary size, transparency and beauty. The following are the weights and dimensions of seven of the principal crystals:

	Weight grams.	Weight oz. troy.	Dimensions Centimeters.
No. 1.	528·7	17·1	17 × 11 × 1
" 2.	528·7	17·1	22 × 8 × 1·5
" 3.	297·	9·55	19 × 5·5 × 1·5
" 4.	256·6	8·25	23 × 4 × 2
" 5.	340·5	10·95	13 × 6 × 2·53
" 6.	239·5	7·70	18 × 4 × 2
" 7.	1000·	31·	18 × 8 × 3

These crystals are extraordinary objects to the eye of the mineralogist; to see flat spodumenes of characteristic form, as large as a man's hand, but with bright luster and perfect transparency, and of this rich delicate pink-amethystine tint, is a novel and unlooked for experience.

The localities of these remarkable tourmalines and spodumenes are near the top of a ridge lying from a mile to a mile and a half from the lepidolite ledge of the old Pala locality, and separated from it by a valley some 900 feet deep. The ledge in which these new minerals occur is on the west side of this ridge, and has been traced for 1,200 feet in a N.W.–S.E. direction. The description given of it suggests a large dike. The rock is a coarse decomposed granite (pegmatite?), the feldspar much kaolinized and reduced to a "red dirt," and with many large quartz crystals, some of them reaching 150 pounds in weight, but not clear.

Similarly colored crystals of spodumene purporting to come from Hermosillo, Mexico, were shown the author during the month of December, 1902. These specimens were found at what is known as the White Queen Mine, section 24, township 9, South Range 2, West San Bernardino, Meridan, California. They are identical in habit with those from Pala, but much smaller. The crystals from Pala belong to the locality ascribed to them. No such spodumene crystals have ever before been found anywhere. They are entirely distinct both from the green variety (hiddenite) from Stony Point, Alexander County, N. C., described by Dr. J. Lawrence Smith,* and from the transparent yellow found in Brazil, described by Pisani,† and more resemble some of the rare remnants of unaltered spodumene from Branchville, Conn.‡

The Meridan (?) crystals were found in a deserted and abandoned gold mine. The rock is an iron-stained granite, and the crystals occur in a vein of quartz with gold, rutile, black oxide of manganese, epidote, orthoclase, "mica," lepidolite, cookeite and black tourmaline. The mineral was not

* This Journal, xxi, 128, 1881.

† Comptes Rendus, lxxxiv, 1509, 1877.

‡ Brush and Dana, this Journal, xx, 257, 1880; and by Penfield, ibid., p. 259.

recognized until sent to the writer in New York, having been pronounced tourmaline by parties to whom it was shown; and many crystals were ruined by lapidaries in the unsuccessful attempts to cut them, as the very highly facile cleavage of spodumene causes it to flake.

The crystals obtained were quite numerous, and vary from half an inch or less to two inches in length, by an inch in breadth. Some are elegant specimens and some could be cut into gems. The hardness is about 7. They are perfectly transparent and remarkably free from flaws, and possess the spodumene pleochroism very markedly. Looked at transversely, they are nearly colorless, or faintly pink; but longitudinally they present a rich pale lavender color, almost amethystine. The characteristic etching is also well developed, especially on the pyramidal faces; but all of the crystals are dull upon the surface and are etched all over as if with a solvent.

Two crystals, the largest and another one, give the following measurements:

a, 53^{mm} ($2\frac{1}{8}$ in.) and 35^{mm} ($1\frac{3}{8}$ in.)
b, 37^{mm} ($1\frac{1}{2}$ in.) and 27^{mm} ($1\frac{1}{16}$ in.)
c, 11^{mm} ($\frac{7}{16}$ in.) and 15^{mm} ($\frac{11}{16}$ in.)

The specific gravity determined on three crystals was found to be 3·183.*

	Color.	Grams. Weight.	Specific Gravity.
Spodumene :	Lavender	20·393	3·179
	Yellow-white	8·359	3·185
	Lavender	10·872	3·187

The crystals are so etched and corroded that the terminals are entirely gone, therefore it is not possible to do very much with them in the crystallographic line. The rounded protuberances and crystallographic points left by the etching are interesting, but it would be exceedingly difficult to make much out of them or to illustrate them. Professor S. L. Penfield kindly measured the prismatic angle on two crystals and reported as follows: "The prism faces were well developed and gave good reflections. The prismatic angle $m \wedge m'$, $110 \wedge \bar{1}10$, on two crystals was found to be 86° 45′, from which $m \wedge m'''$, $1\bar{1}0 \wedge 110 = 93° 15'$.

"For comparison, measurements were made of the cleavage angle of spodumene from Branchville,† $m \wedge m''' = 93° 13'$; also of the prismatic faces of hiddenite from North Carolina,‡

* As this is an entirely new gem of peculiar beauty, a name will be given to it shortly.

† Brush and Dana: This Journal (3), xx, 257, 1880.

‡ E. S. Dana: This Journal (3), xxi, 179, 1881.

$m \wedge m = 93° 14'$. The angle $m \wedge m$ given by Dana in his System of Mineralogy is 93° 0′, and is based on measurements made with a contact goniometer by Prof. J. D. Dana on a crystal from Norwich, Mass."

A prominent feature of these specimens, and also of hiddenite, is the twinning about the *a* (100) face, and is beautifully shown on the etched crystals where the etching proceeds to the twinning plane and there makes a halt. Aside from differences in color, the fragments of the mineral are remarkably like the etched crystals of hiddenite from North Carolina.

The locality brings to mind the famous locality of Branchville, Conn., described by Brush and Dana, but there the gigantic crystals were almost entirely altered to an opaque mineral. In habit these crystals resemble the spodumene from North Carolina, and for beauty, transparency and great size of perfect material are not equalled by any known locality.

If sufficient differences are found to exist between this spodumene and the other known varieties a new name will be given to it.

40 E. 25th St., New York City.

SCIENTIFIC INTELLIGENCE.

Geology and Mineralogy.

1. *The Geology of Ascutney Mountain, Vermont;* by R. A. Daly, U. S. Geol. Survey, Bull. No. 209, 120 pp., 7 pls.—Mount Ascutney is a small eruptive mass having an unusually wide range of composition including gabbros, diorites, essexites, "Windsorite"—a new rock type—nordmarkite, porphyry, pulaskite, paisanite, syenite with granitic and mouzonitic phases, biotite granite, aplite, diabase, and camptonites. The intrusion resulted in the feldspathization of phyllitic country rock. The discussion regarding the method of intrusion is of especial interest because Ascutney is given as a concrete example of Dr. Daly's theory of overhead stoping assimilation and differentiation recently explained in this Journal (xv, 269; xvi, 107).

2. *Wisconsin Geological and Natural History Survey.*—Two volumes have recently been issued: Bulletin No. 9. Preliminary Report on the Lead and Zinc Deposits of Southwestern Wisconsin; by U. S. Grant. 97 pp., 4 pls., 8 figs. A description of the general geology of the zinc region is given, followed by a

discussion of the methods by which the metals have become concentrated in the Galena limestone. Individual mines are described and the belief expressed that an important mining industry is yet to be developed in southwestern Wisconsin. BULLETIN NO. 10. Highway Construction in Wisconsin; by E. R. BUCKLEY. 313 pp., 106 pls. The character of road-making materials and the methods of road construction are discussed by Dr. Buckley in great detail.

3. *Preliminary Note upon the Rare Metals in the Ore from the Rambler Mine, Wyoming;* by THOMAS T. READ. (Communicated.)—In the February issue of this Journal (p. 137), C. W. Dickson has pointed out that in the ores of the Sudbury district, consisting of pyrrhotite and chalcopyrite, the platinum is associated with the chalcopyrite. Whereas the ore of the Rambler mine, about forty miles west of Laramie, Wyoming, consists of covellite and chalcopyrite in nearly equal proportions and carries both platinum and palladium, it occurred to the writer that they might possibly be confined to only one of the sulphides. Experiments were accordingly begun to prove this. The crushed ore was roasted, whereupon the chalcopyrite became magnetic and could be picked out with a magnet from the roasted covellite. Upon assaying the two separately it appeared that the palladium was, apparently, associated with the covellite and the platinum with the chalcopyrite. The best assays, both upon the untreated ore and upon the slimes resulting from the electrolysis of the anode copper from Rambler ore, indicated that palladium is present, usually, in the proportion of four or five parts of palladium to one of platinum. It does not seem likely that this palladium is present as native metal and careful panning tests go to prove that it is not. On the other hand, if in fact associated with the covellite, it may occur as a sulphide and perhaps as Pd_2S, a salt described by Schneider.* The fact that palladium resembles silver in some of its physical and chemical properties lends support to this view. Further work is needed to confirm the suggestions here made.

OBITUARY.

DR. W. C. KNIGHT, professor of geology and mining in the University of Wyoming, and author of many papers on Geology and Paleontology, died on July 8 at the age of forty-one.

DR. HAMILTON LANPHERE SMITH, formerly professor of physics and astronomy in Hobart College, died on August 1 at the age of eighty-one.

M. RENARD, professor of mineralogy in the University of Ghent, has died at the age of sixty years.

* Ann. Phys. Chem., cxli, 419.

FIG. 1.—Mont Pelé from Morne des Cadets, distant 9 km. S. 15° E. from the new cone. The base of the cloud below the spine marks nearly the level of the former summit of the mountain.
Photographed March 31, 1903, for the American Museum, by E. O. Hovey.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXVI.—*The New Cone of Mont Pelé and the Gorge of the Rivière Blanche, Martinique*;* by EDMUND OTIS HOVEY. (With Plates XI–XIV.)

THE world-wide interest which was aroused in the eruptions of Mont Pelé on the island of Martinique and La Soufrière on the island of St. Vincent, which devastated large portions of those islands in May, 1902, and succeeding months, has led to a large amount of study being devoted to these volcanoes by geological commissions and independent geologists from the United States, England, France† and Germany. The purpose of the present article is to record some of the changes which have occurred in and on Mont Pelé since the observations made directly after the eruptions began were published.

Undoubtedly the most striking change which has taken place in either volcano, after the first devastation had been accomplished, is the complete alteration of the sky-line of

* In May, 1902, the author was sent by the American Museum of Natural History to study the eruptions on Martinique and St. Vincent (see Bull. Am. Mus. Nat. Hist., xvi, pp. 333–372, October, 1902, this Journal, IV, xiv, pp. 319–358, November, 1902, and the Nat. Geogr. Mag., xiii, pp. 444–459, December, 1902). In February, 1903, the same institution sent the author on a second expedition to the region to note what changes had taken place in the volcanoes since the previous visit, make additional observations under the more favorable conditions incident to the dry season, and extend his studies to the other recent volcanoes of the Caribbean chain.

† In the fall of 1902 the French government established two observing stations on Martinique, one of which (Morne des Cadets) was provided with seismographs and all other needful apparatus, and systematic and continuous observations have been maintained ever since. The commission has consisted of Professors A. Lacroix, J. Giraud and Rollet de l'Isle with the assistance of Captain L. Perney at Morne des Cadets on the west side, and Adjutant L. Guinoiseau at Assier on the east side of the island. Some of the results obtained by the commission have been utilized in preparing the historical part of this communication.

Mont Pelé. Morne Lacroix, the ancient summit of the mountain, has lost most of its former prominence above the rim of the crater, but within the old caldera a cone has risen which overtops the surrounding walls and terminates in a spine rising hundreds of feet above the main mass of the new cone.

Prior to the beginning of the present series of eruptions,* the mountain was characterized by a great crater about a half a mile across and one thousand to two thousand feet deep below the level of the crater-rim. On the southwest side the crater-rim was breached to the base by a great gash which was continued into the gorge of the Rivière Blanche. Nevis and Montserrat to-day stand as close analogues, on a smaller scale, of Mont Pelé before the eruptions. Within the great crater of Mont Pelé lay the small crater-lake known as L'Étang Sec, and from three or more openings around this lake began the uprush of ejecta which has proved of such moment in the history of the island. A cone or series of cones began forming at once, as is shown by the accounts† of several persons who visited the crater late in April and found cones of "cinders" built up about two vents west of l'Étang Sec and one to the eastward thereof.

The photographs and sketches, taken and made by the author and other observers on May 21, 1902, from the U. S. tug "Potomac," show the existence of a comparatively small cone in the crater at the head of the gorge of the Blanche. This cone was variously estimated at from 200 to 300 feet, certainly not more than 500 feet, in height, but nothing was

* Although the eruptions frequently are spoken of as having begun in May, 1902, the increasing activity of the volcano had been noted long before, and in March the sulphur gases pouring out of the volcano were causing inconvenience to the inhabitants of the coast region between Prêcheur and Ste. Philomene. The St. Pierre daily, *Les Colonies*, in its issue for April 25, 1902, says:

"Depuis quelques semaines, les habitants du quartier du Prêcheur sont constamment incommodés par une forte et désagréable odeur de soufre qui se dégage du cratère du volcan éteint. L'odeur est si forte, parfois, que les chevaux, passant sur le grand chemin du littoral, hésitent.

"Depuis cette nuit, une fumée blanche très épaisse se dègage du cratère. Elle attire de tous côtés des groups des curieux.

"Dans les hauteurs de la Pointe-Lamarre le sol est couvert d'une cendre épaisse.

"De temps en temps la fumée s'arrête pour être vomie ensuite par masses énormes. C'est sans doute alors que sont lancées les matières solides que l'on aperçoit, parait il, avec la lunette de la chambre de commerce. . . . . ."

The first outthrow of cinders seems to have occurred April 23, 1902. In conversation with the author, Mr. Fernand Clerc, a prominent citizen of Martinique, stated that he (Mr. Clerc) had visited the summit of the mountain on May 8, 1901, and had observed that a new fumarole had come into vigorous action in the southeastern part of the crater, while the two well-known vents in the western part of the crater, west of the lake known as l'Étang Sec, were more active than before.

† See *Les Colonies* for May 7, 1902, as quoted in the *Century* Magazine for August, 1902.

observed then to indicate that it was anything other than an ordinary fragmental cone built up by the pericentric deposition of ejecta from the vent or vents. This was after the first-class eruptions of May 8, 19 and 20.

The new cone must have grown with great rapidity, for Professor Heilprin's account and Mr. Varian's sketches* describing and illustrating what was seen on an ascent made May 31, indicate that it must then have attained at least the altitude of the eastern crater rim, or about 3,950 feet above the sea. The surface of l'Étang Sec according to common report was about 700 meters (2,296 feet) above tide. If this determination can be relied upon,† the new cone had an altitude of about 1,455 feet above its base on May 31, 1902. Mr. Varian's sketches and Professor Heilprin's description indicate the existence of great walls or dikes of solid rock in the new cone and Mr. George Kennan's account‡ corroborates this evidence. None of these observers reported the existence of a spine or tooth projecting above the cone.

On June 20, 1902, Mr. George Carroll Curtis and the author got occasional glimpses of the new cone during two or three hours spent on the summit of the volcano. The vertical walls reported by Heilprin, Varian and Kennan were not to be seen —perhaps they had been partly destroyed by the heavy eruption of June 6. The sides of the cone were steep and showed great masses of rock, but in the constantly shifting, momentary views obtained through the steam June 20, these were held to be enormous loose masses in a fragmental cone. The top of the cone was very jagged and the points seemed to surround a shallow crater which was the most active vent.§ No point projected far above its fellows. On June 29, from the sea, Lacroix saw a point emerge from the clouds for a moment.‖ Its altitude was determined by Ensign Deville on board the "Jouffroy" at 1353 meters (4,439 feet), which was so nearly the altitude given for old Morne Lacroix, the former summit of the mountain, that the point was not recognized as being new.

Photographs taken early in July, 1902, show a prominent elevation rising like a shark's fin above the southwestern portion of the new cone. The reports of the gendarmes of Morne

* McClure's Magazine, August, 1902.

† Le Prieur, Peyraud and Rufz however in their official report, "Eruption du Volcan de la Montagne Pelé (1851)," p. 17, published by Ruelle and Arnand, government printers, Fort de France, 1852 (?), give the altitude of the lake at 921 meters (3,021 feet) by aneroid measurement, but their determination does not seem to be accepted.

‡ The Tragedy of Pelée, p. 157. The Outlook Co., 1902..

§ See Bul. A. M. N. H., xvi, pl. 44, fig. 2 and this Journal, IV, xiv, p. 356, fig. 14, for an illustration of the cone as it was on June 20, 1902.

‖ Journal Officiel de la Martinique, October 24, 1902.

Rouge first mention seeing the new cone above the crater rim on August 11 (Lacroix), but no note is made of the existence of a terminal tooth. Heilprin states* that on August 24 he saw horns projecting obliquely from the southwestern part of the new cone, but he does not mention any spine projecting vertically from the top, nor does one of his photographs† indicate the existence of any such feature. He considered the cone to be built up of débris.‡ From the occurrence of the great eruption of August 30, Mont Pelé remained covered almost continuously with clouds and steam until early in October.

On October 10, Lacroix saw from the observatory at Assier the top of the new cone projecting like a cap above the crater rim, and having approximately the same altitude as the remains of Morne Lacroix close by. During the immediately succeeding days the cone grew rapidly, stretching in a north-south direction, and attaining an altitude of about 90 meters (295 feet) above the rim of the crater. Examination through a telescope convinced Lacroix that this top was composed of "solid" rock, not débris, and led him§ to advance the idea that Pelé now was to be classed as a *cumulo-volcano*, a theory which his subsequent observations and those of his colleague Giraud, and of Sapper,‖ Heilprin¶ and the author have fully confirmed.

October 15, 1902, the same observer** stood on the edge of the great crater, and noted that the new dentate ridge rose then but 50 meters (164 feet) above his view-point, and that it had one tooth notably higher than others. Since this date the prominent spine or tooth has grown wonderfully and varied greatly in size and form from time to time. Occasionally there has been a loss of several or even many meters from the top, but the loss has always been recovered within a short time. On November 8, the 100-meter high tooth with its almost vertical walls, the northeastern side of which looked

* Mont Pelée and the Tragedy of Martinique, p. 181. J. B. Lippincott Co., 1903.

† Ibid., plate facing p. 288. ‡ Ibid., p. 281 and elsewhere.

§ Comptes Rendus, October 27, 1902. Author's separate p. 2. *Idem*, December 1, 1902. Author's separate p. 5.

‖ Centralblatt für Min., Geol. u. Pal., 1903, p. 348.

¶ Communicated in a letter to the author under date of July 10, 1903.

** Comptes Rendus, December 1, 1902. Author's separate, p. 4. In this account Lacroix speaks of the tooth as being but 100 meters from the eastern edge of the great crater (Morne Lacroix). When one stands on the top of Morne Lacroix, the great spine or tooth seems overpoweringly near at hand; the true relations, however, can be seen best from the south or the north, whence the base of the rock spine is judged by the present writer to be not less than 150 meters from Morne Lacroix. Sapper (Centralblatt für Min., etc., pp. 350, 351) has mistaken the position of Morne Lacroix, making it part of the old Somma ring of the volcano, whereas, what there is left of it stands directly on the great crater rim and forms an integral part thereof.

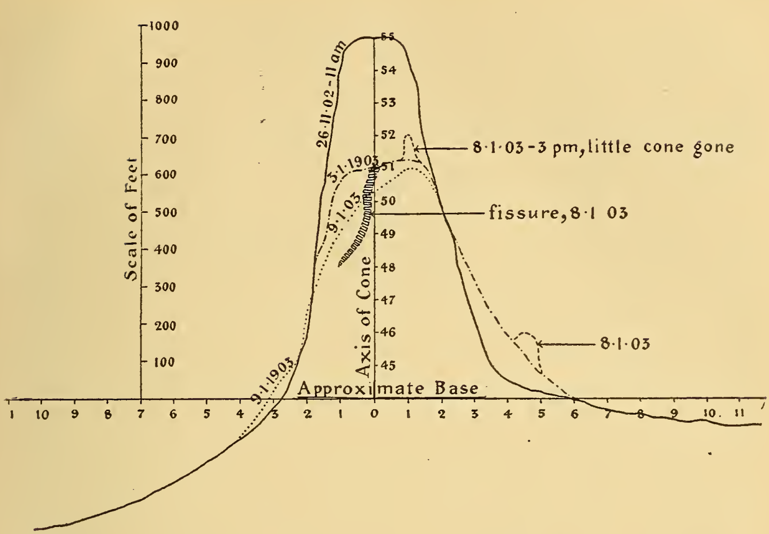


FIG. 2.—The cone of Mont Pelé, as seen from Morne Fortuné, St. Lucia. First phase, from November 26, 1902, to January 9, 1903. After sketch by Major W. M. Hodder, R.E.

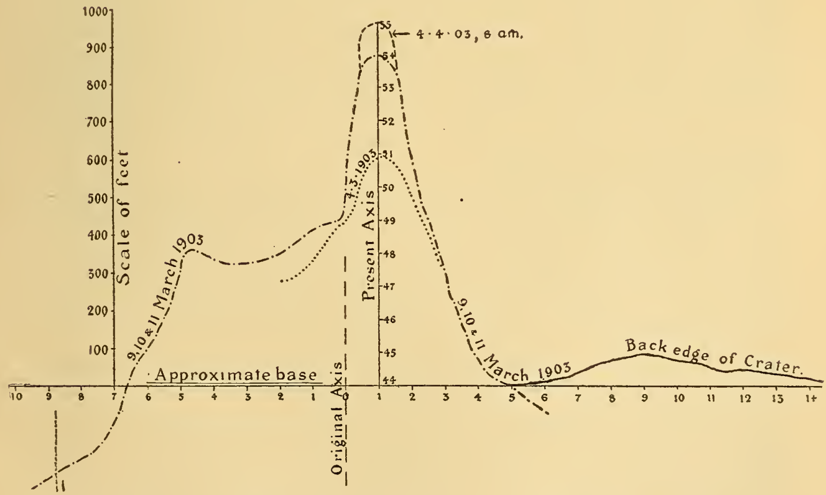


FIG. 3.—The cone of Mont Pelé, as seen from Morne Fortuné, St. Lucia. Second phase, from March 4 to April 4, 1903. After sketch made by Major W. M. Hodder, R.E.

"polished," was the absorbing feature in the view of the new cone from the crater rim beside Morne Lacroix;* this tooth was only beginning to be noticeable three weeks before. At the end of March, 1903, the French Commission† determined the apex of the spine to be 1,568 meters (5,143 feet) above the sea, or 338 meters (1,109 feet) higher than the remains of Morne Lacroix, but in the meantime there had been a period when the cone had reached nearly this maximum and had fallen again. After each considerable explosion the cone is seen to have changed more or less. Portions have fallen off and the altitude has usually diminished. One of the heaviest eruptions which have occurred since August, 1902, took place at 6:12 P. M., March 26, 1903. The next morning Captain Perney, at Morne des Cadets, found that the apex of the spine was 25 meters (82 feet) lower than before the outburst. In April the official bulletins of the commission record a further loss of six or seven meters. In the early part of May, there was a recovery of a portion of the lost altitude, but during the night of the 30th, fifty meters of height disappeared from the spine. The feeble activity of June, however, restored twenty-five meters of the loss.

The profiles reproduced herewith as figures 2 and 3 show the appearance of Mont Pelé as seen from Morne Fortuné, the barracks of the British regiment stationed at Castries, St. Lucia. The observations were made by Major W. M. Hodder of the Royal Engineer Corps at favorable times from November, 1902, to April, 1903, and supplement so well the history of the cone as given above that they are published here, with Major Hodder's permission. Morne Fortuné, at St. Lucia, is fifty nautical miles from the cone of Mont Pelé, but the clear atmosphere which prevails occasionally enables the taking of satisfactory observations.

Quoting substantially from Major Hodder's letter of April 18, 1903, regarding these sections: "Morne Fortuné [the point from which the observations were made] is 835 feet above sea level. We first saw the cone [spine] clearly on 26 November, 1902 [see fig. 2], when I fancy it had attained its maximum. We saw it again just before Christmas, but I could not measure it. It had become obviously lower, and wider at base. I got excellent observations during the first nine days in January, during which time the cone was visibly altering. After that we did not see it again until 4 March, 1903. [See fig. 3.] We had heard that during February the cone had been almost destroyed. You will observe that in the second

* A. Lacroix in Journal Officiel de la Martinique, November 22 (?), 1902. Quoted from a reprint.

† Lacroix, La Depêche Coloniale (Paris), April 30, 1903, p. 98.

phase the axis of the cone is about 100 feet east of where it was in November, also the ridge of rock to the left appears new. The actual cone is also quite different in shape. The first looked like a huge lighthouse, the second like a church steeple. You will observe how rapidly it grew upwards from 4 March to 9 March. My observations were excellent then, so that there can be no doubt about the growth.

"Piton Carbet was my test for altitude, so that refraction, etc., could not produce much proportional effect. Of course since my theodolite reads only to minutes I can count on accuracy at such a distance only within about 20 feet one way or the other, or a maximum error of about 40 feet, but as I took a series of observations I think the error must be much less. On 4 April the cone had reached the same altitude as on 26 November, 1902 [5,032 feet above the sea]."*

These profiles show very clearly the course of events in the history of the new cone during a little more than four months. Morne Fortuné is about S. 12° E. of Mont Pelé, or practically in line with Morne des Cadets, so that figures 2 and 3 give essentially the same outline as that obtained from the French observatory. The altitude for the cone, 5,032 feet, obtained by Major Hodder on November 26 indicates an increase of not less than 735 feet in 18 days, or about 41 feet per day on an average. Probably the rate was much more rapid than this at times, for the growth according to the bulletins of the French Commission was not uniform, and there were days when the cone had lost some of the height shown on the preceding day. Judging from the determination of the more favorably located French observers, Major Hodder's values are somewhat low (see page 272).

Between November 26, 1902, and January 3, 1903, according to figure 2, the spine lost about 340 feet of altitude, but became wider at base. About January 8 began the series of ruptures which split off great slabs from the southwestern side of the spine and changed its shape from that of a "lighthouse" to that of a "church steeple." The shifting of the axis to the eastward seems to have been due, in part at least, to this loss of material from the west side of the spine and in part to the elevation to the eastern side of the spine in a more nearly vertical line from the base.

From January 9 to March 3 no observations could be made from St. Lucia on account of the clouds hanging about the cone. On March 3, according to figure 3, the apex of the

* Major Hodder's letter gives the details of the triangulation by which he determined this altitude. His observations gave the altitude of Piton du Carbet as 3,936 feet, 24 feet less than the height given on the chart. In calculating the height of Mont Pelé, however, he assumed the chart to be correct.

cone was about the same elevation as on January 9; during the next six or eight days it had risen 275 feet, and in another month (April 4, 1903) it had gained another 132 feet, or more.

The author's observations of the mountain and its surroundings in 1903 extended from February 17 to March 1 inclusive, and from March 19 to April 3 inclusive, together with a perfect view of the cone from a sloop becalmed off St. Lucia on March 15. The new cone itself was seen at sufficiently close quarters for productive study on February 17, 19, 20 and 21 from St. Pierre and elsewhere on the southwest side and as far up the mountain as Morne St. Martin at an altitude of 500 meters (1,640 feet), directly in front of the V-shaped gash in the crater walls; on March 21, 25 and 26 from the crater rim, when fully three-quarters of the circuit of the crater was made; on March 28 from the Grand Réduit on the Morne Rouge—St. Pierre road; on March 29 from Morne des Cadets and from St. Pierre; on March 30 from the heights north of the Prêcheur river and then all along the coast back to Carbet; on March 31 and April 2 from the observatory at Morne des Cadets, and from the steamer "Rubis" off St. Pierre on the later date; and on April 3 from the steamer "Yare" en route to Dominica.*

The rim of the crater is irregular in height, rising from 1,070 meters (3,510 feet) beside the head of the Rivière Blanche gorge† to 1,210 meters (3,969 feet) beside the basin of the Lac des Palmistes, and it culminates in the remains of the rock-mass of Morne Lacroix, which the author determined at 1230 meters (4,034 feet) as the average of two readings of his aneroid barometer taken five hours apart on March 21, 1903.‡ North

* The author also spent twenty-four hours on or near the summit plateau (i. e., the Lac des Palmistes basin) February 27 and 28, but the dense fog and rain which caused his guide to lose the way, prevented the making of any observations of the cone. Almost the only note made during that unwilling night's sojourn on the mountain was a negative one—no sound of detonation or grumbling came through the ground to the author's ear during the twelve hours of darkness when he was lying in a gully for shelter from the fierce gale. It does not follow, however, that no explosions took place during this period; the tremendous wind would have prevented almost any sound from traversing the atmosphere contrary to it.

† In June, 1902, Mr. Curtis and the author assumed the crater (see Bull. A. M. N. H., xvi, p. 352; this Journal, IV, xiv, p. 337) as beginning at a rock mass jutting from the south side of the gorge at 3,350 feet (1,021 meters). March 26, 1903, this rock-mass was not observed, and the slight turn in the rim marking the beginning of the crater was at the altitude given here (1,070 meters). The rock-mass seen June 24 and 26, 1902, may have been partly undermined and removed by the intervening blasts and the remainder so covered with mud as not to be noticeable from fifty yards above.

‡ June 20, 1902, Mr. Curtis and the author made Morne Lacroix to be 4.200 feet (1,280 meters) above the sea. (Bull. A. M. N. H., xvi, p. 352. This Journal, IV, xiv, p. 337.) Much of the mass of what was seen then has disappeared and the height lowered 166 feet.

Fig. 4.—Mont Pelé. The new spine from beside the head of the gorge of the Rivière Blanche, looking about N. 30° E. The apex is about 500 meters (1,640 feet) above the point of observation.

Fig. 5.—Mont Pelé. The top of the new spine from the crater-rim, looking about N. 30° W.

Photographs taken March 26, 1903, for the American Museum, by E. O. Hovey.

Fig. 6.—Mont Pelé. The new spine from nearly the same point of view as the preceding. Photographed March 15, 1903, by the Comte de Laneth. The fissures and vertical grooves are well shown. The spine seems to have been about 25 meters (82 feet) lower than on March 25.

Fig. 7.—Mont Pelé. The new spine from the basin of the Lac des Palmistes, looking about S. 60° W. The apex is about 358 meters (1,174 feet) above the rim directly in front. The remains of Morne Lacroix are visible at the right on edge of the crater. Photographed March 25, 1903, for the American Museum, by E. O. Hovey.

Fig. 8.—Southwestern part of Mont Pelé, showing the ash-filled gorge of the Rivière Blanche, February 17, 1903.

Fig. 9.—Mont Pelé. A portion of the ash-filled gorge of the Rivière Blanche, February 20, 1903.

From American Museum Journal for July, 1903. Photos. by E. O. Hovey.

of Morne Lacroix the altitude of the rim decreases gradually till the middle point of the northern rim is reached, where the author got a reading of 1,130 meters (3,706 feet) beside a precipice which prevented further progress westward. The rim here dropped 10 meters, perhaps, but soon rose again, and the western edge of the crater is essentially horizontal at an elevation (judging from the heights above Prêcheur) of about 1,150 meters (3,772 feet) till the remains of Petit Bonhomme are reached. This rock-mass, the only one besides Morne Lacroix on the edge of the crater, overhangs the northern side of the gorge of the Blanche (i. e., the great gash). It seems to have lost some of its altitude and mass since June, 1902; then its altitude was judged by Curtis and the author to be about 4,000 feet (1,220 meters), while in March, 1903, it could hardly have exceeded 1,180 meters (3,870 feet).

The crater is wider than it was in June, 1902, the increase being toward the east, south and southwest. On the east and south the tuff walls are almost if not quite vertical. Numerous landslides have occurred here, and in March, 1903, it was necessary to exercise great caution in traversing the rim on account of the cracked condition of the agglomerate.* The V-shaped gash in the southwestern rim is wider, or rather the southern side of it has been cut away, but the débris from the new cone nearly fills it.

The new cone with the great spine is not central within the old crater. The most important of the openings concerned in the present series of eruptions were on the west side of the old crater-lake, L'Étang Sec, so that the new cone has been built up northwest of the center of the old crater. The spine rises from the northeastern quarter of the new cone. This has resulted in the complete filling of the northwestern quarter of the crater, making the slope of the new cone on the west and northwest sides continuous or nearly continuous with the exterior of the old crater-rim. On the northern, eastern and southern sides, between the new cone and the crater-rim, there is a shallow spiral valley which debouches into the gorge of the Rivière Blanche on the southwest. The deepest part of this valley seems to be beneath the ruins of Morne Lacroix, and is estimated to be about two hundred feet deep below the old crater-rim. It seemed much deeper (500 to 800 feet) during last June. On the southwest the new cone slopes continuously into the débris filling the gorge of the Blanche.

The new cone is a composite affair made up of fragmental ejecta from the vents, lava which has welled up or been pushed

* The edge shown in Bull. A. M. N. H., xvi, p. 44. fig. 1, and this Journal, IV, xiv, p. 356, fig. 13, has been pushed back an indeterminable number of feet and the inner slope is practically vertical instead of having an angle of 65° from the horizontal.

up from below, and masses which have fallen or been blown off from the latter. The spine or tooth consists of "solid" rock which seems to have been pushed up bodily into its present position, and to be maintained there, somewhat like the stopper in a bottle, by friction against the sides of the neck and by the expansive forces underneath. The shape of the spine, with its sides forming angles of 75°, 87° and even 90° with the horizontal, is a strong argument against the theory that it has been formed by ejected blocks or bombs which were sufficiently pasty to stick together on falling, and in favor of the "stopper" theory. Furthermore, the northeast side of the spine presents a fairly smooth, vertically grooved surface, as if it had been slickensided by friction against the side of the conduit during its ascent (see figs. 5, 6 and 7, Pl. XII, XIII). The great and sudden changes in the altitude of the spine with reference to the rest of the cone point in the same direction.

Great ribs or dikes of lava extend to the sides of the new cone from the base of the spine on the northeast, southeast, south and west. Those of the southern and southeastern portions of the cone appear in fig. 4, Pl. XII. The lofty tooth or spine is rifted and fissured in every direction, and portions of it are constantly falling from its sides. Some of the vertical fissures are very prominent on the east side and evidently connect with fluid lava beneath, for they have been observed* to become luminous at night from below upward, and the light has died out gradually from above downward. The author was not fortunate enough to witness this phenomenon, which substantiates the cumulo-volcano theory so well; he only saw the cone luminous at the base of the spine on the southwest side, which is the source from which have originated most of the recent heavy dust-flows and minor eruptions.

The northeast side of the spine is strikingly different in appearance from the southwest side thereof. The former shows a nearly smooth surface which is almost polished in its effect. In the light of the rising sun the spine looks like an enormous white monument rising above the mountain. The true color of the northeast side of the spine, however, is more a reddish brown with a whitish incrustation over a part of it. The southwest side of the spine constantly shows fresh surfaces on account of the portions falling off, and this side is gray or reddish gray in color.

No one can say yet exactly what the nature of the spine is, but the probabilities are that it is largely pumiceous in texture, judging from its being so rifted, from the readiness with which the masses break off from it and especially from the abundance of pumice in the new material filling the gorge of

* Lacroix, Comptes Rendus, Dec. 1, 1902. Author's separate p. 5.

the Rivière Blanche. The surface presented by the northeast side is probably solid and glassy through different conditions of cooling. The bombs, which lie in profusion over the basin of the Lac des Palmistes and other parts of the crater rim, are of all kinds from wholly pumiceous with a thin, densely vitreous crust to those which are mostly lithoidal in texture. The author found one true bomb on the edge of this basin which was fresh pumice in the interior with the usual fresh, densely vitreous crust about an inch in thickness, but a part of the exterior portion of the mass was formed by a lump of oxidized agglomerate. Evidently this mass had been in contact with the walls of the conduit through the old tuff beds of the volcano. Usually one can readily distinguish between bombs which are true bread-crust bombs in the sense that they are portions of the fresh magma which have been blown into the air, where they consolidated, and those which consist of fragments of ancient lava beds which have been broken off and recently reheated to a molten or plastic condition and then ejected. The latter often show characteristic surfaces of conchoidal fracture which are not observed on the former, and they are more lithoidal in texture than the former. Angular fragments of lithoidal lava, one-fourth to one-half inch (1 cm.) across, coat parts of the crater rim near the Lac des Palmistes basin, apparently blown there from the new cone.

There is now no central opening or pit-like depression in the top of the new cone corresponding to the general idea of a crater. The incomplete glimpses of the active cone obtained in June, 1902, seemed to the author* to indicate the existence at that time of a true crater in its top, as has been mentioned on page 271. The growth of the spine has destroyed this crater, if it ever had any long-continued existence. Steam issues with vigor from all parts of the cone, but especially from the top and from the southeastern portion, but not from the spine. Minor explosions occur from the southwestern side at an elevation of apparently about four thousand feet (1,220 meters) above the sea, and from the northwestern side at a somewhat greater elevation. Heavy outbursts have taken place on December 16, 1902, January 25, 1903, and March 26, 1903, with less important ones on other dates, from the southwest side of the cone near the base of the spine or from 4,400 to 4,500 feet (about 1,375 meters) above the sea. There is no one definite conduit through the cone or spine itself, to the exclusion of others.

Next to the new cone and spine, the most striking change in Pelé, to one who was familiar with the appearance of the

* Bull. A. M. N. H., xvi, p. 355, and pl. 44, fig. 2. This Journal, IV, xiv, p. 340 and fig. 14.

mountain before the eruptions began, is the filling of the gorge of the Rivière Blanche with calcined rocks and dust and ashes (lapilli) which have been poured out of the crater by the numerous eruptions (see Pl. XIV). This was the gorge extending seaward from the great gash in the southwest side of the old crater which determined the direction of the explosive volcanic blasts which swept over St. Pierre on May 8 and succeeding days. Now the lower portion of the gorge has been entirely obliterated and the adjoining plateau elevated, while the upper and deeper portion near the crater has been almost filled by the ejecta. The line of this gorge is still the favorite direction of discharge of the volcano, and the great bowlders scattered thickly over the surface attest the violence of the explosions (see fig. 9, Pl. XIV).

The material has been carried into the gorge by the dry dust-flows which have swept down from the crater and from the new cone with great velocity and terrible force. These dust-flows consist of steam saturated with dust to such an extent that the mixture acts like a highly mobile fluid. Great masses of rock are transported by it as easily as corks are carried along by water. As the flows proceed on their way they drop their load of stones and liberate vast volumes of steam which carry into the atmosphere the finest dust from the flow. The clouds of dust always are incandescent when they leave the cone, but they lose their high temperature during the latter part of their course to the sea.* The beds of ash may retain heat enough for several months to furnish occasional dust-flows. This has been observed in the re-excavated gorge of the Wallibou River, St. Vincent. On March 6, 1903, a cauliflower column of dust was seen to rise from one of the ash beds left in an angle of the gorge, and the next day the author found that a dry dust-flow had taken place, covering an acre or two of the bottom of the gorge with a hot dust- and pebble-flow from one or two feet to eight or ten feet in thickness.

Unquestionably a portion of the filling of the gorge of the Blanche has been done by flows of mud. The mud-flow which overwhelmed the Usine Guérin seems to have been caused by the waters of the Étang Sec breaking through a temporary dam formed by new ash from the western vents within the crater, but succeeding mud-flows have been caused by the rain-soaked dust and ash on the slopes of the great crater and the remainder of the drainage-basin of the Blanche descending in

* Lacroix (Comptes Rendus, 26 Jan., 1903, author's separate p. 2) determined by means of metal wires put in the path of the dust clouds about 6 km. (3¾ mi.) from the center that the temperature at that locality was less than 230° C. for the heavy cloud of December 16, 1902, while his thermometer showed the dust to retain a temperature of 125° C. two days after the eruption.

terrible avalanches. It is not difficult, however, to distinguish the mud-flows from the dust-flows, at least when both are fresh.

The mud-flows when dry are hard and compact, and are black or nearly so; the dust-flows are very light gray in color and have a calcined appearance, and are so soft and loose that one sinks in them nearly to the knees. Water, however, will cement together the surface of a dust-flow, forming a crust over it. Mud-flows, especially where their motion is comparatively slow, show a surface wrinkled transversely to the direction of the flow, while dust-flows do not present such a phenomenon.

Enormous masses of rock, some of them forty feet across, lie scattered about along the middle altitudes of the Séche-Blanche plateau, some of which were thrown there probably by the eruption of August 30, 1902, while others were ejected by the earlier outbursts. These lie out of the line of and considerably higher than the path of the dust-flows down the Blanche, hence the suggestion that they were hurled through the air during a part at least of the journey to their resting places. Some of the blocks were broken into many fragments through striking on other rocks, while others landed in ash and were not even cracked. On the summit and eastern side of the mountain, especially, "bread-crust bombs" are more numerous than they were in June.

In spite of the fresh lava forming the spine, the dikes in the new cone, and the numberless bombs, no *stream* of molten lava has issued from Pelé during the present series of eruptions. This phenomenon is probably due to the great excess of water-vapor (steam) connected with the eruptions, as compared with the amount of liquid lava rising in the conduit or series of conduits. The excess of water vapor combined with the viscidity of the lava has caused the outbursts to be violently explosive without permitting the quiet exudation of liquid rock in sufficient quantities to form streams.

The author's subsequent studies of the Grande Soufrière of Guadeloupe and the peak of Saba on the same expedition lead him to the conclusion that they have passed through the phases through which Mont Pelé is now passing, and that they belong to the same class of volcanoes. This is especially clear in the case of the Grande Soufrière, the cone of which rises above an old crater-rim which it has buried in the same way that Mont Pelé is now striving to bury its surrounding crater-walls; and great dikes intersect and spines surmount the cone. Bombs closely similar in appearance to those of Mont Pelé occur on the Grand Soufrière of Guadeloupe and on Saba.

American Museum of Natural History,
July 15, 1903.

Art. XXVII.—*The Colors of Allotropic Silver;* by J. C. Blake.

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

A great deal has been written concerning the allotropy of silver, perhaps the most remarkable phenomena described being the beautiful color effects obtained by Carey Lea.* No satisfactory explanation of such effects has ever been published, however. I have repeated most of the work described in the literature relating to "allotropic" silver, "colloidal" silver, and, to some extent, the so-called "sub-salts" of silver, and have arrived at the conclusion that all of the color effects observed may be explained by assuming the existence of three or possibly four allotropic forms of silver. Before describing these forms it will be necessary to point out specifically that each of them has a characteristic color in reflected light, and another, very nearly complementary color in transmitted light. In the case of mirrors transparent to certain wave-lengths of light, the colors of the reflected and transmitted light are commingled when such mirrors are viewed in ordinary light, to mutual obliteration. The confusion of colors resulting from the commingling of the various allotropic forms of silver among themselves, as well as the blending of colors due to the intermixture of allotropic silver and foreign colored substances, especially when such intermixtures are present in solution together, must be constantly borne in mind.

These four assumed allotropic forms of silver, together with their most pronounced characteristics and convenient modes of preparation, are as follows:

Form of silver, named after the color most readily observed.	Color in reflected light.	Color in transmitted light.
"White silver"	Nearly white	Nearly opaque, even in the thinnest films
"Blue silver"	Golden yellow	Blue
"Red silver"	Indigo-blue	Red
"Yellow silver"	Indigo-blue	Yellow

The transmitted colors are easily observable. They are the colors seen when the substances are in pseudo-solution—permanent suspension or colloidal solution,—and in mass, provided no mirror surface has been formed. The colors in reflected light, on the other hand, are observable only when a mirror surface has been formed, either by deposition on glass, by

* This Journal, xxxvii, 476, and many articles closely following. Phil. Mag., xxxi, 238, 320; xxxii, 337.

spreading on glass or other material, by undisturbed sedimentation from water, by burnishing, or by crystallization. In proportion as the mirror surface becomes more and more imperfect, the reflected light of "white silver" changes toward gray, the reflected light of "blue silver" changes to copper-colored, the substance finally appearing black. The light reflected by "yellow silver" has been observed only in the case of mirrors on glass, backed by bone-black. Indeed, "yellow silver" has been obtained satisfactorily in no other form. All four forms of silver have been obtained suspended in water, but suspensions of "blue silver" and "red silver" alone are permanent—the so-called colloidal solutions.

"White silver" is formed by treating "blue silver" and "red silver" with strong acids in considerable amount, and, consequently, whenever silver is thrown out by reduction in strongly acid solution. Roughly speaking, the greater the concentration of the acid present the more nearly white the silver will be. It is ordinarily gray, as noted by Lea in the transformation of his allotropic forms of silver to the "ordinary" form by treatment with acids. Silver nitrate reduced by ferrous sulphate in solutions sufficiently dilute gives a colloidal solution of "blue silver." In stronger solutions a gray, opaque precipitate is formed ("white silver"). If, however, a little sulphuric acid be first added to the ferrous sulphate solution, the product is plainly crystalline silver consisting of perfect and distorted microscopic octahedra; and the greater the dilution and the stronger the acid, within the limits tested, the more distinctly crystalline the silver will be and the more its color will approach to white. Such crystals are usually intermixed with grape-like clusters which, if crystalline, show no evidence of it in their external form.

"Blue silver" may readily be obtained in a great variety of ways, as indicated in Table I. It is, in fact, formed whenever silver is reduced in neutral or alkaline solution in the presence of small amounts of electrolytes and without the presence of too much organic matter. When electrolytes in sufficient amount are added to colloidal solutions of "blue silver" aggregation and subsequent sedimentation take place, the coagulum appearing blue or black when settled in mass according to its compactness and volume, the addition of salts and alkalis in sufficiently large amount tending to produce the black effect.

When such a blue or black precipitate of "blue silver" is spread upon glass while moist, the particles arrange themselves in mirror surfaces. If the preparation is made and handled in the dark, these mirrors reflect a very deep and rich golden color, transmitting blue light. No preparation was found which gave these mirrors in better form than those obtained by following Lea's directions for the preparation of his "gold silver"; that is by the action of Rochelle salt and ferrous sulphate on a solution of silver nitrate. Drained and dried quietly in masses, these preparations give Lea's golden lumps.

Heat converts this blue silver to "white silver." Pressure does the same, and with great ease in the case of mirrors on glass. Exposure to light gradually brings about the same effect, the golden reflection slowly paling. If such mirrors of "blue silver" are originally prepared in the daylight, the surface reflection at first is pale yellow, which likewise fades into white by lapse of time. This partially converted yellow reflecting silver is Lea's "intermediate" form, scarcely sensitive to pressure. Its pale yellow color may reasonably be attributed to the dilution of the golden yellow surface-reflection of "blue silver" by the white light reflected by intermingled "white silver" formed by the exposure to daylight.

Mirrors of "red silver" and of "yellow silver" on glass may be conveniently prepared by the action of silver nitrate upon an ammoniacal solution of tannic acid, and mirrors of "red silver" may likewise be readily obtained by spreading on glass portions of the red-brown precipitate formed in the mixture. The mirrors of "yellow silver" thus formed tend to change into "red silver" spontaneously, and both, when gently heated, are transformed into "blue silver." These mirrors of both forms of silver are slowly soluble in water, but mirrors of "red silver" are stable for some weeks under atmospheric conditions, ultimately becoming dull gray and lusterless.

Colloidal solutions of "red silver" of approximate purity can be readily obtained by reducing a solution of silver nitrate with ferrous citrate (ferrous sulphate and sodium citrate) in the presence of a little free alkali, according to Lea's method of obtaining his "A" form of silver. The mother liquor should be withdrawn by suction through a porous cell, as recommended by Schneider, and the red precipitate suspended in water. If no free alkali is added the solution will be blue (experiment (19) of the table), a trace of free alkali in excess rendering most collodial solutions more stable. On adding an electrolyte in sufficient amount to such a red solution, the silver is changed to "blue silver" and usually settles out. If the yellowish brown mother liquor has not been removed, the addition of an electrolyte will cause the solution to look green instead of blue, owing to the commingling of colors. To the intermixture of yellow sulphur is due the blue-green effect observed in experiments (39) and (48) of the table. "Red silver" may be looked for whenever silver is thrown out by reduction in the absence of electrolytes, or in the presence of electrolytes in small amount, accompanied by considerable amounts of organic matter or typical colloids. This effect of typical colloids in rendering colloidal solutions of the metals more stable, discovered by Faraday, has been investigated at length by Zsigmondy* and others.

Mirrors formed by spreading on glass portions of a precipitate of "red silver" containing electrolytes, like that obtained by the action of ferrous citrate, transmit red light and reflect indigo-blue light only while moist. At the moment of drying, the substance suddenly changes over to "blue silver"—a change which undoubtedly served to prevent Lea from recognizing clearly the distinction between "red silver" and "blue silver," especially as he was accustomed to observe the "surface" and the "body" colors of these substances, instead of differentiating the colors of the reflected and transmitted light. When mirrors which show the color change are viewed in ordinary light after drying, the reflected (golden) and transmitted (blue) lights are commingled and the mirrors have a beautiful bright fluorescent green appearance. This effect was seen by Lea, who determined that the blue and the yellow colors were oppositely polarized.

Another variety of green effect, noted by Gutbier† in the action of hydrazine hydrate on a solution of silver nitrate, is still more deceptive. The green in this case is due to an intermixture of "blue silver" with "yellow silver" formed simultaneously. In order to see this it is only necessary to act with hydrazine hydrate on a solution of silver nitrate at considerable dilution. No action takes place for some minutes; then an orange-yellow color appears in the liquid and a yellow mirror forms on the sides of the containing vessel. Such yellow mirrors may even form in the more concentrated green solutions. In solutions still more concentrated pure blue effects may be readily obtained. The same sequence of colors was observed less clearly in other cases.

The detailed observations are collected in the following table. It is to be understood that the solutions used, both of the silver compounds and of the reducing mixtures, were in no case very strong, those marked "concentrated" containing about five or ten grams of the material per liter, those marked "dilute" containing from a tenth to a hundredth part as much. Care was taken to avoid a local excess of any electrolytic reagents employed, and the reducing mixture was always finally added in excess of the silver compound. Except for the purpose of avoiding known precipitates, the order in which the

* Zeitschr. anal. Chem. xl, 697. Schulz and Zsigmondy, Hofmeister's Beiträge, iii, 137. Lettermorer and Meyer, Jour. prakt. Chem. lvi, 248.

† Zeitschr. anorg. Chem. xxxi, 448; xxxvii, 347.

TABLE I.

A. Water Solution of Silver Nitrate.

Reagents.	Opaque precipitate, color in reflected light.	Solutions, color in transmitted light.			
		Blue.	Red, dilute.	Red, concentrated.	Yellow.
1. Formalin	If large excess, gray	Hot or moderate excess.	On standing		
2. Formalin + NH_4OH		Mirror			If little ammonia; mirror
3. Formalin + NaOH		+			
4. Hydrazine hydrate		+			If dilute, mirror
5. Hydrazine hydrate + ether		+			"
6. Hydrazine hydrate + alcohol		+			"
7. Hydroxylamine		+			
8. Hydroxylamine sulphate + NH_4OH	Hydroxylamin sulph. in excess, gray	+			If little ammonia; mirror
9. Phenylhydrazine		+			
10. Ether + $FeSO_4$ (trace)		Add ether first, mirror			
11. Chloroform + NH_4OH		+			
12. Chloroform + $FeSO_4$		Soon changes to AgCl			
13. Carbon bisulphide + $FeSO_4$		+			
14. Hypophosphorus acid		+	Unstable		Unstable
15. Phosphorus acid		+	+		
16. Phosphorus trichloride + NH_4OH		+			
17. Phosphorus in ether					+
18. Phosphorus in ether + NH_4OH		+			
19. Sodium citrate + $FeSO_4$		+			
20. Rochelle salt + $FeSO_4$		+		If little $FeSO_4$ w. prec., turns red	
21. Rochelle salt + NaOH		+	Turbid, stable		
22. Sodium citrate + NaOH + $FeSO_4$				Stable if little $FeSO_4$	
23. Rochelle salt + NaOH + $FeSO_4$				"	
24. Tannic acid + NH_4OH or NaOH				Mirror, stable	Mirror, unstable
25. Tannic acid + NaOH + $FeSO_4$				Solution, stable, mirror, unstable	
26. Sulphur dioxide			White prec., turns pink		

TABLE I (continued).

B. Ammoniacal Solution of Silver Nitrate.

Reagents.	Opaque precipitate, color in reflected light.	Solutions, color in transmitted light. Blue.	Red, dilute.	Red, concentrated.	Yellow.
27. Formalin	If large excess, gray	+			
28. Phenylhydrazine		+			
29. Chloroform		+			
30. Chloroform + NaOH		+			
31. Methyl alcohol + NaOH		+			
32. Ethyl alcohol + NaOH		+			
33. Amyl alcohol		+			
34. Amyl alcohol + NaOH		+			
35. Hypophosphorus acid		+			
36. Phosphorus acid		+			
37. Phosphorus trichloride in NH_4OH		+			
38. Sulphur dioxide			Slowly, faint pink		
39. Acid sodium sulphite		Blue-green, unstable, contains sulphur		Unstable	Unstable
C. Ammoniacal Solution of Silver Oxide.					
40. Formalin	If large excess, yellowish-gray	+	Stable		
41. Formalin poured into silver solution; dilute	Yellowish gray changes to purple solution		Purple, stable		
42. Hydrazine hydrate		+	Stable		
43. Hydroxylamine sulphate		+	Stable		
44. Hypophosphorus acid		+	Stable		
D. Water Suspension of Silver Oxide, filtered after treatment.					
45. Hydrazine hydrate		+			
46. Hydroxylamine			Turbid, stable		
E. Water Solution of Silver Nitrate, slightly acid, with Sulphuric or Nitric Acid.					
47. Phenylhydrazine		+			
48. Acid sodium sulphite, solid or in concentrated solution		Blue-green, contains sulphur, turns black		Coagulated by shaking	Coagulated by shaking

reagents are added is usually immaterial, although if a non-electrolyte which alone does not cause reduction of the silver compound is to be added, it is best to mix it with the silver solution before adding the final reducer in order to take advantage of the power which non-electrolytes possess of inhibitating the action of electrolytes toward colloidal solutions, as already pointed out. The resulting colloidal solutions were generally clear in ordinary light, but all gave the Tyndall effect when the light was concentrated with a lens. Except when otherwise stated the colors refer to transmitted light. A + sign indicates that the phenomenon takes place without special characteristics or conditions.

In the light of the foregoing discussion most of these results will be readily understood. It will be noticed that the gray effects ("white silver") were obtained only in acid solutions. In solutions sufficiently acid such effects are always obtained. The tinge of yellow noted in experiments (40) and (41) was doubtless due to the golden reflection of intermixed "blue silver," formed while the solution was still alkaline, as in experiment (2). The blue solutions obtained in experiments (3) and (10) were especially stable. In most cases the blue color was preceded by a red, brown, green, or purple color. It was found impossible to prepare red silver solutions which were stable except in the presence of organic matter or typical inorganic colloids, as stannic acid. "Yellow silver" was never obtained in stable solution. Except for the fact that glass is colored yellow by silver and not red, this "yellow silver" might be regarded as a variety of "red silver." The other forms of silver—"white," "blue," "red"—seem sufficiently distinct to be regarded as allotropic forms until their exact properties can be investigated. So far as that work has progressed it fully bears out the idea that silver does exist in allotropic forms.* Grimm worked with silver mirrors which transmitted blue-gray light, and found that the increase in electrical conductivity induced in them by lapse of time, by heat, light, burnishing, and other agencies, all indicated a gradual change from "molecular" to "normal" silver, corresponding, in the terminology here used, to the change from "blue silver" to "white silver."

The kind advice and helpful assistance of Prof. F. A. Gooch, who suggested this subject for investigation, is gratefully acknowledged.

* Grimm, Drude's Ann. [4] v, 448.

Art. XXVIII.—*Notes on the Development of the Biserial Arm in Certain Crinoids**; by Amadeus W. Grabau.

In 1898, while working in Professor R. T. Jackson's laboratory at Harvard, I noticed that in a perfect arm of *Encrinus liliiformis* the apical portion was uniserial. This feature had never been stated to be the case in any text-books or works on crinoids that were available, and figures of this species of Encrinus always show the condition of imperfect specimens, with the apices of the arms broken away and the biserial arrangement unchanged to the end. It is, of course, well recognized that crinoids the adults of which have biserial arms are uniserial when young, the change from uniserial to biserial beginning at the tip of the arm and passing gradually proximal-wards. But that, after the animal has reached the biserial condition, the new plates added at the top begin uniserially and only later on become biserial, has never been explicitly stated, so far as I am aware, though it may have been recognized. Wachsmuth and Springer, indeed, after speaking of the arms of the young Platycrinus as strictly uniserial, go on to say: "In somewhat older specimens, the plates at the tips gradually interlock, and new ones still forming at the distal end *are strictly biserial.*† With advancing maturity the interlocking gradually extends to the proximal ends, until finally in the adult Platycrinus *the whole arm becomes biserial*,† except perhaps as to a few plates near the calyx, which permanently retain their larval condition."‡ This, as shown beyond, is not the case in any perfect specimen of Platycrinus which I have examined, not even in *P. huntsvillæ*, which is used as an illustration of their statement by Wachsmuth and Springer.

The facts here discussed have apparently been recognized by Bather, for he writes: "The change from uniserial to biserial . . . . . . begins in both ontogeny and phylogeny at the growing tip of the arm, and proceeds gradually proximal-wards."§

*This paper was originally read before the Boston Society of Natural History, Nov. 7, 1900. It was again read at the Albany meeting of the Geological Society of America, January, 1901. Its publication has been deferred in the hope of finding more illustrative material, but this has been only partially realized. A summary was published by Jackson in his memoir on localized stages in development. I am under great obligation to Professor Jackson for loan of specimens from his laboratory, to Mr. Schuchert for loan of material from the National Museum, and to Mr. Edwin Kirk, student in Columbia University, for access to his collection of crinoids.

†Italics are mine.

‡Wachsmuth and Springer, North American Crinoidea Camerata, vol. 1, p. 79.

§Bather, F. A., The Echinoderma, Part III, of Lankaster's Treatise on Zoology, p. 116, 1900.

The arguments which this paper attempts to support may be briefly stated as follows: 1. So far as observations have been made on perfect material, new arm plates introduced at the tip of the growing arm are uniserial. 2. The apical plates, at least in the less specialized biserial species, are rectangular, and change with further growth to wedge-shaped and later to biseriality. 3. This is not primarily an old age character, since this condition is found in the apical arm plates of young crinoids. (See fig. 4.)

The following theses are suggested, but not proved. They may be borne in mind in further study. *a.* In specialized or accelerated genera the newly added plate *may* be wedge-shaped instead of rectangular. *b.* In highly specialized genera the newly added plates *may* be biserial. *c.* In old age individuals the last added plates *may* never pass beyond uniseriality, the animal losing the power to further modify the plates. *d.* In extremely phylogerontic types the biserial condition of the plates *may* be dropped out, and a uniserial type thus derived from a line which at its acme was supplied with biserial arms.

The Case of Encrinus liliiformis.

In this species the uniserial condition of the terminal plates was first noted in a perfect specimen belonging to Professor R. T. Jackson of Harvard. Other perfect specimens showing the uniserial terminal plates were studied in the collection of the Boston Society of Natural History and in that of the University of Rochester. The first brachial of *Encrinus liliiformis* is nearly rectangular, while the second is axillary. Above this the 1st plate of the divided arm (No. 1 in fig. 1) is roughly an oblique parallelogram, followed by a somewhat wedging plate, the thinner edges of the wedges being directed towards each other in the two arms of a series. This much may be considered as incident upon the division of the arm. Above this, however, are three plates of the primitive rectangular type, after which (the 6th plate of the separate arm) the plates begin to wedge out, quickly becoming shorter (the 7th plate only rarely extends all the way across the arm), and by the 9th or 10th plate normal biserial conditions are established. It is not until the 16th or 17th plate, however, that the characteristic tubercles appear on the inner side of the plates. At first these tubercles are faint, but they quickly become of normal strength.

In figure 1, the right member of each of two arm groups is represented. In *a*, normal biserial conditions continue up to the 79th plate, after which the plates become more wedging. Not, however, until the 85th plate is reached are uniserial conditions found. This plate is completely wedge-shaped or cuneate and extends entirely across from side to side. This cuneate condition continues to the 87th plate, after which the wedge becomes more and more truncated, and the upper and lower sides more and more parallel, until in the 96th plate the rectangular outline of the primitive plate is all but retained. Thus there are at least twelve uniserial plates at the tip of this

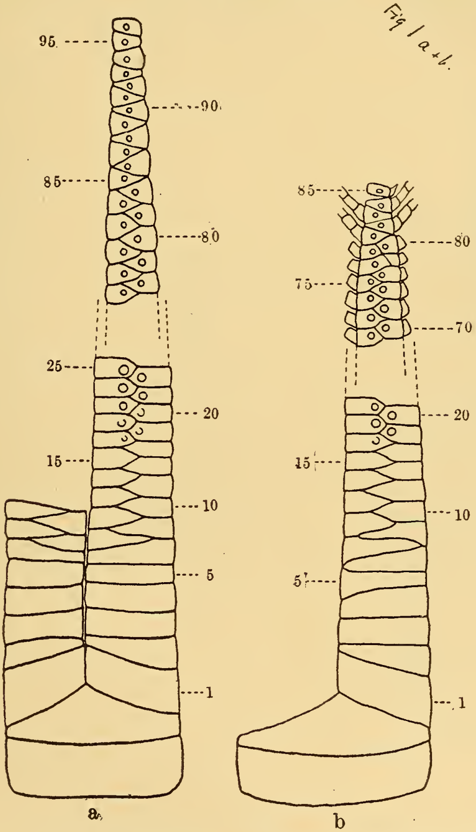
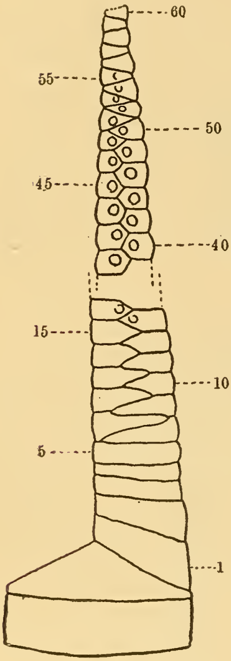


FIG. 1, *a–b*. Encrinus liliiformis. Diagram of arms showing uniserial apical plates. (Harv. Univ. Pal. Lab. Coll.)

arm. The faint development of a tubercle on the 96th plate suggests that this is not the terminal one, and that the arm is therefore not quite perfect. (Compare fig. 2.)

In an adjoining arm of the same individual (fig. 1b) biserial conditions continue to about the 80th plate, but there is a slight inequality of development in plates 77 and 78, the former of which is developed at the expense of the latter. Plate 81 is the only perfect wedge-shaped plate, the succeeding ones approaching a rectangular outline, which is nearly, if not quite, reached in plate 85 by a rather abrupt transition. It will be seen that this arm is retarded with reference to the adjoining one (fig. 1*a*). Thus in arm *b* plate 81 is still wedge-shaped, while in arm *a* the corresponding plate has already become biserial. Again, plate 85 in arm *b* is rectangular, or nearly so, while in arm *a* this plate has already become perfectly cuneate.



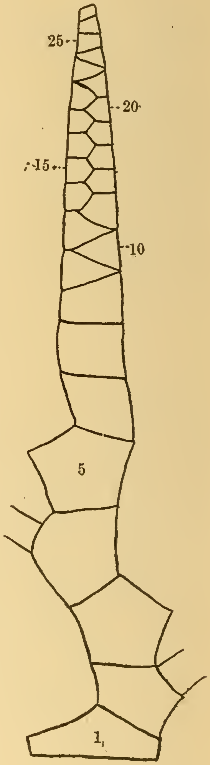


Fig. 2. Encrinus liliiformis. Diagram of arm showing uniserial apical plates. (Coll. Bost. Soc. Nat. Hist.)

Fig. 3. Platycrinus huntsvillae. Diagram of arm of young individual, showing uniserial character of plates. Length of arm, 9^{mm}. (Kirk Coll.)

Fig. 4. Platycrinus huntsvillae. Diagram of arm of youthful individual, showing uniserial apical plates. (Kirk Coll.)

Since we cannot postulate a difference in age between the two arms of the same crinoid, we must consider that one is retarded in development with reference to the other.

An arm of a somewhat younger individual in the collection of the Boston Society of Natural History is illustrated in fig. 2. Here, normal biserial conditions continue only to plate 49, after which the plates are wedged out, extending all the way across in plate 53. Plate 60, the last one preserved, approaches closely to primitive rectangular outline. Here there are at least ten uniserial plates, the upper five of which are without median tubercles. Compared with fig. 1*a* this arm is much less developed, having nearly thirty-five fewer biserial plates. This is readily accounted for if we consider specimen fig. 2 as a younger individual, which appears to be indeed the case from the size of the two specimens. A number of specimens of this species in the collection of Rochester University show uniserial conditions at the apex.

In an immature individual, in the left arm of a pair, the 76th arm plate is wedge-shaped and extends entirely across the arm. Rectangular plates are not preserved. In the adjoining right arm, which is less accelerated, the 73d and 74th plates are wedge-shaped, extending entirely across the arm, while the 75th plate is a truncated wedge.

In an older specimen (left arm) the 89th plate is wedge-shaped but does not extend entirely across. The 90th, however, does extend all the way across the arm and is the lowest uniserial plate at the apex of the arm. The 92d plate is still truncated, while the 94th is broadly truncated.

In the youngest individual yet seen (left arm) the 7th is the first biserial plate, as in adults generally. The 43d plate, however, is still wedge-shaped and uniserial. The 44th plate is slightly truncate, the 45th more so, while the terminal plate is rectangular.

A somewhat abnormal individual (left arm) has five normal rectangular plates above the two oblique ones at the base. The 8th plate still extends across but is wedge-like. The 9th hardly extends across, being still more wedge-shaped. From the 67th plate upwards the plates are wedge-shaped and uniserial, extending entirely across.

In the various species of *Encrinus liliiformis* examined we have thus found the lowest apical plate in which uniseriality is retained to be the following:

Specimen No.		1st arm.	2d arm.
4.	(Univ. of Rochester)	89	
1.	(Harvard Univ.)	85	81
3.	(Univ. of Rochester)	76	73
6.	(" ")	67	
2.	(Bost. Soc. Nat. Hist.)	52	
5.	(Univ. of Rochester)	43	

In this series, specimen 4 is the oldest, all the plates up to the 89th having matured or nearly so, while specimen 5 is the youngest, only forty-two plates having matured.

Quenstedt (Petrefactenkunde Deutschlands, iv, p. 461, pl. 106) figures what he considers the apex of a perfect arm. His figure (164) shows biseriality to the end, but with the plates more wedge-shaped. He figures a very young individual of *Encrinus liliiformis* (fig. 178, p. 406) in which the arms are

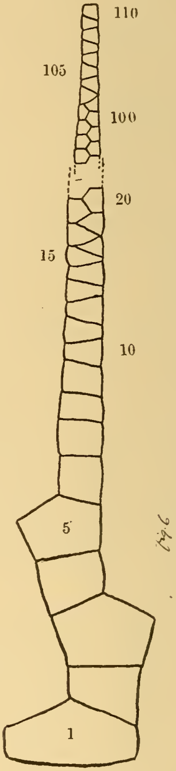


Fig. 5. Platycrinus huntsvillae. Diagram of basal plates of adult arm. (Kirk Coll.)

Fig. 6. Platycrinus hemisphericus. Diagram of arm showing terminal uniserial plates. (Harv. Univ. Pal. Lab. Coll.)

uniserial throughout, the plates of the middle arm, however, showing a wedge character. The terminal ones are perfectly quadrangular. The same thing is true, according to Beyrich, of the young of *Encrinus gracilis*.

Quenstedt also figures several cases of abnormal development of the arm tips, in which the suddenly constricted apices are uniserial. (Loc. cit., figs. 175 and 181.)

Platycrinus.

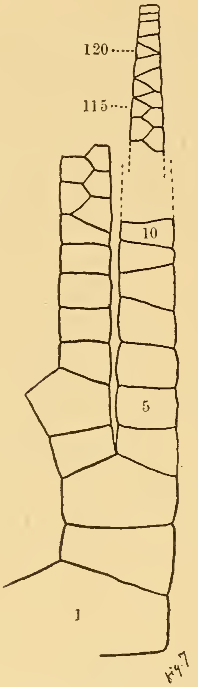
Wachsmuth and Springer figure a young *Platycrinus americanus* (N. A. Camer. Crinoidea, pl. 75, fig. 11) in which the arm joints are long and slender, with a uniserial arrangement throughout and wavy in outline. In adults of the same species the arms are biserial, except for a few joints near the calyx, the lowest of which are rectangular. Upward, these pass into wedge-shaped plates by a gradual transition. But the transition from uniserial cuneate to interlocking biserial plates is quite abrupt.

Young specimens of *Platycrinus huntsvillæ* (Troost) from the St. Louis group of Huntsville, Alabama, show uniseriality throughout. The arm represented in fig. 3 is almost 9^{mm} long. There are thirteen joints including the basal one, i. e., the first brachial; and all are more or less rectangular and much longer than wide. The cuneate stage, through which most of these joints will pass, is suggested by the manner in which the plates bulge on the pinnulate side. The pinnules at this stage are relatively large, having more the aspect of branches.

A somewhat older specimen is shown in fig. 4, the length of the arm being 12^{mm}. The 8th plate has become more wedge-like than the preceding ones, and the 9th, 10th, and 11th are regularly cuneate. Plates 12 to 21 represent the biserial stage, the first and last of these being transitional. Plate 22, however, is a uniserial cuneate plate, and so are plates 23 and 24. Plate 25 is truncated, while 27 is rectangular. It is thus seen that the biserial plates do not appear as such after that stage in development has been reached, as held by Wachsmuth and Springer; but that the newly formed plates at the apex are uniserial and rectangular, and gradually change through cuneate to a biserial interlocking condition.

In the adult of this species (fig. 5) the biserial condition has been pushed down to the 8th plate, while plates 7 and 8 have become cuneate. But somewhat more retarded individuals have been observed which, though of adult size, had eight and even nine uniserial plates at the base of the arm. A single specimen was found in which eleven uniserial plates occurred at the base of the arm, though the upper two or three were strongly cuneate and of a transitional character.

Two specimens of *Platycrinus hemisphericus* from the Keokuk of Crawfordsville have the arms shown in figures 6 and 7. In this species there are five groups of arms, each consisting of six or eight arms. Fig. 6 represents the second arm from the right, of a group of six, this arm becoming free above the fifth brachial. There are about thirteen brachials of this arm uniserial; i. e., up to and including the 18th arm plate. After this, biserial conditions prevail to the 103d plate, which is cuneate and uniserial. Then the plates become more and more truncated, until the 110th plate is nearly rectangular. In this species, according to Wachsmuth and Springer, biseriality appears late in life. They cite a specimen in which the crown measures 22^{mm} while the arms are still uniserial to the tips.*



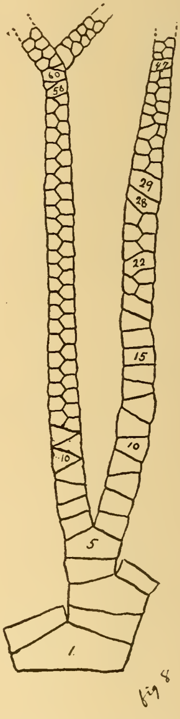


Fig. 7. Platycrinus hemisphericus. Diagram of part of group showing character of plates. (Harv. Univ. Pal. Lab. Coll.)

Fig. 8. Platycrinus hemisphericus. Diagram of two arms showing great irregularity in plates, and a bifurcation. (U. S. Nat. Mus. Coll.)

Fig. 7 represents the outer arm of a group of six in another specimen. The transition plates from uniserial to biserial at the base are broken away, but there are at least eight or nine of the uniserial ones. After that (from about the thirteenth plate from the base of the group) biserial conditions obtain through the 117th plate, after which the plates are again uniserial. An irregularity occurs in plate 119, which is

* Loc. cit., p. 704.

enlarged so as to occupy the place of two plates. The last three plates of the arm are rectangular.

A specimen of *P. hemisphericus* in the collection of the National Museum (cat. 24,183) shows some very interesting abnormal features. Fig. 8 represents two out of a group of six arms. In the right hand member represented, uniserial conditions obtain to the 18th plate. While most of these plates are more or less cuneate, some rectangular ones are interspersed. These apparently retain their primitive condition. Biseriality begins abruptly with the 19th plate. The 22d plate is a double one, or, at least, occupies the place of two. It has either retained its primitive character or developed at the expense of another plate, which became abortive. The same thing holds true of plates 28 and 29. These seem to be primitive plates. Plate 35 is developed at the expense of plate 36. Number 47 is again a uniserial plate. The terminal plates are not well enough preserved to determine their character. The next adjoining arm has seven uniserial plates; i. e., to the 12th plate of the arm. This and the two preceding ones are regularly cuneate. Above this, biseriality commences abruptly and continues uniformly through plate 57. Plates 58 and 60 appear abruptly as uniserial plates with plate 59 wedged in between them. Above plate 61 the arm divides into two branches, the left branch continuing normally biserial, the right one beginning with a uniserial plate. The terminal portions of these branches are not preserved. The same specimen shows another bifurcating arm, and several more arms with uniserial plates interspersed. Perfect specimens of this species always show the uniserial terminal plates, so far as I know; this species being, next to *Encrinus liliiformis*, one of the best to show this feature.

Dichocrinus inornatus W. *and S.*

This species from the Kinderhook of Marshall Co., Iowa (National Museum collection), has three uniserial plates at the base of the arm above the first division. After that the plates become biserial. In the arm represented in fig. 9 the 84th plate from the base has become biserial, while from the 85th upwards uniserial conditions still persist. In this arm, the apex of which is broken away, nine uniserial plates persist, the topmost one having passed but little beyond rectangular form. In a more perfect arm of the same specimen (fig. 10) twenty uniserial plates occur at the apex, the lower of which are cuneate, while the upper closely approach rectangularity.

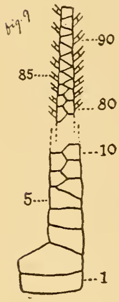
In Wachsmuth and Springer's figure of the type specimen of *Dichocrinus hamiltonensis* Worthen* the apical plates of

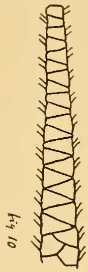
*Loc. cit., pl. 76, fig. 10.

the arm are represented as uniserial. As nearly as can be determined from the figure, there are fourteen uniserial plates above the biserial ones. The lower are cuneate, the uppermost quadrangular. In the text the arms are stated to be "composed of long, cuneate plates, which slightly interlock." I have not seen this specimen, but it is highly probable that Mr. Westergren's figure of it represents the true characters.

Acrocrinus amphora W. and S.

A specimen of this rare species from the St. Louis of Huntsville, Alabama, in the collection of Mr. E. G. Kirk, has an unusually well preserved arm. Eighteen or nineteen of the terminal plates of this arm are uniserial; the apical one is





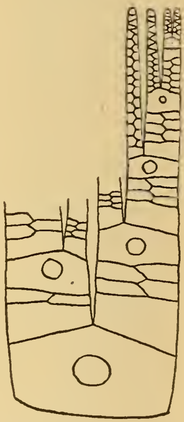


FIG. 9. Dichocrinus inornatus. Diagram of arm showing terminal uniserial plates. (U. S. Nat. Mus. Coll.)

FIG. 10. Dichocrinus inornatus. Diagram of apex of arm showing numerous uniserial plates. (U. S. Nat. Mus. Coll.)

FIG. 11. Hydreionocrinus depressus. Diagram of part of an arm group, showing mode of branching, and terminal uniserial plates. (Kirk Coll.)

quadrangular, the one next below nearly so. The third and fourth from the tip are slightly truncate, the fifth to eighth cuneate, and the ninth to eighteenth cuneate with the point of the wedge extremely thin and slender, but extending entirely across. The nineteenth to twenty-first from the tip mark the transition from the uniserial to the biserial.

Zeacrinus commaticus Miller.

This species is normally uniserial throughout. Specimens from the Warsaw limestone of Boonville, Mo., show an approach to biseriality in a few of the adult plates, which do not extend entirely across, so that the two cuneate plates of the same side are in contact for a short distance. Normally, in the adult, the plates of the arm above the middle are cuneate, but above this they are again rectangular to the tip. This cuneate character of plates is much less marked and often wanting entirely on young individuals.

Eucalyptocrinus ovalis Hall.

In a young specimen of this species from the Niagara of Waldron, Ind., the terminal plates, though not quite clearly defined, appear to extend entirely across. They furthermore seem to be cuneate to the tip. It thus seems that this species has its terminal arm plates introduced in cuneate form.

Hydreionocrinus depressus (Troost).

This species from the Chester of Sloans Valley, Ky. (Kirk Coll.), is remarkable for the curious development of its arm plates. (Fig. 11.) The first brachial is large, spine-bearing and axillary. Upon this follows on each side a simple, nearly rectangular plate, each followed in turn by one or two sets of interlocking or biserial plates. This is again followed by a single spinous axillary plate, which is in its turn succeeded on each upper face by a single large plate. On the inner branches a large number of biserial plates follow immediately upon this plate, continuing to near the apices of the arms, where they become uniserial, with rectangular terminal plates. The outer arms branch again, only a few biserial plates intervening between the first plate and the simple spinous axillary of the new division. The inner one of the branches is again simple, with biserial plates, uniserial at the apex; while the outer arm, after a few biserial plates, branches again, making the fourth division. Again the inner arm continues simple, with biserial plates changing above into uniserial, with quadrangular terminal plates. A final division, the fifth, occurs in the outer arm after a biserial interval. Each of the final divisions is biserial at first, but uniserial at the apex. It may be noted that as we proceed upwards an increasing number of biserial plates intervenes between the base of a branch and its division.

We have now seen that in the representatives of the three most important orders of crinoids, the Articulata, the Camerata, and the Fistulata, the terminal arm plates are introduced as uniserial quadrangular ossicles, which later change to cuneate and finally to a biserial interlocking condition. It may therefore be considered as highly probable that all arm plates are normally introduced as quadrangular plates in a uniserial condition. In primitive forms they never pass beyond that condition. In more specialized types the earliest arm plates alone remain in that state, the later added ones passing beyond this stage into a cuneate condition. In still more specialized types the later added plates are endowed with potential biseriality, which appears in the development after the youthful condition is passed. In accelerated types earlier and earlier plates are thus endowed, the biserial condition appearing in them in the inverse order of their age, until only the oldest one or two remain uniserial. It is to be expected that in old age individuals this endowment with potential biseriality is weakened, or perhaps absent altogether, in which case gerontic individuals would permanently remain uniserial. From this we might argue that phylogerontic types would have permanently uniserial plates in the normal adult; and thus, carrying the argument to its logical conclusion, we may have in extreme phylogerontic types uniserial plates in the greater part or the whole of the arm, even though biserial conditions obtained in ancestral types. Phylogerontic types may have biserial conditions begin very early in the adult individual, while at the same time a large number of uniserial plates are found at the summit of the arm. *Dichocrinus inornatus* (figs. 9 and 10) may possibly serve as an illustration of this. On the other hand, we may expect primitive types to have a large number of uniserial plates at the base of the arm in the adult, while at the tip of the arm only a few uniserial plates would exist at any time.

In adults of acmic types only a few uniserial plates, or none at all, should exist at the base of the arm, while at the summit, likewise, very few uniserial plates are to be looked for. In fact, it is not difficult to conceive that in highly accelerated types the newly introduced plate may be cuneate if not biserial from the beginning. For examples of this we must look among the highly accelerated Actinocrinidæ and Batocrinidæ.

While a uniserial apex in a biserial arm *may* represent old age conditions in the individual or the race, as well as a pathologic state, it does not always represent this. For uniserial apical conditions have been found in individuals of all ages, even young ones, so that it is perfectly clear that normally a uniserial character of an apical plate indicates the youth of that plate, and only secondarily the old age conditions of the individual.

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Columbia University.

Art. XXIX.—*Notes on the Geology of the Hawaiian Islands*; by J. C. Branner. (With Plate XV.)

Introduction.—The few notes I was able to make during a recent visit to Hawaii are necessarily fragmentary, but our knowledge of the geology of these islands is so strictly confined to volcanic phenomena that I venture to publish these facts for what they are worth.

It is much to be hoped that the territory will make early provision for a geological study of the group. A modest territorial survey could be readily and cheaply carried on in connection with either the government survey or with the Bishop Museum at Honolulu. Such a survey could bring together illustrative material of the greatest scientific importance and educational value, and it would reflect great credit upon the intelligence of the people of the islands.

The canyons on the north side of Hawaii.—One of the most striking features of the island of Hawaii is the series of canyons on the northern coast of the island. These gorges are mentioned by Dutton,* but he says nothing further of them than that they are valleys of erosion.

One of the most striking things about them is that as one sails round the extreme north end of the island the coast bluffs are low—averaging less than a hundred feet—and the land but little broken and under cultivation. Suddenly there is an abrupt change in the coast topography: the bluffs facing the area have an elevation of a thousand feet, and enormous gorges extend inland with almost perpendicular walls, some of which it is said are as much as 2,000 feet in height. These gorges, great and small, continue for twelve miles along the coast, where they end as suddenly as they began, against comparatively smooth arable lands. The region of gorges is covered with forests, and, save in the flat valleys, is not cultivated. The gorges extend back inland for five or six miles, in the direction of the cluster of highlands near Waimea Village. The summit of this cluster is reported to be 5,505 feet high. One of the remarkable features of these valleys is the fact that they are nearly or quite as deep at or near their upper ends as they are at their lower ends. Another striking feature is that the largest of them have flat bottoms.

This deeply eroded part receives no more rain than the adjacent areas north and south of it, and the difference in topography is due, I believe, to the difference in age between

* Hawaiian Volcanoes. By C. E. Dutton. Fourth Ann. Report U. S. Geological Survey, 1882–83, pp. 75–219. Washington, 1884.

the different portions of the island. Lava flows from Mouna Kea have encroached upon this eroded region from the south,

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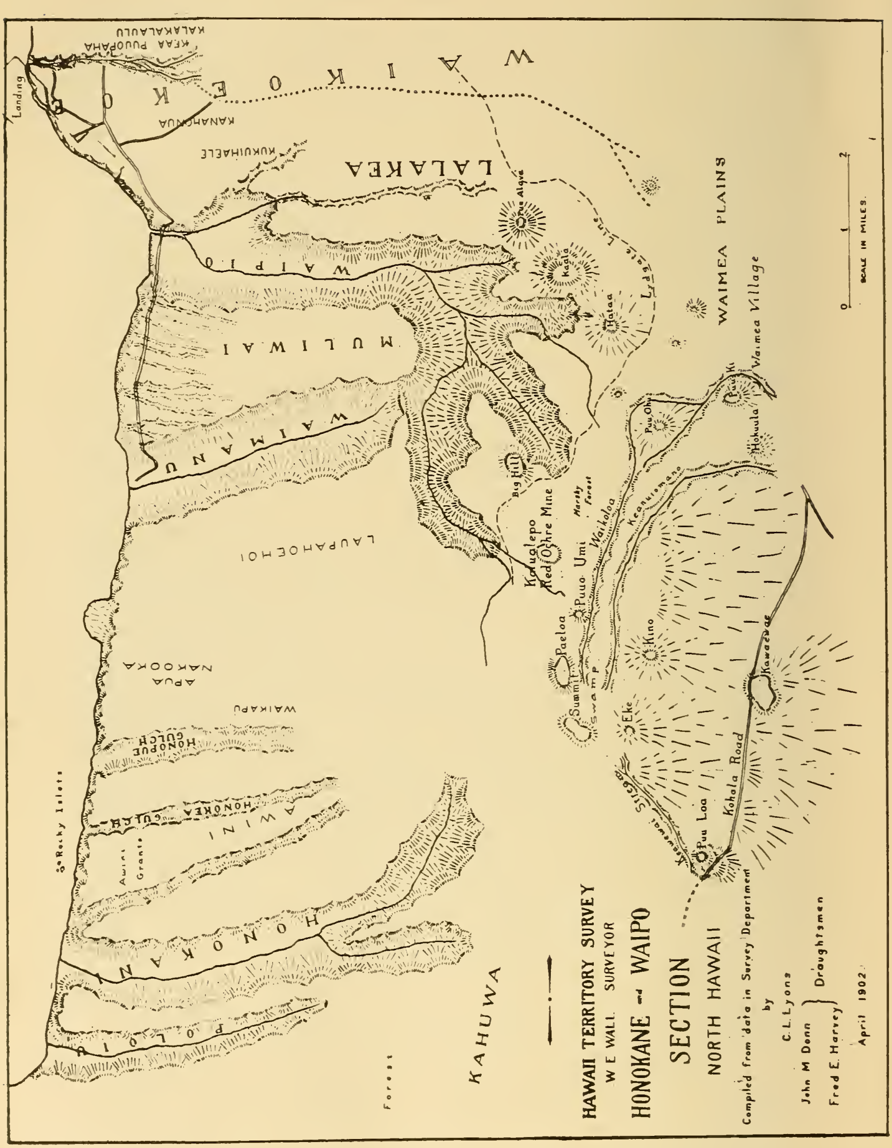

burying the lower and more eroded land surfaces, while on the north similar flows have likewise encroached upon that side.

The great height of the sea bluffs is due to the long encroachment of the sea upon this old land margin. The flat bottoms of the largest of these canyons are due to the fact that the canyons were formed as V-shaped gorges on the land and have sunk until their lower ends were filled by the sea, forming deep fjords which were soon filled by the material cut by the waves from the headlands and thrown back into them, and by the debris brought down from the land by the streams. An approximate idea of the depression might be obtained by borings in the lower ends of these valleys. I am unable to learn of any deep wells having been put down in them. The accompanying photograph (fig. 2) gives some idea of the striking topography of the Waipio Valley, the largest of the group.

Professor W. T. Brigham, the able director of the Bishop Museum at Honolulu, tells me that there are precisely similar valleys on the north side of the island of Kauai. An assistant in the office of the government surveyor at Honolulu, who has lately visited the region, also states that the bluffs on that part of Kauai are from 1,000 to 1,500 feet high, and that some of these valleys are flat-bottomed while others are V-shaped and truncated above tide level.

The origin of Pearl Harbor (Plate XV).*—The topography of Pearl Harbor is so different from that of most harbors that it is sometimes spoken of as being unusual and difficult of explanation.

Briefly, this harbor has been formed by the depression beneath the sea of a small group of dendritic valleys previously carved by subaerial erosion in horizontal beds of rocks. If this explanation is not at once suggested by a glance at the map, it is made quite plain by a brief study of the rocks exposed about the harbor. The rocks are horizontal and consist of alternate beds of volcanic tuff and coral rocks. The so-called coral rocks, however, are not necessarily all of coral but are often mixtures of shells and other fragmental calcareous materials commonly found in and about coral reefs.

The low bluffs that surround the harbor are nearly all horizontal beds of tuff. Coral rocks are shown on the government map of the harbor at a few places. Those particular points I did not examine, but there is no reason for doubting this identification of the rock, for a few miles east of the harbor the coral rocks are exposed ten or more feet above tide level. In the wells put down in the vicinity of the harbor the coral rock is also found a very short distance below tide level.

The harbor is now quite shallow over most of its area, but this shallowness is due to the silts having been washed down

* The explanation here given was presented before the Social Science Association of Honolulu in March, 1903.

2

The Waipio Valley looking up the valley from near the sea shore.

from the surrounding land and deposited in the harbor's quiet waters. In the first edition of his work upon volcanoes Dana says (p. 282) that it would be necessary to cut a channel through the outer reef in order to make a harbor of this place. Later it has been found that there is a natural opening quite through the reef, and dredging is now going on to remove the bar of sand just outside of the narrow entrance. The shallowness of the water outside and its greater depth in the neck of the harbor is caused by tidal scour.

The depth of the silts in the harbor has probably been determined, but I have not been able thus far to get any information on this subject. The topography and geology offer no suggestion further than that the depth is likely to be approximately the same as that of the harbor at Honolulu, that is, about thirty feet. The depth of the silts can be readily determined by driving steel rods down into them.

We shall readily understand the process by which this topography was made if we imagine the whole island elevated fifty or seventy-five feet and the original rock-beds restored right across the present channels. We should then have the streams that now enter the upper parts of Pearl Harbor flowing across a table land of horizontal rocks, uniting at or near the point marked A on the map and entering the sea below the boat landing through a single channel. In the course of time these streams would all cut steep-sided gorges, and where the gorges, by bends of the streams, approached each other the watershed between the two streams would be lowered below the general land surface. Such a place would eventually be an isolated bit of high land and after depression would form an island, such as we have in Mokuumeume. A depression of the island would back the sea into the valleys; the cutting of the streams would then cease, and the land silts would settle in the quiet water of the submerged channels, forming shallows, later mud-flats, and then the swampy lands.

The map of the island (see Plate XV) shows that the entrance to Pearl Harbor through the coral reef is very like that opening into the harbor of Honolulu and like another similar one known as the Kalihi entrance about two miles east of the Honolulu harbor. It seems probable, therefore, that all three of these harbors and their passages through the coral reef have been formed in the same way.

Aside from the form of Pearl Harbor there is evidence of depression of Oahu and the other islands of this group. The evidence of depression on Oahu consists partly of the great depth at which coral rock has been found in deep wells; some of the evidence on the island of Hawaii is mentioned in the preceding note upon the Waipio and other canyons.

The east base of Diamond Head.—In an article published in vol. xi of the Bulletin of the Geological Society of America, pp. 57–60, Dr. Dall speaks of certain beds at the base of Diamond Head on the island of Oahu. It is possible that my own observations about the eastern base of that mountain were not made upon the same beds as those spoken of by Dr. Dall, but as nearly as I can make out from the text of his article, the beds are the same. If so I do not agree with some of his conclusions in regard to geologic structure. He says: "It (Diamond Head) is composed of horizontal layers of tuff, interstratified with thin layers of calcareous sand, the lime from which, leached out by the rain, is redeposited in a thin superficial crust of a brilliant white, giving the effect, among the

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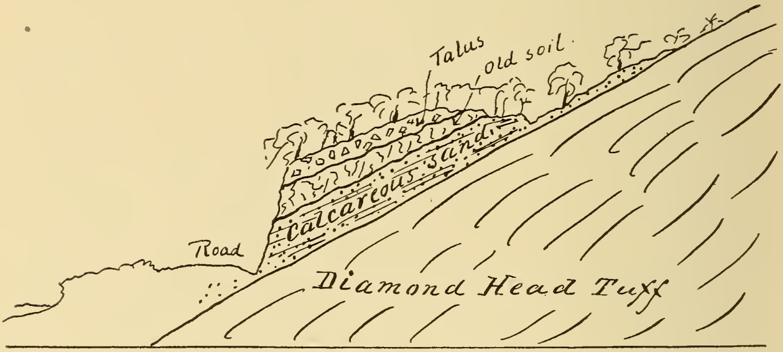

The section exposed beside the road at the southwest base of Diamond Head.

sparse arid vegetation, of a thin layer of snow. The strata of the head have not the 'onion peel' aspect of layers of successive subaerial eruptions, but are strictly horizontal and have every aspect of having been deposited in water. . . . . My observation was not carried to a point more than 100 feet above the sea-level, but it is evident that the sand layers occur, interstratified in the mass, clear to the top (700 feet). The upper limy layers appear, so far as observed, to be composed almost entirely of calcareous sand, and no shells or corals were observed in them in a recognizable state. At about 50 feet above the sea the heavy tuffs overlie the uppermost heavy layers of calcareous rock. The latter is nearly or quite horizontal, and consists of coral-sand grains more or less compactly consolidated, with occasional patches where marine fossil shells were abundant. There are hardly traces of coral larger than fine gravel and no coral masses."

Calcareous beds like those mentioned by Dr. Dall are exposed along the road leading from Waikiki beach past the lighthouse, and these beds appear to be horizontal. This appearance of horizontality, however, is deceptive and is due to the direction of the sections cut along the road. The beds are mostly calcareous sands dipping seaward an angle of from thirty to thirty-two degrees. (The highest angle of dry sand is thirty-five degrees.) The accompanying photograph shows the bedding fairly well. These beds are about fifteen feet thick at this place, and it is my opinion that they are old sand dunes that were blown up from the beach against the eastern flank of Diamond Head after the crater ceased to be active. In any case, these sands rest directly upon the Diamond Head tuffs, and are overlain by an old soil containing fossil plants, and by talus derived from the breaking up of the tuffs of the upper part of Diamond Head. The beach was farther north when these sands were blown up than it is now, for the waves have long been cutting away and encroaching upon the land.

The talus along this same road and near the lighthouse at the base of Diamond Head deserves a word. This talus for the most part has the same dip as the tuffs beneath them, but here and there they are horizontal for a short distance. Nearly all of them, however, appear to be horizontal owing to an angle at which they are cut by the road. This appearance of horizontality, therefore, is deceptive. The talus deposits are probably as much as thirty feet thick at and near the quarry south of the lighthouse. It is evident, however, that if they were really horizontal, as they were regarded by Dr. Dall, they would have a much greater thickness than they really have. The talus beds contain scattered throughout them a great many fossil shells. These shells are sometimes found in old soil layers, but they are found in almost every part of the materials, even among the loose, open angular rock fragments. These fossils are land shells. Whether they are living forms I did not ascertain. The animals have died, have fallen on the surface, and have eventually been buried by talus sliding down the steep slopes of Diamond Head. It is to these that Dr. Dall seems to refer when he says the tuffs, i. e. the talus beds, overlie the calcareous rock.

Since the above was written I have seen an article published (American Geologist, Jan., 1901) by Mr. S. E. Bishop of Honolulu in which he also disagrees with Dr. Dall in regard to the origin of the calcareous sand. He says that it is aeolian, and he accounts for the shells in the same way as the writer. I do not agree with either Mr. Dall or Mr. Bishop about the tuffs of Diamond Head having been deposited in shallow water. I think they are all land deposits; at least I

4

Aeolian sandstone at the east base of Diamond Head, Honolulu.

see no reason why they may not have been deposited on land, for in structure and contents they are similar to the other cinder cones on this and other islands of the Hawaiian group.

Cirques.—On the sides of Diamond Head near the top are many small cirques that throw light upon the origin of these topographic forms. The beds of tuff at the rim of the crater dipping outward, erosion has cut deep funnel-shaped pits—small cirques—in the outside of the crater. The back walls of these pits are very steep, even vertical or overhanging in the middle. In the development of these cirques or barriers separating two of them disappear and the cirques unite at the top but are separated below by symmetrical cones that form the spurs or ridges that radiate from the main mountain. Such cones are beautifully developed on the east face of Diamond Head. I have tried in vain to represent the cirques of Diamond Head by a diagram. The figure accompanying shows their relation to the edge of the crater on the right.

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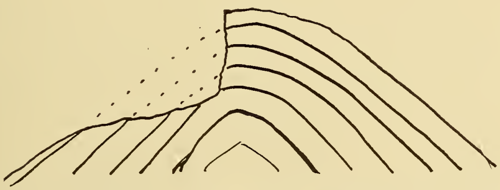

Section through a cirque on the outer rim of a crater.

On the island of Hawaii are several cirques of enormous size. The one shown on the next page and made from a photograph has walls said to be more than a thousand feet high. The upper ends of several of the deep valleys of northern Hawaii appear to have been cirques originally. It should be noted that the rocks both of Hawaii and of Diamond Head on Oahu in which the cirques are cut are of even texture throughout, and that they spall off rapidly in small angular lumps. Those who believe in the glacial origin of cirques find here good evidence that cirques both large and small may be and are formed without the aid of ice.

The craters near the Pali.—Dana mentions (Volcanoes, 2d ed.) the small crater at Pali as probably the last expiring effort of the volcanic phenomena of the island of Oahu. Mr. S. E. Bishop in his interesting paper upon the geology of Oahu, published in the Hawaiian Annual for 1901, also speaks of this crater. It occupies a striking position in relation to the topography of the island. The structural relation of its tuffs are shown by the accompanying sketch (fig. 7). It is clear that this crater

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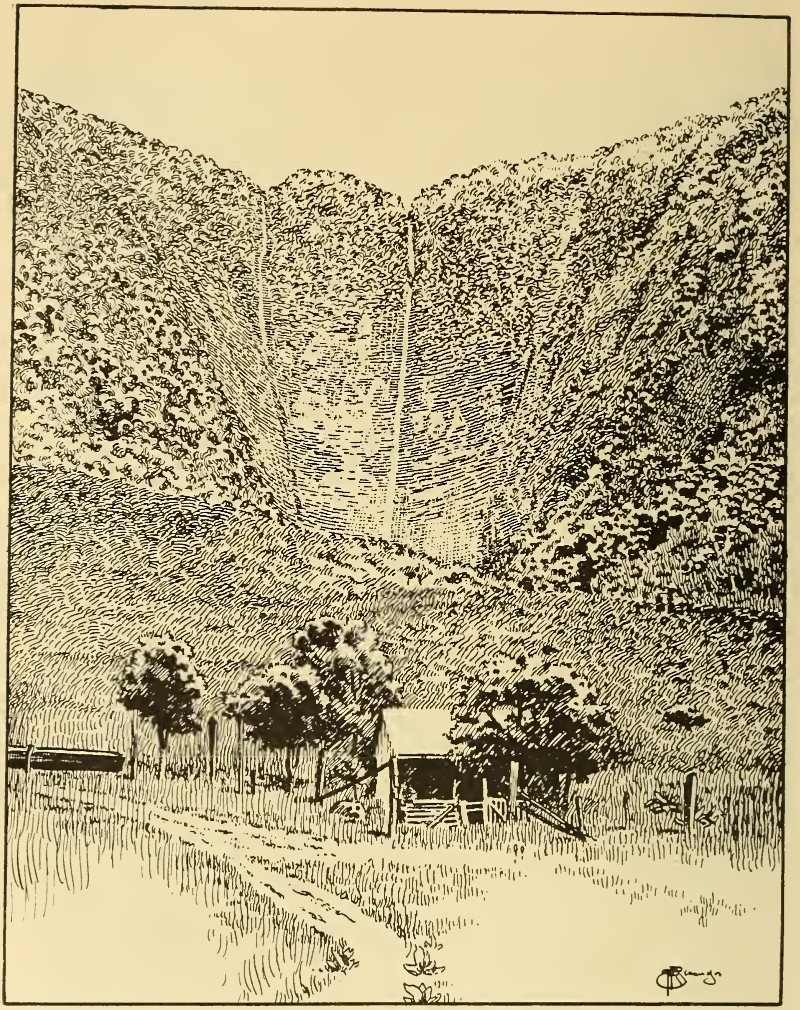

A cirque at the side of Waipio Valley, Island of Hawaii. The wall at the rear is more than a thousand feet high. From a photograph.

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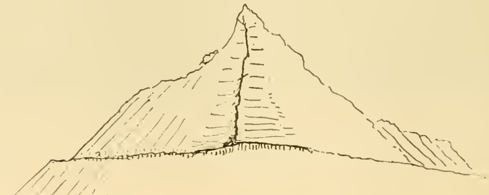

Section above the road at the Pali looking east. The horizontal beds are lavas; the sloping ones are tuffs deposited after the cutting of the steep north face of the Pali.

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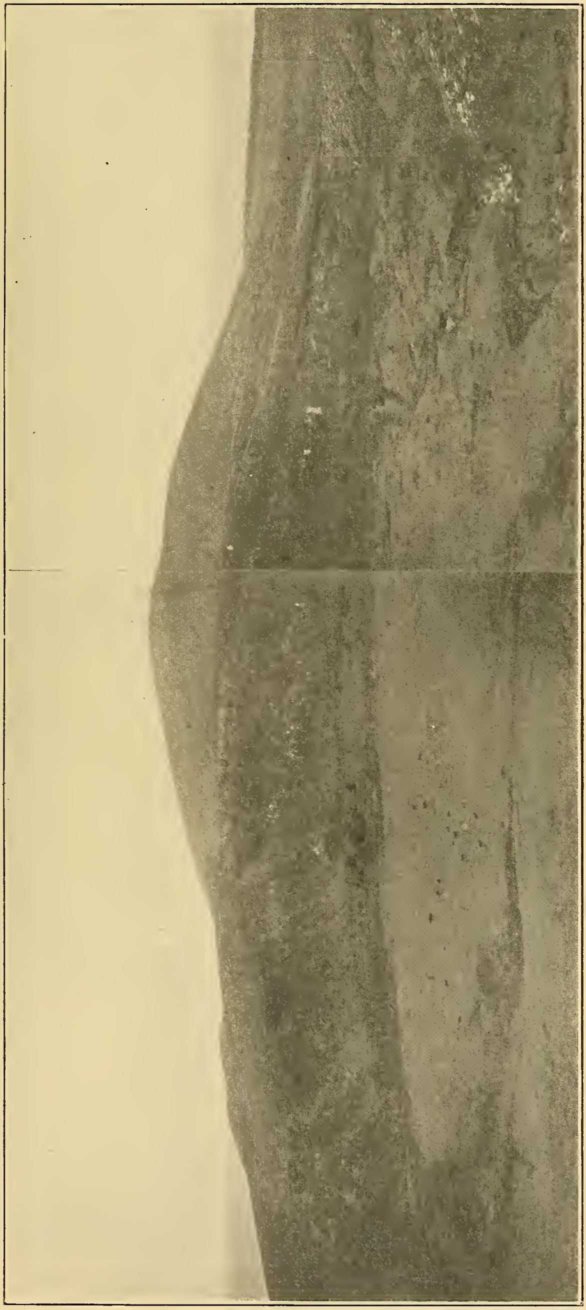

The Waipio Valley. In the foreground is the small crater just east of Kokohead. The whiteness of the beds is produced by coral fragments in the tuff. Hanauma Bay is just over the ridge and to the left of the highest hill.

became active after the excavation of the Nuuanu Valley that leads down to the city of Honolulu, and also after the removal of the northern half of the volcanic cone of which these mountains are the remnant, the cinders having fallen upon the steep —almost vertical—face of the bluffs on both sides of the Pali. The road down the north face of the mountain cuts these tuff beds at many places.

The eminence in the Nuuanu Valley on the west side of the road and less than half way from the Pali to Honolulu is also a crater. This crater, also mentioned by Mr. Bishop, is likewise necessarily newer than the Nuuanu Valley in which it is situated. I should add here that I quite agree with Mr. Bishop and with Major Dutton that subaerial erosion is quite competent to explain the more rapid wearing away of the north side of the Pali.

A small crater next to Kokohead.—The most interesting of the small craters examined on Oahu is one at the east base of

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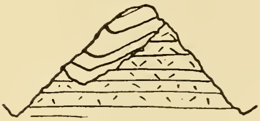

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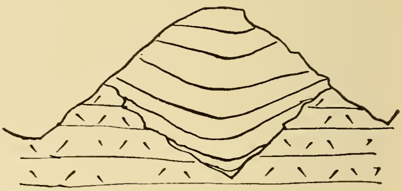

Sections exposed on the east side of Kokohead showing old gullies filled with tuff.

the great Kokohead crater at the east end of the island. Its chief interest is in the great quantity of coral blown out and now mingled with its tuffs, and in its age relation to the Kokohead crater. The Kokohead crater is newer than the basalt of the great mountain ranges, for its tuffs overlap the basalt at the west base of Kokohead. The small crater at the east base of Kokohead did not come into existence until Kokohead had ceased to be active and its sides had been deeply scored by erosion. This is shown by the fact that gulches on the east face of Kokohead were filled by the coral-laden materials blown from the smaller crater. These later materials extend half way up to the summit of Kokohead. The accompanying section is made from a photograph of one of these refilled gulches. This line of separation between the two series of tuffs is clearly visible at many places. Aside from the structural relations the two series are readily distinguishable by the great amount of coral and other calcareous materials in the newer while none is recognizable in the older series.

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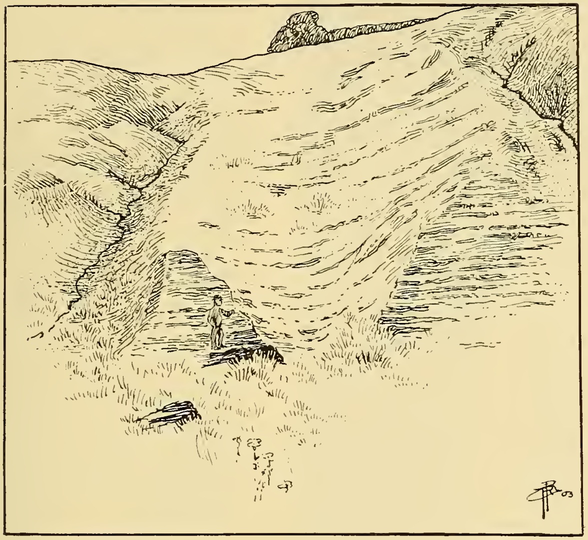

An old gully on the east side of Kokohead filled with tuff from the newer crater. From a photograph by F. E. Harvey.

The deepest part of the smaller crater is now being filled by debris washed down from the east slope of Kokohead. The west side of the small crater is now about 120 feet above the bottom of the pit. This entire wall is made up of tuffs with which are mingled corals, shells and other bits of reef rock. The lumps of coral are sometimes as much as a foot and a half in diameter, but for the most part they are smaller. These bits are usually well preserved and the life forms are readily recognizable. They are rather evenly scattered through the tuffs. The study of these fossils would be of much interest, as it would possibly show the age of the reef through which the crater broke and thus give us another clue to the ages of the various eruptions.

The beds from the smaller crater lap over and form the ridge that separates it from Hanauma Bay. This bay is not the site of a single crater as stated by Dutton,* but of several small ones. It is worthy of note also that the exposure on the sea shore that so closely resembles a section cut through to the middle of a crater is not such a section, but rather the encroachment of the sea upon this group of five or six craters.

* Fourth Ann. Rep. U. S. Geol. Survey, 218.

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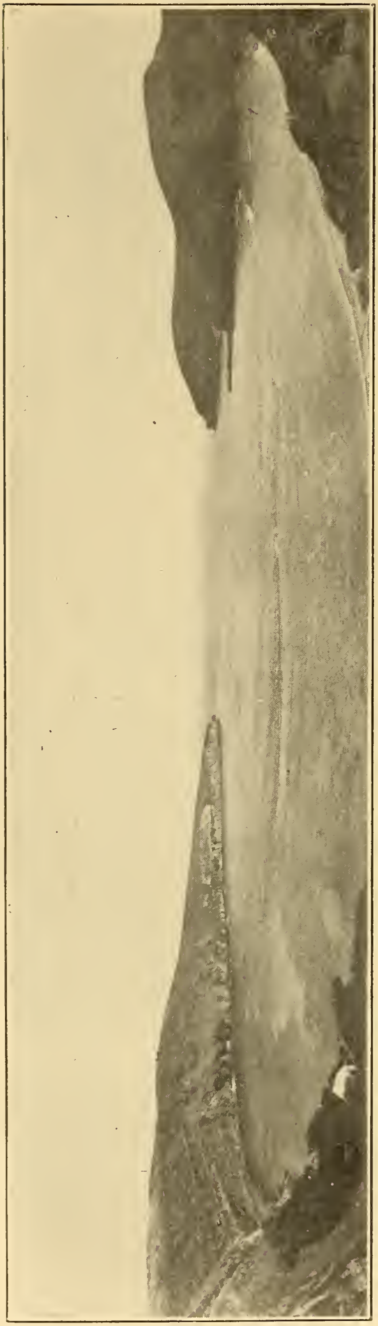

Hanauma Bay, the site of several extinct craters.

Well borings on Oahu.—Several records of wells bored for water near Honolulu are given by Dana and Hitchcock.* In addition I have, with the aid of Mr. Fred E. Harvey of the Government Survey, been able to collect several others, and these records, about forty in all, have been plotted to scale for the purpose of attempting a correlation of the beds penetrated. It was found that the characters of the materials passed through as reported are not sufficient to warrant correlation. Herewith are given four of the sections that appear to resemble each other closely. They are all in the city of Honolulu. The enormous quantity of water flowing or being pumped from the wells on Oahu afford a valuable contribution to our knowledge of subterranean waters. It is to be noted that in every instance the wells penetrate beds of coral or other calcareous rocks. These rocks appear to be built round the volcanic core of the islands, but they are sometimes interbedded with lavas, tuffs, or water-worn bowlders. The chief rainfall is in the mountains, but the waters follow down the valleys, sink into porous beds that occupy the lower ends of the valleys and pass seaward as underground waters. It

* Geology of Oahu. Bul. Geol. Soc. Amer., xi, 15–17.

is said that several places are known about the islands where these fresh waters issue beneath the sea.

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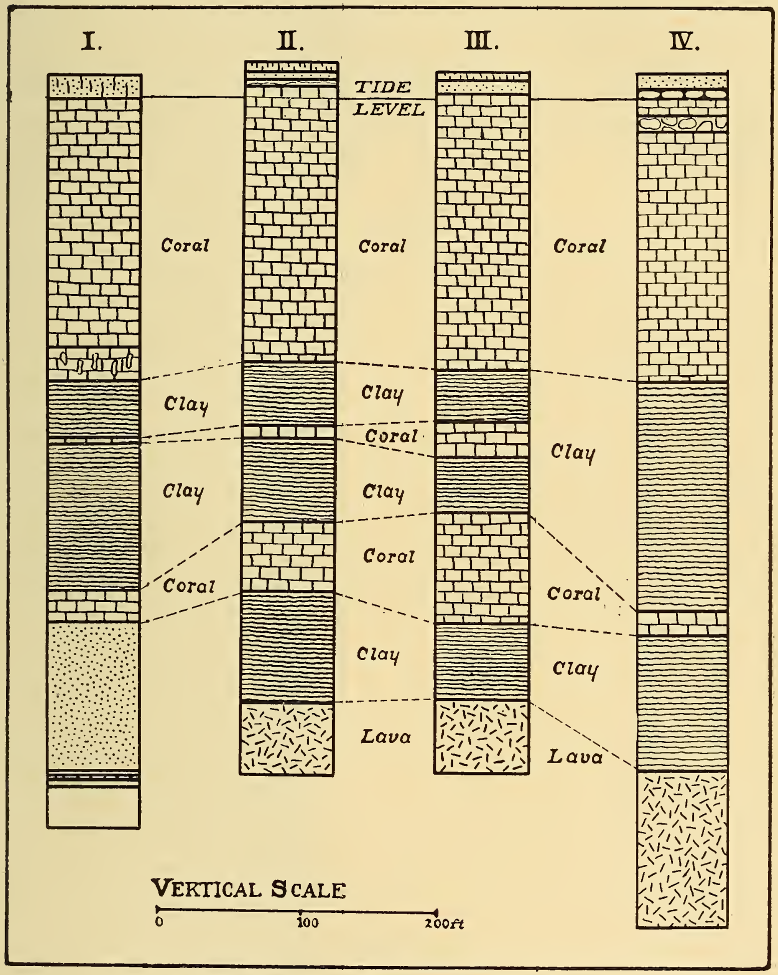
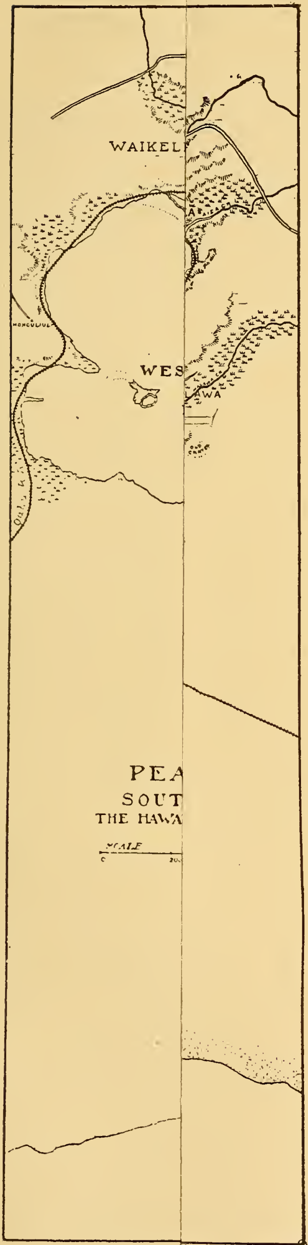


A Group of Well Records in Honolulu.

I. Mrs. Ward's well at Kukuluaeo below King st.
II. Thomas Square well near corner of Beretania and Kapiolani sts.
III. Mr. Sass' well in Kukaokahua ice works.
IV. Pumping Station, corner of Alafai and Beretania sts.

Buried soils.—The tuffs in the vicinity of Salt Lake (west of Honolulu) in many instances fell upon a region covered with forests. This is shown by the tuffs resting directly upon the old soil surfaces. These soils still retain many root impressions, while at the base of the tuffs are abundant plant fragments preserved as petrifactions. In many places by roadsides and in quarries one may see vertical holes left in the tuffs where the plants have decayed out after being buried. Examples are visible in the new cut opposite Coral Island and in the old cuts near the railway just west of Mr. Dimon's place in Moanalua. In some instances the tree trunks have been petrified and preserved. They often show branches of the plants. The largest trunks seen were about four inches in diameter.



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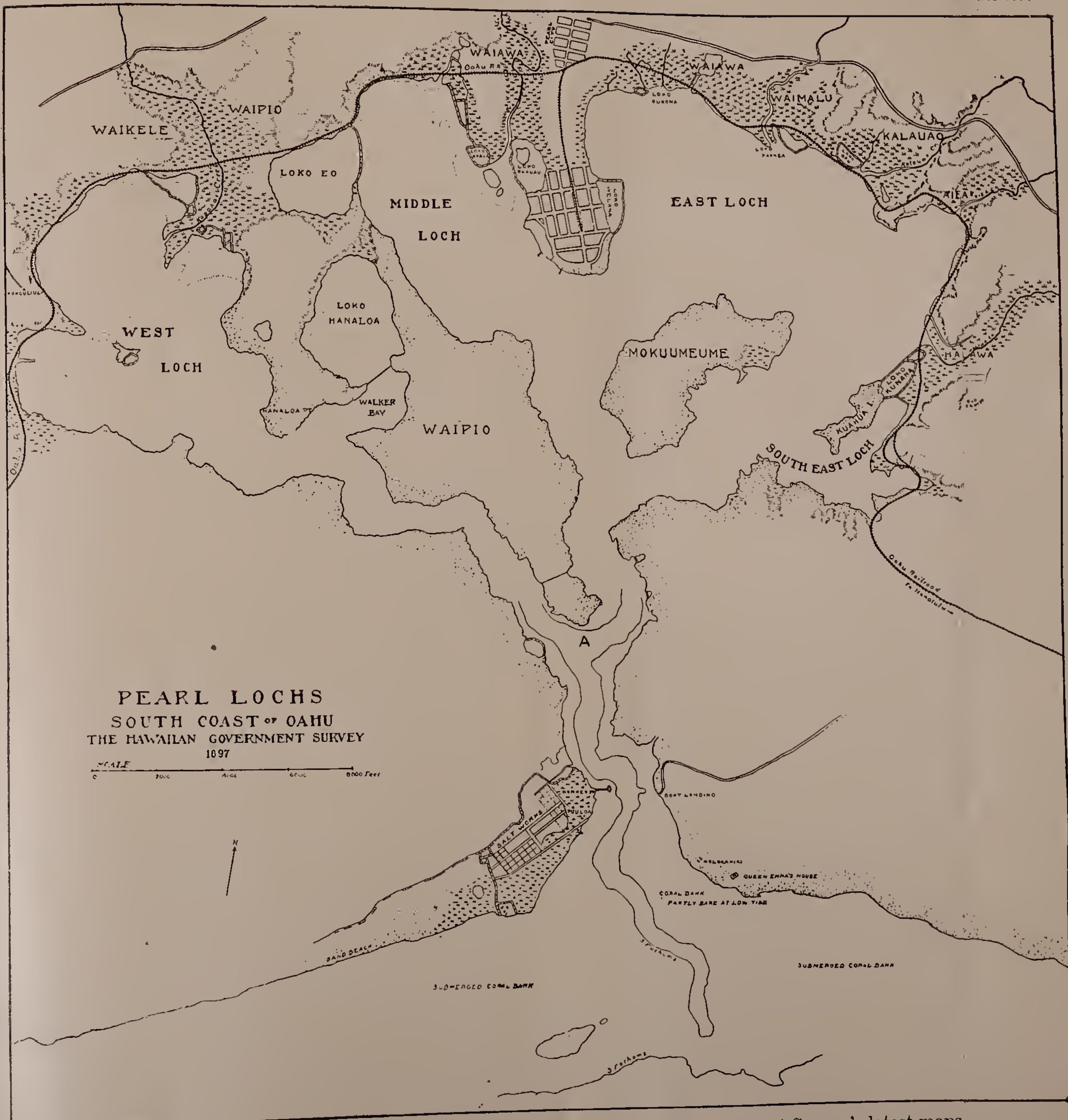

Map of Pearl Harbor or Pearl Lochs near Honolulu. From the Government Survey's latest maps.

Art. XXX.—*Recent Tuffs of the Soufrière, St. Vincent*; by Ernest Howe.

When geologists visited the region of the West Indian volcanoes after the violent eruption a year ago, a detailed study of the vast deposits of ejecta was all but impossible, and in papers which have appeared during the year, writers have confined themselves to descriptions of varied phenomena of the eruptions and to discussions of complex physical problems. Matters which for the time were of less general interest, such as the forms and character of the new deposits, were to a large extent left untouched. It was my good fortune in February last to be able to spend several days in the vicinity of the Soufrière in St. Vincent, and while there, to study under favorable conditions the enormous deposits of recent ejecta.

Geography.—The Island of St. Vincent lies just north of the Grenadines and Grenada toward the southern end of the chain of the Lesser Antilles. It is about 18 miles in length and 11 in breadth, the longer diameter having a north and south direction. It is wholly mountainous, several peaks rising over 3,500 feet above the sea, and before the last outbreak of the volcano the interior was everywhere densely wooded.

The northern third of the island is dominated by the Soufrière, between which and the abrupt cliffs of Morne Garu, the northern outlier of the hills to the south, is a well marked depression or pass leading from the eastern to the western side of the island. It is from this pass northward that the havoc was wrought, the rampart of the Morne Garu having protected the lands to the south from more than relatively slight and temporary damage.

Topography.—The Soufrière rises on all sides, with even, constructional slopes of rather low angle, to an altitude of a little over 4,000 feet. The sides of the hill have been deeply eroded by streams that have eaten back almost to the crater rim, leaving sharp, radiating spurs between them, the crests of which are in places a thousand feet above the stream-beds on either side. To the north and west abrupt cliffs look down upon the present crater; they are the remains of a much older crater-wall that Drs. Flett and Anderson have aptly compared with Monte Somma. In times past recurrent eruptions have obliterated more or less completely previous drainage systems and presented fresh initial slopes, partly controlled by earlier sculpturing, to the attack of streams. Taking this into account, as well as the only partial consolidation of the fragmental rocks, the erosion of the slopes of the Soufrière may be considered to have advanced into late youth or early maturity.

The devastated area has been admirably described by various writers, notably Drs. Anderson and Flett, in their report to the Royal Society,* and Dr. E. O. Hovey,† and a further description would involve unnecessary repetition.

The bolder forms of the consequent drainage which had been developed on the slopes of the Soufrière have been little changed as a result of the recent eruptions. Changes that have taken place are due less to the new material thrown out than to the abnormal erosion resulting from the complete removal of vegetation and the unusually heavy rains following eruptions. The effects of this erosion are naturally best observed in the areas adjoining the larger streams near their mouths. Directly after the great eruptions the valleys of the Wallibou and Rozeau Dry rivers were almost completely filled in their lower portions with the ejected material from the Soufrière, and about a mile back from the coast these accumulations were nearly a hundred feet in depth, according to the accounts of many who saw them soon after the eruptions, and my own observations some months later confirmed these estimates. From the regions of maximum accumulation there was a gradual decrease in thickness towards the mouths of the rivers, where landslides occurred, leaving cliffs of the older and younger tuffs not more than 20 feet high. The old drainage systems were still sufficiently well marked to direct the new streams that were at once formed, and these began actively to attack the new deposits, with the result that at the time of my visit there had been developed a miniature system of canyons which showed in their nearly vertical walls excellent sections of recent deposits.

Recent deposits.—The ejecta of the recent eruptions now occur in formations of three distinct types, with characters directly related to their modes of origin. The composition of all of them is essentially the same and corresponds closely to that of some of the larger ejected blocks, which appear to be basalts, rich in plagioclase. The material varies from the finest powder to blocks of massive rock several feet in diameter, the most abundant being a coarse sand in which broken crystals of plagioclase, augite and a little hornblende may be distinguished. In the great eruption of September considerable pumice was thrown out, hardly any of which is to be found in the earlier deposits.

The most conspicuous deposits and probably the oldest are

*Preliminary Report on the Recent Eruption of the Soufrière in St. Vincent, and of a visit to Mount Pelèe, in Martinique. Proc. Royal Soc., vol. 70, pp. 423–445. London, 1902.

†Martinique and St. Vincent: A Preliminary Report upon the Eruptions of 1902. Bull. Am. Mus. Nat. Hist., vol. xvi, Art. 26, pp. 333–372, 1902. This Journal (4) xiv, 319–359.

the valley fillings. Hovey says of them: "The chief of these beds were formed in the Wallibou, Trespé and Rozeau valleys, on the leeward (west) side, and in the valleys of the Rabaka Dry River and its tributaries, on the windward (east) slope, with by far the greatest thickness along the Wallibou and Rabaka Dry rivers. In the valley of the Wallibou the deposits were not less than 60 feet deep in places, while in the Rabaka Dry River the fresh material filled a gorge which is said to have been 200 feet deep before the eruptions began."* These tuffs, now well exposed in typical "bad-land" topography, consist of a mixture of clay and fine grit, with numerous coarser, angular rock fragments seldom larger than a clenched fist. The prevailing color is a bluish gray where they are moist, but some deposits of the September eruption, still hot and causing secondary steam eruptions, are of a light reddish brown or straw color. The ejecta of repeated eruptions, accumulating layer upon layer, have produced a fairly well marked stratification in these beds, the individual strata, for the most part, consisting of unassorted materials.

Resting in places upon the deposits just described, and everywhere covering the hillsides and ridges, are accumulations of quite a different kind, ranging in thickness from a few inches to five or six feet. They are in all cases distinctly stratified and extremely uniform in character. The lower portions consist of typical unconsolidated lapilli, slightly coarser than peas and becoming smaller in size upward, and mixed with a fine sand until the top layer of the finest dust is reached, the line between the two sorts of materials always being a sharp one. This upper member has been converted into mud by the rains and has subsequently hardened into a firm crust, two to six inches thick, which protects the unconsolidated material below. On close examination, this crust is found to consist of numerous layers or overlapping lenses made up of small pellets of clay as large as buck-shot, closely packed, but not mashed, together. When not too crumbling, portions may be removed whose structure at once suggests that of an oolitic limestone. Material of precisely the same character was collected from the tuffs of Montserrat, and I was told that similar layers have been found in the older deposits of St. Vincent. Last summer, at the crater rim of Kilauea in the Hawaiian Islands, Dr. Whitman Cross collected a quantity of pellets, which differ in no way from those that came from St. Vincent. This structure would seem to be explained by the fact that at the time of violent eruptions, and after the fall of the coarser material, particles of dust still held in suspension would be attracted to the globules of condensing steam, which, on fall-

*Op. cit., p. 342.

ing, would accumulate more and more of the fine material, until, on reaching the ground, they would be in the form of hard clay pellets. When I visited the crater, such drops, although much diluted, were falling almost continuously, following the small intermittent eruptions of steam and mud that were taking place from time to time. Flett and Anderson make reference to the same phenomenon in speaking of the Soufrière. They say: "Before midday there had been very heavy rain-showers, and it was noticed that the rain-drops carried down fine particles of ash."* And again, in describing the eruption of Pelée, which they witnessed: "In a minute or two fine, grey ash, moist and clinging together in small globules, poured down upon us. After that for some time there was a rain of dry, grey ashes."†

It may not be out of place to suggest here that this globular oolitic structure might be looked for in older tuffs in other parts of the world, as for example, in the great Tertiary deposits of the Rocky Mountains, and that its occurrence might serve as a means of indicating the proximity of the vent from which the breccias and tuffs were derived, since from the nature of their origin, deposits of this character could not occur at any great distances from the source of supply.

The third kind of deposit is stream-laid volcanic debris in the bottoms of the canyons near where they empty into the sea. This is in all probability largely composed of recent ejecta, but there is considerable old material mixed with it, such as fragments removed from the older tuffs exposed by erosion. These fluviatile deposits are only prominent near the mouths of the larger streams, and are hardly to be separated from the submarine deltas where an enormous quantity of material has been laid down. Unfortunately nothing is known of the changes in depth that have taken place along the coastline, nor of the effect of coastal landslips that continued to take place for some time after eruptions. These fluviatile deposits, plainly due to the overloading of the streams during the rainy season, are of only relative importance in St. Vincent, and the chances are that after another period of heavy rains only faint traces of them will be left. They are of interest, however, for purposes of comparison with tuffs of other regions, where similar deposits should be found, and where, on account of included fragments of older rocks, the actual age relations with other tuffs of the same series of eruptions might be misinterpreted. They are obviously the youngest deposits in St. Vincent.

Where fresh sections of the older and younger tuffs have been exposed by landslips from the ends of small spurs and

* Op. cit., p. 428. † Op. cit., p. 443.

ridges, along the coast, an interesting structure is brought out. Deposits of the second kind, following as they do the rolling surfaces of the ridges and sides of the spurs, appear to have been compressed into a series of anticlinal folds. Precisely this structure occurs in the sea-cliffs about one mile south of Basse Terre, Guadeloupe, where the unconformable relations with the underlying beds are obscured and the pseudo-folding most perfect and deceptive.

Mode of Origin.—Whatever interest the deposits may have depends very largely upon their mode of origin, and in regard to this there is considerable trustworthy information.

The events attending the first eruption of the Soufrière, as reported by eye-witnesses, may be briefly summarized as follows:

On Wednesday, May 7, 1902, explosions occurred and vast clouds of steam rose from the Soufrière, but no damage was done, and only a film of fine dust was noticed on the leaves of the trees on the lower slopes. Almost at the same time, streams such as the Wallibou and Rabaka became raging torrents of hot, muddy water, probably due to the overflow of crater lake. According to information which I received from several persons who witnessed the eruptions, no mud-flows occurred, and I could find no evidence in the deposits themselves to show that they had descended directly from the crater as mud streams. Doubtless these torrents scoured their stream-beds clean, and possibly removed a little soil and vegetation, but brought about no marked changes. It was not until the early afternoon of this same day that the eruptions reached destructive violence, when an enormous black cloud, "laden with hot dust, swept with terrific velocity down the mountain-side, burying the country in hot sand, suffocating and burning all living creatures in its path, and devouring the rich vegetation of the hill with one burning blast."* Although added to by subsequent violent eruptions, it was at this time that the great tuff beds in the valleys were formed. The exact nature of this "down-blast" may not be clearly understood as yet, but the fact of its occurrence in St. Vincent and of a similar one in Martinique cannot be questioned. Briefly, its effect was to sweep the ridges clean and to fill the ravines and valleys with the enormous quantities of hot dust and lapilli with which it was charged, in the same way that depressions and spots protected from the wind are filled with great drifts of snow by a driving storm. Deep deposits did not occur in the upper portions of the ravines, since they radiated from the crater and lay directly in the line of the blast, which could sweep them

*Anderson and Flett, op. cit., p. 427.

as clean as the ridges. It was only in the lower valleys, whose directions were more or less transverse to that of the blast, that great accumulations of ejecta were formed. Following this blast came a fall of lapilli and dust from clouds that had been carried upward, and not until then were the ridges and upper ravines covered with new material to an appreciable extent.

In all probability these events did not take place in as simple a manner as has been indicated, but were complicated by repeated eruptions of greater or less intensity, but which would hardly modify the general relations of the two deposits. What did undoubtedly affect the character of the deposits filling the valleys were torrents, due to the unusual precipitation of rain connected with the eruptions. The action of these streams was very interesting and peculiar and was described in detail by the first observers. The loose and unconsolidated materials were picked up so readily by the torrents that the streams became overloaded and clogged, and dams were formed which soon gave way, permitting a rush of accumulated and partly cleared water to lower portions of the channel, where the process was repeated. Hovey,* in speaking of the Wallibou River, describes how "it cut into and undermined the beds of dust and lapilli along the banks. Its waters became so overloaded with sediment that they could only flow in pulsations, showing that intervals of time were needed by the stream to gather strength to force its way along with its burden." Water was also soaking into the beds of extremely hot ejecta and being converted into steam, which broke forth at intervals with force enough to throw dams across the streams and to divert them from their channels. These processes undoubtedly did much to add to the incoherent character of the valley fillings and to obliterate in many instances their original stratification.

Of the submarine deposits nothing is known. Extensive deltas were developed at the mouths of the larger streams, only to disappear after a brief existence, the angle of the submarine slopes being too great to support the unwonted loads which had been suddenly laid down upon them.

One cannot fail to be impressed by the geological processes that are being carried on at the Soufrière—the ejection and deposition of comminuted rock, the first partial consolidation into stratified tuffs, their erosion, and redeposition on the sea-bottom. For years to come the West Indian volcanoes should continue to be worthy of the detailed study of the general geologist, as well as the petrographer and physicist.

U. S. Geological Survey, Washington, D. C.

*Op. cit., p. 344.

ART. XXXI.—*Discovery of Fossil Insects in the Permian of Kansas;* by E. H. SELLARDS.

THE question of the age of the Upper Paleozoic formations of Kansas has occasioned considerable difference of opinion among geologists and paleontologists. Professor C. S. Prosser, who, among others, has been a thorough student of the problem, in a recent very full review of the evidence from zoöpaleontology and stratigraphy, concludes, in harmony with his earlier results, that "the weight of evidence" favors "correlating the upper formations with the Permian." * In his synopsis of the views of geologists who have written on the subject, however, Professor Prosser makes it evident that this opinion, although perhaps receiving the greatest support, is not unanimous. Any additional paleontological evidence is therefore especially welcome. Until recently the discussion has been confined largely to the marine invertebrates, which unfortunately become extremely rare near the top of the series.

During the summer of 1902 the writer discovered a rich insect locality in the Marion formation, in the southern part of Dickinson county, Kansas. The condition of preservation of the insects is exceptionally good. A very large proportion of the wings are complete and their details of structure clear, even the minute hairs often being present. The entire bodies of the insects are occasionally preserved. A considerable number of insects had been previously obtained from the Coal Measures near Lawrence, Kansas, mostly by the University Geological Survey of Kansas. The insects from the Marion seem on the whole very different from those of the Lawrence shales and other Coal Measure deposits. The Coal Measure insects, as far as known, are on the average large; on the contrary, most of the Marion species are small. Cockroaches at this new locality are much in the minority. Of some six hundred specimens collected, not more than about sixteen are cockroaches and these are of small size and belong for the most part to the Coal Measure and Permian genus *Etoblattina.* Fossil plants were discovered in the Marion in 1899.† The collections made from the Marion and Wellington (?) during 1899–1900 seemed to the writer at that time to indicate a Lower Permian flora.‡ These collections have since been increased, and it may now be said with a good deal of confidence that, although a few species have survived from the Upper Coal Measures, the Marion contains on the whole a dis-

* Journal of Geology, vol. x, p. 728, 1902.

† The occurrence of two specimens of insects among the plants was noted by the writer in connection with the description of the Tæniopterid ferns from this formation (Kansas Univ. Quart., vol. x, p. 11, 1901).

‡ Trans. Kansas Acad. Sci., vol. xvii, p. 208, 1899–1900.

tinctly Permian flora. The marked change in the insect fauna in passing from the Lawrence shales to the Marion formation is therefore paralleled by the plant evolution.

From the biological side the discovery of a productive insect horizon in deposits of Permian age is of the greatest importance. Aside from the cockroaches, the number of insects known from the Permian system is confined to a few interesting specimens. The terrestrial habits of most adult insects, together with their soft bodies, cause them, as a rule, to be rare fossils as compared with marine shelled animals, especially in Paleozoic deposits. The conditions of deposition, however, during the latter part of the Paleozoic seem to have been more favorable for the preservation of insects as well as of plants, and thanks, especially, to the faithful researches of Scudder in this country and of Brongniart and others in Europe, a good deal is now known of Coal Measure insects. The degree of organization of Upper Carboniferous insects indicates a much earlier origin for the class, and their remains, if not already found, may be confidently expected in pre-Carboniferous deposits. Unfortunately there seems to be as yet no unquestioned record of the occurrence of Hexapoda back of the Carboniferous. Insects have been reported from three pre-Carboniferous localities,—Ordovician (Lower Silurian) of Sweden, Middle Silurian of France, and Devonian of Canada. Regarding the Ordovician fossil, Professor Moberg with commendable frankness has written the writer that, as no more examples of *Protocimex siluricus* have been observed, he is now of the opinion that it is not impossible that he and the entomologist may have been misled by a "lusus naturæ." Brongniart, although still retaining faith in the Silurian fossil *Paleoblattina Douvilli*, admits that it has been regarded by some as a piece of a trilobite. According to White, Kidston, and Ami, the "fern ledges" at St. John, New Brunswick, heretofore regarded as Devonian and from which several insects have been obtained, contain a Carboniferous flora closely related to that of the lower part of the Upper Carboniferous, or the Meso-Carboniferous. Papers by Dr. G. F. Matthew may be consulted, however, in which the deposits are referred to a much earlier terrain.

The classification of Paleozoic insects and their relation to Mesozoic and recent forms are still in an unsettled condition. The Permian types coming in the interval between the better known forms of the Coal Measures on the one hand and of the Mesozoic on the other will perhaps throw some additional light on the interrelation of the older and younger members of the class.

Paleontological Laboratory, Yale University Museum,
New Haven, Conn., June 24, 1903.

ART. XXXII.—*Note on the Constants of Coronas*; by C. BARUS.

1. IN the course of my work with atmospheric nucleation, it appeared that the standardization of coronas which I published some time ago* is inadequate for the purpose. A revision has become necessary of such a kind as to include the features which have developed in the intervening time, in particular the occurrence of marked periodicity in the nucleation (n particles per cubic centim.) as related to aperture, and of the exhaustion losses of which there was no indication in my earlier work. The origin of the latter was for a long time puzzling, but they are now completely referable to the subsidence of fog during the brief period within which the coronas are visible and the nuclei loaded by condensation. I will show elsewhere that if successive identical partial exhaustions of the volume ratio y are presupposed, the phenomena are expressed by

$$n_z = n_Z\, 10^{(z-Z)\log y} \prod_{Z}^{z-1} (1 - S/s^2)$$

where Z is the number of the fiducial and z of any subsequent exhaustion, n_Z and n_z the corresponding nucleations, S the appropriate subsidence constant and s the current relative aperture of the corona. Π is the function $(1-S/s_Z^2)(1-S/s_{Z+1}^2)$ . . . . . $(1-S/s_{z-1}^2)$. The constant S may either be computed from observation of s and n in the region of normal coronas (where $n = C s^3$ is known) or it may be computed from the observed time of fog suspension. Clearly all observations must be made strictly in time series.

To be independent of the optics of coronas which are not worked out, I have determined the diameter of fog particles from subsidence experiments. Thus for an observed aperture, s_0, the diameter d_0, from subsidence gives the fundamental constant, $s_0 d_0 = a''$. This constant differs materially from $a' = d\,s$ as found from diffraction measurements, as the tables show. The corresponding n values in the former case are about twice as large as the n values in the latter, seeing that the cube of a enters the equations.

2. *Explanation of tables.*—To correlate the present with my earlier investigations I will give a series of results found by using a small circular part of the Welsbach mantel as a source of light. Coronas in this case are more easily identified becaused of the simplified color scheme, to the practical advantages of which I have already referred. These are followed by results with electric light seen through ruby glass.

* This Journal, xiii, p. 81, 1902; Phil. Mag. (6), iv, 1902, p. 24.

Table 1. Constants of coronas. Condensation chamber 20^{cm} broad, 25^{cm} high, 35^{cm} long. Distances of eye and source from chamber 85^{cm} and 250^{cm}, resp. $\theta=22^{\circ}$; barom. $75{\cdot}3^{cm}$; $\delta p=16{\cdot}9^{cm}$; $y={\cdot}77$; $a={\cdot}064$; $\beta=0$; $S=2{\cdot}6$; $a''={\cdot}0029$ (subsidence); $a'={\cdot}0032$ (diffraction); $n_0=209{,}000$; $m=4{\cdot}7\times10^{-6}$; s measured to outer edge of first ring. Phosphorus nuclei. First Series, Welsbach lamp.

z	t	s	corona*	$n'=275\ s^3$	$n''=470\ s^3$	$N\Pi\left(1-\frac{S}{s^2}\right)$	n_0	n	$d={\cdot}021n^{-1/3}$
1	17m	cm	----	$\times10^{-3}$	$\times10^{-3}$	2·2	$\times10^{-3}$	460000	cm
2	20	--	b′r′	----	----	1·7	----	350000	·000290
3	23	--	g′	----	----	1·3	----	270000	320
4	27	10·3	y o b	300	403	1·000	----	210000	350
5	30	8·3	w c g	157	212	·751	----	158000	385
6	34	6·8	w p b g	86·3	116	·557	----	117000	425
7	37	6·0	g b p	59·4	80·0	·403	----	84600	475
8	41	5·8	w r g	53·6	72·2	·289	----	60700	530
9	44	4·6	w br b p	26·7	36·0	·204	----	42800	595
10	48	4·2	w r g	20·4	27·4	·137	200	28800	680
11	51	3·7	corona	13·9	18·8	·090	208	19000	780
12	54	3·2	"	9·0	12·1	·055	221	11500	920
13	57	2·6	"	4·8	6·5	·032	205	6700	·001110
14	60	2·0	"	2·2	3·0	·015	199	3100	1430
15	63	1·3	"	·6	·8	·004	220	800	2250

Second Series. Electric and ruby light. $\theta=15{\cdot}5^{\circ}$; barom., $75{\cdot}8^{cm}$; $\delta p=16{\cdot}9^{cm}$; $a={\cdot}0632$; $S=2{\cdot}5$; $m=4{\cdot}2\times10^{-6}$; $n_0=188{,}000$. Other data as above.

z	t	s	corona	$n'=250\ s^3$	$n''=335\ s^3$	$N\Pi\left(1-\frac{S}{s^2}\right)$	n_0	n	$d={\cdot}020\ n^{-1/3}$
0	min	cm		$\times10^{-3}$	$\times10^{-3}$		$\times10^{-3}$		cm
1	41	--	----	----	----	2·2	----	412000	.000269
2	44	--	v′g′r′	-- -	----	1·7	----	318000	293
3	48	--	w y g′ v′	----	----	1·3	----	244000	320
4	51	9·0	w o p g	182	244	1·000	----	188000	349
5	55	8·3	w′c y g	145	195	·746	----	140000	385
6	58	6·5	w g b p	70·2	94·1	·554	----	104000	426
7	62	5·7	w y g b	47·5	63·6	·402	----	75600	473
8	65	5·4	w r g	39·2	52·6	·286	----	53800	531
9	68	4·7	w g b p	26·0	34·8	·201	----	37800	595
10	71	4·2	w r b g	19·2	25·7	·137	188	25800	676
11	74	3·7	w y b g	12·7	17·0	·091	186	17200	775
12	78	3·1	w o b g	7·8	10·5	·056	186	10500	913
13	81	2·7	corona	4·9	6·6	·033	200	6200	.001090
14	84	2·1	"	1·9	3·1	·017	188	3100	1370
15	87	1·4	"	·7	1·0	·006	180	1000	1960

* Dashes denote approaches to a color, thus g′ is greenish. Dots denote deep color.

In table 1, z denotes the number of the partial exhaustions each of volume ratio, y, and made in succession, t the current time in minutes (the interval being about 3 min. to allow for adjustments and for diffusion), s the chord of the angular aperture, ϕ, at radius R, so that $s = 60 \sin \phi$. The eye and source of light were at distances 85 and 250^{cm} from the intervening condensation chamber and the former was focussed for long distances. The pressure and temperature of the atmosphere were P and θ, and the fixed pressure decrement on exhaustion uniformly $\delta p = 17^{cm}$, nearly, so that the precipitate per cub. cm. is $m = 4{\cdot}7 \times 10^{-6} g$. Measurements were made to the outer edge of the first ring. In the column marked "coronas," the color of the annuli is specified from within outward, using obvious abbreviations. The nucleation is marked n' if computed from the aperture s, standardized with lycopodium, n'' if computed from s standardized by subsidence measurements, N if computed relatively as a geometric progression, n when the latter is reduced as suggested and the absolute values corrected for time and exhaustion losses, etc. The arbitrary initial nucleation is shown under n_0, and corresponds to $z = 4$. The other coefficients are β, referring to time losses, a referring to exhaustion losses, S referring to subsidence losses. Though n is measured for the partially exhausted receiver, a final correction $(1/y)$ need not be added, for the influx of filtered air leaves the nucleation undisturbed. The ratio $n'/N = 275\ s^3/10^{z \log y}$ if constructed in charts, shows the wide departure from the constancy which would be anticipated. Diameters of the fog particles are given under d, the equation referring to the method of computation. All data will be fully discussed later.

As to the nature of the color sequences of the first ring of coronas corresponding to successively increasing sizes of particles, the clue may be obtained from extremely small particles and excessively large (opalescent) coronas, using the electric light as a source. In such a case the colors follow the order of wave-length, and one sees w v, w b, w g, w y, w o, w r, w c, with all intermediate color gradations. In succeeding series this is repeated with more and more overlapping until after two cycles have been passed all periodicity is lost (appreciably) in the normal coronas.

If the data of the table be mapped out graphically in terms of s, the periods of n and d are now sharply marked. In the d curves for instance, cusps in the region of 6, 4, 3, 2 times ·00018^{cm} (large in comparison with wave-length) may be recognized.

Brown University, Providence, R. I.

Art. XXXIII.—*Note on a Radio-active Gas in Surface Water;* by H. A. Bumstead and L. P. Wheeler.

During the visit of Prof. J. J. Thomson to New Haven last spring, he called the attention of the writers to the work done in the Cavendish Laboratory on a radio-active gas found in waters coming from deep levels. At his request we undertook to ascertain if a similar gas existed in the deep level waters of this locality. For this purpose water from a spring near New Milford, Conn. of an estimated depth of 1500 feet was obtained, the gas driven off by boiling and tested in an electroscope. The normal air leak was found to be increased about three times. The gas was very much diluted owing to air spaces in the boiling apparatus, so that the leak found does not represent the real activity of the gas as it comes from the water. In the meanwhile the water from one of the New Haven city reservoirs (an artificial lake fed entirely by surface drainage) was tested and found, somewhat to our surprise, to contain a strongly active gas. From 7·5 liters of this water about 175^{cc} of gas were obtained and this introduced into a Wilson electroscope of about 380^{cc} capacity increased the normal air leak about twelve times. The result was the same whether the water came through the city supply pipes or was obtained directly from the lake. Water, from which the gas had been expelled and which was aerated by dropping, had not recovered the power of giving off a radio-active gas after sixteen days. This would indicate that the gas is not an emanation from any radio-active substance dissolved in the water; and this is further evidenced by the fact that the residue from the water is very slightly, if at all, active.

In casting about for an explanation of the presence of an active gas in surface water, where none had been found in England, we were led to test the gas drawn from the ground (about five feet deep), which proved to be approximately three times as radio-active as the gas from the surface water. The rate of decay of the activity of both gases was measured by enclosing a sample of each in a gas-tight electroscope and taking readings twice daily for two weeks. The curves obtained are identical within the limits of accuracy of the measurements, and show an initial rise of activity lasting four or five hours and a subsequent falling off which follows fairly well an exponential curve. The activity falls to half its value in a time very close to four days. After the gas is blown out the excited radio-activity on the walls of the electroscope can be detected for about two hours. In these respects these gases follow closely the behavior of the emanation from radium as determined by Rutherford and Curie. Further investigation of the properties of the gases is in progress.

Sheffield Scientific School of Yale University,
New Haven, Conn., Sept. 16, 1903.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Radium and Helium.*—Speaking at a dinner of the Society of Chemical Industry at Bradford, England, last July, Sir William Ramsay announced that he and Mr. Soddy, of Montreal, who has been working in his laboratory, had found that helium is a constituent of the gas emanating from radium. The gas from radium was first passed through a tube cooled with liquid air, in which the active part of the emanation was condensed and remained behind, while the gas which passed through, when examined in a microscopic Plücker tube, showed undoubtedly the whole spectrum of helium. There is, in Ramsay's opinion, a production of helium continuously from radium.

A few days after the above announcement was made, a statement appeared in the London *Times* that Sir W. and Lady Huggins, upon photographing the spectrum of the light emitted by radium at ordinary temperature, had obtained eight definite bright lines in the ultra violet, entirely different from the spark-spectrum of radium, four and perhaps five of which lines agreed with the lines of helium.—*Chem. News*, lxxxviii, 39. H. L. W.

2. *The Action of Salts of Radium upon Globulins.*—W. B. Hardy has given an account of some experiments carried out in the laboratory of Sir William Crookes, and with his assistance.

Two solutions of globulin from ox serum were used, one electro-positive, made by adding acetic acid, the other electro-negative, made by adding ammonia.

They were exposed in shallow cells, one wall of which was made of thin mica, to the radiations from 50 m.g. of pure radium bromide, enclosed in a capsule covered with mica, so that two sheets of mica were interposed between the radium and the solution. No action took place in one hour. The globulin was then exposed as naked drops, separated by 3 mm. of air from the radium salt, with suitable controls, shielded from the radium. In the positive solution the opalescence rapidly diminished—that is to say, solution became more complete. The negative solution was turned to a jelly, at first transparent, rapidly becoming opaque. The action was complete in about three minutes.

Radium, like other radio-active bodies, gives off matter in three states—(1) an emanation having the mobility of a heavy gas, (2) positively charged particles of little penetrating power, and relatively large size, (3) ultra-material negative particles, of a size much smaller than atoms. A mica plate will screen off 1 and 2, therefore the globulin solutions are unaffected by the ultra-material negative particles. The rate of action and conditions of the experiment make it unlikely that the emanation was the active agent, though, owing to its nature, intense solvent or coagulating power may safely be predicated of it. The action observed may be almost certainly due to the positive particles. These are of material dimensions.

Globulin systems, therefore, seem to be completely transparent to the ultra-material electrons, and so too, probably, are the living tissues, since the physiological influences of the discharges from radium seem to be limited to a superficial layer a few millimeters deep.—*Chem. News*, lxxxviii, 73.

3. *Chlorine Smelting with Electrolysis.*—In a paper read before the Faraday Society, JAMES SWINBURNE gives an outline of a novel metallurgical process, which, if successful, promises at least to revolutionize the treatment of certain complex ores, particularly those containing zinc and lead together, which present great difficulties when treated by the present methods of smelting.

The first operation, which is the distinctive feature, consists in forcing chlorine gas, under pressure, into a receptacle, called the transformer, which resembles a blast-furnace. The chlorine is here made to act upon sulphide ores with the result that metallic chlorides are formed and sulphur distils off. The heat produced by the reaction is sufficient to effect the distillation and to fuse the chlorides. Chloride of sulphur is not formed as long as the sulphides are in excess, hence the sulphur in the ores is saved as such. The chlorides are tapped from the transformer in the molten condition. The next step usually consists in treating the chlorides with water to separate soluble chlorides from insoluble ones, and also to separate gangue which comes from the furnace suspended in the fused chlorides. The subsequent operations depend upon the nature of the chloride mixture. Lead and silver chlorides are dried and fused in contact with metallic lead, which extracts the silver and any gold; the lead chloride is then fused in contact with metallic zinc, which gives lead practically pure, and anhydrous zinc chloride. The soluble chlorides are treated with spongy copper, when lead and silver are precipitated; then copper is precipitated with "cement" zinc. Ferric oxide is then precipitated, after the solution has been oxidized by chlorine, by means of zinc oxide, and manganese dioxide is separated by the further action of the same reagents. The final liquid, containing only zinc chloride, is evaporated to dryness, and the anhydrous chloride is fused and electrolyzed with the formation of metallic zinc and chlorine. The chlorine thus produced is then used for the decomposition of ore, and is thus used over and over.—*Chem. News*, lxxxviii, 63. H. L. W.

4. *The Mazza Separator for Gases.*—For a long time centrifugal force has been used as a means of separating liquids of different densities, as in the well-known cream separators. A process for separating gases from their mixtures, depending upon the same principle, has been recently devised by SIGNOR MAZZA, formerly an officer in the Royal Engineers of the Italian Army. The machine consists essentially of a drum revolving with great velocity, into which the gaseous mixture is sucked in consequence of the rotation, and the components, divided by the effect of

centrifugal force, are automatically driven out by the same means. It is stated that it is possible in this way to obtain air so much enriched in oxygen as to make it much more effective in the combustion of fuel, and it is expected that the applications of the process will be important in metallurgical operations, in the production of steam, etc. It is expected, also, that the method will be used in the treatment of illuminating gas in order to separate a mixture rich in hydrogen from one of higher heating and illuminating power, and also for separating a large part of the carbon dioxide from blast-furnace gases, in order to make them more efficient.—*Chem. News*, lxxxviii, 68, 76. H. L. W.

5. *A Double Salt of Potassium and Barium Nitrates.* — A double salt having the formula $K_2Ba(NO_3)_4$ has been prepared by Wm. K. Wallbridge of the Sheffield Laboratory. The compound is remarkable because double salts of alkali metals and barium have been entirely unknown, and also because double nitrates are very rare. For these two reasons the salt is a very unusual one, and one whose existence would not be expected from analogy. The salt crystallizes from solutions containing the components under considerably varying conditions, but the crystals are very rough and opaque. They are tetrahedral in habit, like simple barium nitrate, and the author suggests that it is possible that their structure is pseudomorphic.—*Amer. Chem. Jour.*, xxx, 154. H. L. W.

6. *Light Waves and their Uses*; by A. A. Michelson. 166 pp. Decennial Publications of the University of Chicago, 1903. —The eight lectures which make up the present volume were delivered at the Lowell Institute in 1899, and it is a source of satisfaction to all who are interested in physics that their publication has not been longer delayed. Among instruments of precision there are few which rival Professor Michelson's interferometer in simplicity, in accuracy and in wide range of application, and perhaps none which is so interesting in respect to the natural phenomena which it incidentally illustrates. The author has succeeded in giving an admirably clear and simple account of the phenomena of interference, and of the many important researches which he has carried out by means of the interferometer and the echelon spectroscope. The presentation is so skilfully managed that the book can scarcely fail to hold the interest of the general reader, while at the same time physicists and astronomers will find in it much valuable information. H. A. B.

7. *The Sub-Mechanics of the Universe*; by O. Reynolds. xvii + 254 pp. Published for the Royal Society of London. Cambridge, 1903.—In this memoir Professor Reynolds believes that he has shown that there is "one, and only one, conceivable purely mechanical system capable of accounting for all the physical evidence, as we know it, in the Universe." Whether this belief is correct in whole or in part, whether the author's fundamental hypotheses are reconcilable with all known facts, and, more particularly, whether, if this be a legitimate explanation, it

is the only conceivable one, are questions which only time and careful criticism can settle. But in any event the work is a very remarkable one and will doubtless receive the careful attention of mathematical physicists both on account of the distinguished reputation of the author and of the extraordinary results which he has obtained. The theory assumes, as the substructure of the universe, a system of uniform spherical grains of changeless shape and size, so close that they cannot change their neighbors but are continually in relative motion with each other. Where the grains are in normal piling the properties of the medium can (by properly choosing the diameter, mean relative velocity, and mean path of the grains) be made identical with those of the ether within the limits of observational accuracy. If, in any space, the number of grains is less than in normal piling, such "negative inequalities" will move without resistance through the medium, will possess an apparent mass and will attract each other with a force varying inversely as the square of the distance; these are therefore taken to represent the molecules of ordinary matter. In a similar manner, electrical changes are accounted for by a different sort of inequality in the piling of the grains, and the mechanical structure of the granular medium is shown to be capable of accounting for many of the phenomena of electricity and of light. Like Professor Reynolds' other works, the memoir is throughout marked by great originality of thought and analytical skill. H. A. B.

II. Geology and Mineralogy.

1. *U. S. Geological Survey;* C. D. Walcott, Director.—The following publications have recently been issued:

Twenty-third Annual Report, 1901–02, 206 pp., 26 pls. 436 persons are now on the roster of the Geological Survey and the appropriation for 1901–02 was $1,079,800. In addition to the regular geologic and topographic work, the survey has now in charge the reclamation of the arid lands. The ideas advanced in 1877 by Major Powell, then Director of the Survey, regarding the arid regions have at last been enacted into law. In the matter of publications, great improvement is shown. Hereafter the annual report will be confined to one volume and the matter formerly contained in the unwieldy reports is to be published as "professional papers." The work in Alaska is in charge of four parties and is yielding results of great scientific and economic value. (See Professional Papers, Nos. 1, 2, 10.)

Professional Papers. No. 1. Preliminary Report on the Ketchikan Mining District, Alaska; by A. H. Brooks, 120 pp., 2 pls., 6 figs.

No. 2. Reconnaissance of the Northwestern Portion of Seward Peninsula, Alaska; by A. J. Collier, 68 pp., 12 pls.

No. 4. The Forests of Oregon; by Henry Gannett, 33 pp., 7 pls.

No. 5. The Forests of Washington—A Revision of Estimates; by HENRY GANNETT, 36 pp., 1 map.

No. 6. Forest Conditions in the Cascade Range, Washington; by FRED G. PLUMMER, 39 pp., 11 pls.

No. 7. Forest Conditions in the Olympic Reserve, Washington; by A. DODWELL and T. F. RIXON, 107 pp., 20 pls.

No. 8. Forest Conditions in the Northern Sierra Nevada, California; by J. B. LEIBERG, 186 pp., 12 pls.

No. 9. Forest Conditions in the Cascade Range Reserve, Oregon; by H. D. LANGILLE, F. G. PLUMMER, A. DODWELL, T. F. RIXON and J. B. LEIBERG. With an Introduction by Henry Gannett, 289 pp., 41 pls.

No. 10. Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska; by WALTER C. MENDENHALL, 65 pp., 9 pls.

WATER SUPPLY AND IRRIGATION PAPERS. No. 77. The Water Resources of Molokai, Hawaii; by WALDEMAR LINDGREN, 60 pp., 4 pls. Molokai, the fifth in size of the Hawaiian Islands, is of basalt fringed by coral reefs on the south. There are no impermeable strata, and the extreme porosity of the rocks allow free access of sea water as well as of rain, and zones of varying salinity result.

No. 78. Preliminary Report on Artesian Basins in Southwestern Idaho and Southeastern Oregon; by I. C. RUSSELL, 51 pp., 2 pls., 3 figs. Four artesian basins are described by Prof. Russell and a sketch of the general geology of the Idaho-Oregon region is given.

No. 79. Normal and Polluted Waters in Northeastern United States; by M. D. LEIGHTON, 186 pp., 17 figs., 148 analyses and tables. The river systems discussed are the Merrimac, the Blackstone, the Connecticut and its tributaries, the Housatonic, the Delaware, and the Ohio.

FOLIOS. No. 87. Camp Clarke Folio, Nebraska; by N. H. DARTON.

No. 88. Scotts Bluffs Folio, Nebraska; by N. H. DARTON. Western Nebraska shows typically the geological conditions of the Central Great Plains area. It is a region of flat-lying sediments, including volcanic ash, not older than the Eocene. Erosion has developed "bad land" topography in the soft strata. As illustrations of simple structures the Camp Clarke and Scotts Bluffs folios will serve as Physiographic texts.

No. 89. Port Orford Folio, Oregon; by J. S. DILLER. Taken in connection with the Coos Bay folio (No. 73), the Port Orford folio furnishes a description of an area adjoining the Pacific coast large enough to give a clear idea of the geological structure of the region. The area is chiefly occupied by pre-Cretaceous schists of sedimentary origin and sandstones of Cretaceous and Tertiary age. The igneous rocks are gabbros (basic and acid types) with corresponding basalts, serpentines and dacite porphyry dikes. The region has undergone a series of elevations and depressions apparently without faulting.

No. 90. The Cranberry Folio, North Carolina-Tennessee; by ARTHUR KEITH. The mapping of the Cranberry district involves the solution of some of the most difficult problems in Appalachian geology. The region includes gneisses and granites of Archean age, Algonkian? schists, rhyolites and diabases, Cambrian sediments and basalt. The metamorphism has been extreme and the fault structure is complicated and presents some unique features. The text of this folio deserves especial mention as an illustration of what can be done to make difficult geological structure intelligible to the non-expert.

No. 91. Hartville Folio, Wyoming; by W. S. TANGIER SMITH. The Hartville area shows a section of practically horizontal sediments from Carboniferous to Recent. These stratified beds are underlaid unconformably by Algonkian metamorphics, which in turn are cut by small masses and dikes of granite and pegmatite. Iron and some copper are the economic products.

2. *The Correlation of Geological Faunas. A Contribution to Devonian Paleontology;* by HENRY SHALER WILLIAMS.—U. S. Geol. Surv., Bull. No. 210, 147 pp. Washington, 1903.

Shifting of Faunas as a Problem of Stratigraphic Geology; by HENRY SHALER WILLIAMS. (Bull. Geol. Soc. America, vol. 14, pp. 177–190, 16 pls. Rochester, April, 1903.)

These two papers present the mature ideas of their author on the subject of geological correlation. The studies were commenced in 1881 and have been carried on almost continuously since. The chief area investigated has been the Devonian region extending from Ohio across the southern counties of New York, and the sections include all the Middle and Upper Devonian strata from the top of the Onondaga limestone to the base of the Olean conglomerate.

The fauna of the typical Hamilton formation is called the *Tropidoleptus carinatus* fauna. The fauna of the Black Shales is the *Lingula spatulata* fauna. The third fauna, the Portage Shales, is characterized as the *Cardiola speciosa* fauna, while the Chemung is the *Spirifer disjunctus* fauna.

A great many of the frequency and range values of the species occurring in these fossil faunas were determined, and from the results it was possible to construct standard lists of the dominant species with their relative percentages. These must always be of great service in any faunal comparisons of the Devonian. The methods employed are of course applicable to the Silurian or any other formation, as well as to the Devonian, and similar comparative studies would result in standard lists for each.

Considerable discussion is given regarding the shifting and recurrence of faunas, and concrete examples are shown, together with the methods of their correlation. The statistics of all this work in its various aspects demonstrate the intrinsic value of fossils for measuring and indicating time. No such positive evidence is furnished by the sediments when considered on the side of their lithological constitution, their structural form, or their stratigraphical position. C. E. B.

3. *Pseudoceratites of the Cretaceous;* by ALPHEUS HYATT. Edited by T. W. Stanton.—Mon. U. S. Geol. Survey, vol. xliv, pp. 351, pls. xlvii, Washington, 1903.

This work was first submitted to the Director of the United States Geological Survey as early as 1897. It was greatly revised and extended by the author up to the time of his death in 1902, and contains the results of his last work.

The Pseudoceratites are considered as retrogressive Cretaceous ammonites, showing the sutures and simple outlines characteristic of the Triassic. They are distinctly accelerated in development as compared with the Jurassic species. It is shown under Placenticeras that the arrest of development takes effect only after the three principal lateral saddles and lobes are formed in the neanic stage. Up to this stage their development is more complex than in the young of the Jurassic species. This explains the imaginary anachronism of the group in its relations with the apparently more complicated allies of the Jurassic.

Two hundred and six species are described, belonging to fifty-two genera. C. E. B.

4. *Publications of the Earthquake Investigation Committee* in Foreign Languages. No. 13, 142 pp.—During the year 1900, 385 earthquakes occurred at Hitotsubashi, (Tokyo) Japan. The seismograms of these earthquakes have been analysed by Dr. F. OMARI.

5. *The Lilac-colored Spodumene from California.*—In a note, recently published in *Science* (Aug. 12, vol. xviii, p. 304), CHARLES BASKERVILLE discusses the remarkable phosphorescence shown by the transparent lilac-colored spodumene from Pala, California, described by G. F. Kunz in the last number of this Journal. He states that a crystal was excited "by the action of X-rays for five minutes sufficiently to cause it to photograph itself when subsequently placed directly upon a sensitive plate (thin white paper being interposed) and allowed to remain in an especially constructed padded black box in a dark room for a period of ten minutes." He also proposes the name *Kunzite,* after Mr. G. F. Kunz, for this variety of spodumene.

6. *Tabellen zur Bestimmung der Mineralien mittels äusserer Kennzeichen von Albin Weisbach.* Sechste auflage durchsehen und ergänzt von Dr. FRIEDRICH KOLBECK. Pp. viii, 120. Leipzig, 1903 (Arthur Felix).—This well known and long valued work has been revised and brought up to date by Dr. Kolbeck without essential change in form or arrangement. Since the publication of the previous edition, three years since, the honored author has passed away, his death occurring on February 26, 1901.

7. *Purchase of the Siemaschko Collection of Meteorites.*—It is announced that the collection of meteorites of the late Julien de Siemaschko of St. Petersburg, containing some three hundred and sixty different occurrences, has been purchased by Prof. H. A. Ward and added to the Ward-Coonley collection, preserved in Chicago. A catalogue of this collection, numbering now 580 kinds, is promised for the near future.

8. *Meteoritenkunde* von E. COHEN. Heft II, pp. vii, 302. Stuttgart, 1903 (E. Schweizerbart'sche Verlagshandlung, E. Nägele).—The second part of Cohen's important and comprehensive work on meteorites, recently issued, is devoted to the discussion of the physical features of meteorites : the structure both of irons and stones, the crust and black veins, the form and character of the surface, the number and size of the individuals of a given fall. All of these most interesting topics are treated with care and conciseness and with especial reference to the observations and views of the many writers who have contributed to our knowledge of them. The author, however, also gives the reader the benefit of the results of his own extensive studies. The latter part of the volume (pp. 192–290) is devoted to supplements to Heft I, treating of the methods of investigation and the mineral constituents of meteorites.

9. *Meteorites from New South Wales.*—An account is given by A. LIVERSIDGE in the *Proceedings of the Royal Society of New South Wales* (vol. xxxvi, 341), of several recently discovered Australian meteorites. One of these, the Boogaldi meteorite, is an iron remarkable for its pear-shaped form and well-preserved fused crust. The others are largely stony in character; they include two masses from Barratta belonging with that found in the same locality in 1860 ; two masses from Gilgoin found in 1889 and 1893 ; also the Eli Elwah or Hay meteorite first exhibited in 1888.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Ostwald's Klassiker der Exakten Wissenschaften*, Leipsig 1903 (Wilhelm Engelmann).—The following are recent additions to this valuable series :

Nr. 20. Abhandlung über das Licht ; von Christian Huyghens. 115 pp. Second edition.

Nr. 21. Über die Wanderungen der Jonen während der Elektrolyse : von W. Hittorf. Part 1, 115 pp. Second edition.

Nr. 134. Experimental-Untersuchungen über Elektricität ; von Michael Faraday. Series xvi–xvii, 102 pp.

Nr. 135. Theorie der Gestalt von Flüssigkeiten im Zustand des Gleichgewichts ; von Carl Friedrich Gauss. 73 pp.

Nr. 136. Experimental Untersuchungen über Elektricität : von Michael Faraday. Series xviii–xix. 58 pp.

Nr. 137. Abhandlungen zur Thermodynamik chemischer Vorgänge ; von August Harstman. 73 pp.

Nr. 138. Über die Bewegung der Körper durch den Stoss. Uber die Centrifugalkraft ; von Christian Huyghens. Edited by Felix Hansdorff. 79 pp., 49 figs.

Nr. 139. Thermodynamische Abhandlungen über Molekulartheorie und Chemische Gleichgewichte ; von C. M. Guldberg. 85 pp.

Spodumene (Var Kunzite), Pala, California.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XXXIV.—*Mineralogical Notes*; by C. H. Warren.

I. *Native Arsenic from Arizona.*

A recent discovery of native arsenic at Washington Camp, Santa Cruz Co., Arizona, adds still another interesting occurrence of this mineral in North America to those already recorded.

We are indebted to Mr. George A. Lonsbery, superintendent of the Double Standard Copper Mine, now operated by the Copper Century Mining Co. of Boston, Mass., for calling the attention of Professor W. O. Crosby of the Massachusetts Institute of Technology to the occurrence, and for generously presenting him with the best and largest part of the find. The specimens, together with the following data regarding its occurrence, were very kindly placed with the writer for study by Professor Crosby.

The arsenic occurred in reniform masses attached to the walls of a small pocket in a dolomitic limestone. The pocket was situated in close proximity to an important fault at a depth of about sixty feet. Many of the masses are remarkably fine ones, weighing in some instances several pounds, while the aggregate weight of the arsenic was something over fifty pounds. The limestone of the region is highly metamorphic and is traversed by two parallel and closely adjoining veins of copper ore (chalcopyrite, sphalerite and some galena with a gangue of garnet, quartz and calcite) on which some development has been done. The faulted zone is characterized by considerable brecciation. Masses of igneous rock, granite and an acid porphyry outcrop in the immediate neighborhood, and their intrusion is undoubtedly closely connected with the formation of the ore-bodies, and also with the subsequent faulting.

The reniform masses, as is usual with native arsenic, are black in color, or gray on freshly broken surfaces, and consist of many thin concentric layers. While no distinct crystallographic outlines can be seen, each layer appears to be made up of semi-crystalline arsenic having a prismatic structure normal to the surface. What appear to be extremely small prismatic crystals have been noticed in a single instance. The masses are considerably fissured and the openings thus formed have been largely filled with later minerals, which also appear abundantly on the surface and in the solution cavities mentioned beyond. Of these minerals quartz and calcite are the most abundant, the former as small but well-terminated prismatic crystals, the latter in a slightly discolored, massive crystalline form.

1

FIG. 1. Side view.

2

FIG. 2. Top view.

The arsenic has been attacked to a considerable extent by some solvent. This has removed portions of the arsenic by attacking first the edges of the layers, where these were exposed by a fissure. It then encroached gradually on the substance of the layers by dissolving out narrow channels varying in width from that of a line to 0·5^{mm}. These channels ramify into networks, which give rise to an appearance suggesting that of a finely sun-cracked piece of mud. This appearance is illustrated by figs. 1 and 2. The outlines of each layer are marked by extremely thin but distinct shells, in many instances also curiously corroded, which represent the more refractory upper surface of each layer. The distances between such shells indicate a thickness for the original layers of from 0·2 to 1·5^{mm}.

Associated with the quartz and calcite, and evidently of the same age, is a little reddish sphalerite and minute crystals of iron pyrite. (Iron pyrite also occurs abundantly in the wall of the pocket.) In a vein of quartz traversing one specimen, extremely minute, gray prismatic crystals of arsenic are embedded, and on the reniform surface of the same specimen can be seen a light gray druse of arsenic. This arsenic is clearly of the same age as the quartz and indicates that the same solutions which deposited the quartz were carrying some arsenic, evidently derived directly from the reniform masses.

Careful qualitative tests showed the presence of a small amount of antimony and a trace of sulphur in the arsenic.

N. N. Evans,* in a recent description of native arsenic from a vein traversing a nepheline-syenite rock in the vicinity of Montreal, attributes its formation there to deposition by fumarole action. It is believed that a similar method of formation obtained for the Arizona arsenic. Gaseous emanations, carrying some volatile arsenic compound, may very probably have escaped from underlying igneous rocks into a pocket in the limestone, and finding there, as suggested by Professor Crosby, a local relief of pressure, decomposed and deposited successive layers, eventually forming the reniform masses. After their formation these were fissured to some extent by shrinking but chiefly through movements connected with the faulting. Subsequently, solutions carrying silica, carbonate of lime, and a small amount of sulphides removed a portion of the arsenic and deposited the minerals named.

The author is indebted to Mr. John L. Gardner of Boston for the very excellent photographs from which the present figures were taken.

II. *Anthophyllite with the Fayalite from Rockport, Mass.*

During the fall of 1902 a mineral was submitted to the author for identification by Messrs. F. W. Horton and Cutler D. Knowlton, students in the Massachusetts Institute of Technology. The mineral was found by them in the quarries of the Rockport Granite Co. at Rockport, Mass., and proved to be fayalite, the first occurrence of which was described by Penfield and Forbes,† who analyzed it and established the optical constants for the species.

* This Journal (4), xv, 92.

† This Journal (4), i, 129.

It is the object of this paper to once more call attention to the remarkable occurrence of this rare mineral, and to describe an interesting zone of a new fibrous amphibole which has resulted from the reaction between the silica of the enclosing pegmatite and the fayalite.

The fayalite of this second find appears to be identical in character, and in its general mode of occurrence, with that described by the authors cited above, although it was somewhat larger in size. The several large and fine specimens, which the discoverers very kindly brought to the author for examination, indicate clearly that the mass was roughly lenticular in form, having a maximum thickness of about ten inches and tapering from this to an edge of about 0·5 inches. Mr. Horton states that about 250 pounds was taken out in all, and that it was entirely surrounded by the pegmatite, portions of which still adhered to the specimens studied. The mineral was for the most part fresh, showing, however, in some of the thinner portions alteration to a brown ferruginous powder.

Magnetite occurs chiefly as a marginal secretion. A narrow granular rim never exceeding a few millimeters in width practically surrounds the fayalite, while single grains often attaining a diameter of 4^{mm} are often observed near the outside of the mass.

Thin sections examined under the microscope show that magnetite is quite plentifully scattered through the fayalite in the form of very minute grains, which have the characteristic cross sections of magnetite. The grains are frequently arranged in rows, which extend across the fayalite very much in the way that inclusions do in the quartz of many rock sections.

Where the fayalite comes in contact with the quartz of the pegmatite, a reaction rim is developed consisting of radial fibrous aggregates. The fibers shoot out into the fayalite on one hand and into the quartz on the other. The line of separation which marked the original contact is distinct, and passes through the centers of the radial groups. The zone varies in width from 3 to 8^{mm}, although in one instance, where an overlapping of an edge of the fayalite had occurred, a mass of fibrous mineral some 3^{cm} in thickness was observed.

The fibers are translucent, white to a light brown in color, and at once suggest anthophyllite by their appearance. On the side toward the fayalite, magnetite grains are embedded in the mass of fibers, which, as will appear later, are residual after the alteration of the fayalite to anthophyllite. The mineral is seen both in radiating groups and as isolated fibers in portions of the fayalite near the margin, but none has been observed at a greater distance than three or four centimeters from it. The larger magnetite grains usually act as the center for a group of radiating fibers. Thin sections from such portions show clearly that the fayalite has been altered by mineralizing solutions which gained access along crevices, cleavage cracks, or along the lines of magnetite inclusions, evidently drawn in by the force of capillary action. Every stage in the alteration of the fayalite can be seen, from that of the pure iron silicate with only now and then an encroaching fiber of anthophyllite, through those stages where patches or islands of fayalite are entirely surrounded by the secondary fibers, to the stage where the change is complete and the field is entirely composed of anthophyllite with grains of residual magnetite. The magnetite shows no evidence of having played a part in the reaction other than to serve as nuclei for the radiating groups of fibers.

Under the microscope between crossed nicols, the fibers show parallel extinction, a fairly high single and a high double refraction. Cross sections of a group of fibers show that each one is a minute prismatic crystal of an amphibole, the sides of the prisms making angles that measured approximately 123 and 57 degrees. A careful study of prismatic and basal sections was made in parallel polarized light with a quartz wedge in order to determine the position of the different vibration directions. The following relations were established; $c = \mathfrak{a}$, $a = \mathfrak{c}$, $b = \mathfrak{b}$, axial plane parallel to the brachypinacoid. In convergent light a biaxial interference figure is obtained from sections parallel to the macropinacoid. The axial angle is large, the loci of the hyperbolas lying just in the edge of the field of the microscope. The character of the double refraction is positive and the dispersion is well marked, red less than violet.

Basal sections are also confirmatory of the above since they show the central portion of an obtuse interference figure.

Before the blowpipe the fibers blacken, round slightly and become strongly magnetic. They are insoluble in acids. Careful qualitative tests show the mineral to be a practically pure iron silicate, with only traces of aluminium and magnesium. It seems, therefore, that the fibers are those of a pure iron anthophyllite, and represent a new member of the amphibole group. The formation of this metasilicate of iron from the orthosilicate by the addition of SiO_2 derived from the pegmatite, may be illustrated by the following equation:

$$\underset{\text{Fayalite}}{Fe_2SiO_4} + SiO_2 = \underset{\text{Anthophyllite}}{Fe_2Si_2O_6}.$$

A quantitative analysis to verify the above conclusion is desirable, and it is hoped that the time and facilities for making it may soon be available.

Intimately associated with the anthophyllite is a dark green lepidomelane mica. It usually lies with its cleavage faces parallel to the surface, although it is occasionally seen lying along cleavage planes in the fayalite. On one specimen where a considerable amount of the lepidomelane was developed, a large number of zircon crystals, one to three millimeters in diameter, were embedded. The mica corresponds to the variety annite, described from this locality by Cooke.* It fuses to a black magnetic globule, gelatinizes with acids, and reacts for aluminium, potash, and a little magnesium. Its axial angle in oil (refractive index 1·515) was found to be $8°-24'$. This mica is probably not a reaction product like the anthophyllite. It is present in other parts of the pegmatite of the quarries, and its occurrence in connection with the fayalite is indicative of nothing more than of the tendency of the ferromagnesian and other minerals belonging to an early period of crystallization to collect about anything that might have induced crystallization, in this case the mass of basic iron silicate. The presence of the zircon strengthens this view.

Two theories may be advanced regarding the origin of the Rockport fayalite; first, that it is a basic inclusion which has been thoroughly fused and recrystallized under conditions which led to the development of a coarsely crystalline texture like that of the pegmatite itself, during which process of crystallization the magnetite segregated toward the margin and the anthophyllite was developed: second, that the fayalite was formed from the pegmatite by the action of superheated vapor or steam under pressure as suggested by Iddings† for the fayalite crystals occurring in the lithophyses of the obsidian of the Yellowstone National Park. After its formation and segregation, the temperature and pressure diminished, allowing the crystallization, etc. It is perhaps hard to understand just how the segregation took place, and if it did, it would seem as if smaller masses of a similar nature should exist in the pegmatite. None have been found, however, except the one before alluded to.

In favor of the inclusion theory may be cited the occurrence of fayalite described by Gmelin.‡ He describes the mineral as an enclosed mass in trachytic lava at Fayal. It is stated that the mass showed evidences of fusion and that it was filled with bubbles in places. There is a possible analogy between the two occurrences.

The inclusion theory calls for the existence of a rock which is nearly a pure orthosilicate of iron in composition, a supposition that seems rash. The second theory seems the most reasonable to the author.

*This Journal, xliii, 222, 1867.
† U. S. G. S., 7th Ann. Report, p. 280.
‡ Chemische Untersuchung des Fayalits, Poggendorff Annalen, li, 160, 1840.

The author wishes here to thank Messrs. Horton and Knowlton for generously furnishing him with the material for study.

III. *Cerussite and Phosgenite from Colorado.*

In making blowpipe tests on some specimens of cerussite it was noticed that when the finely-powdered mineral was heated on a platinum wire in the Bunsen flame, after the color due to the lead had disappeared, a persistent crimson coloration was imparted to the flame, indicating the presence of strontium.

The cerussite was purchased from Messrs. George L. English & Co. of New York, and through their courtesy it was learned that it came from the Terrible mine, Isle, Custer Co., Colorado.

It is crystalline and massive in character, of a prevailing grayish white color, which changes in places to a light amber tint. The surface is discolored with a yellowish brown earthy coating.

A chemical analysis* made on carefully selected fragments, having a specific gravity of 6·409, yielded the following results:

		Ratio.	
CO_2	= 17·02 ÷ 44	= ·387	·387
PbO	= 79·59 ÷ 223	= ·357	·387
SrO	= 3·15 ÷ 103·3	= ·030	
Alks.	trace.		
FeO	trace.		
	99·76		

Careful tests were made for barium and calcium with negative results. The ratio is very sharp, $PbO + SrO : CO_2 = 1 : 1$, and indicates the formula $(Pb, Sr) CO_3$ for the mineral. Calculated to one hundred per cent, the composition becomes $PbCO = 95·52$ per cent; $SrCO_3 = 4·48$ per cent. No strontium could be detected in the phosgenite.

It is, perhaps, not surprising to find such a notable amount of strontium carbonate isomorphous with the lead carbonate, but, so far as the author has been able to ascertain, it is the first recorded instance of such a carbonate, and adds another undoubted case of isomorphism to those already known among the orthorhombic carbonates.

By plotting the specific volumes (the specific gravity of lead and strontium carbonates being taken as 6·517 and 3·697 respectively) of lead and strontium carbonates as ordinates and the percentages of strontium carbonate as abscissas, a specific grav-

*The analysis was made by the author while he was connected with the Mineralogical Laboratory of Sheffield Scientific School, during the spring of 1900.

ity of 6·329 was calculated for a carbonate having the same composition as that of the one analyzed. This compares very satisfactorily with the actual specific gravity, 6·409.

Associated with the cerussite is the chlor-carbonate of lead, phosgenite. This is distinguished in appearance from the cerussite by its clear brown color and by three excellent cleavages, prismatic and basal, at right angles to each other. It was possible to identify the basal cleavage by the positive uniaxial interference figure obtained when sections parallel to this cleavage were examined under the microscope. On such fragments a much poorer cleavage approximately half way between the prismatic cleavages was also observed, indicating the presence of the cleavage parallel to the face 100. The prismatic and basal cleavages are of about the same degree of perfection. In one specimen a somewhat tabular habit was noticed parallel to the basal cleavage.

The relative amounts of cerussite and phosgenite vary considerably in different specimens, but the latter has always been observed as a core surrounded by the former. In one specimen, weighing nearly two pounds, the cerussite is simply a rim averaging 1^{cm} in thickness. This is separated from the phosgenite by a very narrow white band of powdery material. The above facts suggest that the cerussite is an alteration product of the phosgenite. Small cavities, possibly formed by solution, lined with minute acicular crystallizations of cerussite have been noticed on most of the specimens examined.

Contributions from the Geological Department of the Massachusetts Institute of Technology, No. 116, vol. 15.

Boston, Mass., June, 1903.

EXPLANATION OF PLATE XVI.
Cheiromys madagascariensis, the Aye Aye. (After Owen.)

EXPLANATION OF PLATE XVII.

Cheiromys madagascariensis, the Aye Aye ; showing the slender third digit of the hand. (After Owen.)

ART. XXXV.—*Studies of Eocene Mammalia in the Marsh Collection, Peabody Museum;* by J. L. WORTMAN. (With Plates XVI and XVII.)

[Continued from vol. xv, p. 436.]

THE first suborder, or the Cheiromyoidea, is of great interest, inasmuch as it numbers among its representatives the very curious and interesting creature commonly known as the Aye Aye, now living in Madagascar (Plates XVI and XVII). This species was first brought to the attention of naturalists by the French traveller Sonnerat more than a hundred years ago, and was for a long time looked upon as belonging to the order Rodentia, or the Gnawers, closely allied to the squirrel.

In 1862, Richard Owen received a specimen of the animal, and from a careful study of its anatomy conclusively demonstrated its lemurine affinities. As we have already seen, the character of its incisors and the form and general make-up of its jaws are exceedingly like those of the rodents; but in the complete bony ring surrounding the orbit, as well as in the prehensile extremities and the remainder of its anatomical structure, it bears the unmistakable stamp of its Primate relationship.

The hands are long and slender and the fingers are provided with claws. The third digit of the manus is curiously modified, in that while of the same proportional length as the others it is exceedingly slender. It has, indeed, been aptly compared to a wire with a hook at its end. The animal is nocturnal in its habits, inhabiting the dense forests of Madagascar, where it is said to be rare.

The specimen which was sent to Owen was kept in captivity for some time, and Dr. Sandwith, who obtained the animal, was enabled to learn its curious habits. He wrote as follows: "I observe he is sensitive of cold, and likes to cover himself up in a piece of flannel, although the thermometer is now often 90° in the shade. He is a most interesting little animal, and from close observation I have learned his habits very correctly. On receiving him from Madagascar, I was told that he ate bananas; so of course I fed him on them, but tried him with other fruit. I found he liked dates,—which is a grand discovery, supposing he be sent alive to England. Still I thought that those strong rodent teeth, as large as those of a young Beaver, must have been intended for some other purpose than that of trying to eat his way out of a cage—the only use he seemed to make of them, besides masticating soft fruits. Moreover he had other peculiarities,—*e. g.*, singularly large, naked ears, directed forward, as if for offensive rather than defensive purposes;

then, again, the second finger of the hands is unlike anything but a monster supernumerary member, it being slender and long, half the thickness of the other fingers, and resembling a piece of bent wire. Excepting the head and this finger, he closely resembles a Lemur.

"Now, as he attacked every night the woodwork of his cage, which I was gradually lining with tin, I bethought myself of tying some sticks over the woodwork, so that he might gnaw these instead. I had previously put in some large branches for him to climb upon; but the others were straight sticks to cover over the woodwork of his cage, which *alone* he attacked. It so happened that the thick sticks I now put into his cage were bored in all directions by a large and destructive grub, called here the *Moutouk*. Just at sunset the Aye-aye crept from under his blanket, yawned, stretched, and betook himself to his tree, where his movements are lively and graceful, though by no means so quick as those of a Squirrel. Presently he came to one of the worm-eaten branches, which he began to examine most attentively; and bending forward his ears, and applying his nose close to the bark, he rapidly tapped the surface with the curious second [third] digit, as a Woodpecker taps a tree, though with much less noise, from time to time inserting the end of the slender finger into the worm-holes as a surgeon would a probe. At length he came to a part of the branch which evidently gave out an interesting sound, for he began to tear it with his strong teeth. He rapidly stripped off the bark, cut into the wood, and exposed the nest of a grub, which he daintily picked out of its bed with the slender tapping finger, and conveyed the luscious morsel to his mouth.

"I watched these proceedings with intense interest, and was much struck with the marvellous adaptation of the creature to its habits, shown by his acute hearing, which enables him aptly to distinguish the different tones emitted from the wood by his gentle tapping; his evidently acute sense of smell, aiding him in his search."

I have quoted thus at length these interesting observations upon the grub-eating habits of the Aye Aye, for the reason that there can be no doubt, apparently, that they are directly responsible for the rodent-like character of the incisors, as well as for the tendency to degeneration and reduction of the molars and the curious modification of the third finger of the hand which is made to fulfil the functions of a probe, plex-imeter, and scoop. We shall presently see in what way these modifications throw light upon some of the extinct American forms of this same group.

The chief diagnostic features of the suborder have already been given, and to these should be added the lack of bony union of the two rami of the lower jaw, as in the Rodentia. It is probable that this condition is in some way correlated with the enlargement of the incisors and their final growth from persistent pulps, as seen in the most advanced species. Of the extinct American forms, I recognize two groups, which, on account of the wide differences between them in point of structure, I classify in two distinct families. The structure of one of these groups is imperfectly known, and it is impossible to state with certainty whether or not they are Primates. Osborn has recently proposed* to arrange them as a primitive suborder of the Rodentia, Proglires, but there are so many serious objections to such a view that I choose to regard them as Primates allied to *Cheiromys.* My reasons for such a course will be given after the species have been described.

The suborder as thus constituted includes three families, defined as follows:

Incisors reduced to a single pair above and below, enlarged, faced with enamel, and growing from persistent pulps, rodent-like; premolars reduced to one above and absent below; molars quadritubercular above and below, and rodent-like in pattern, with tendency to degeneration. Cheiromyidæ.

One pair of incisors above and below, enlarged, recurved, transversely compressed, and slightly twisted; crowns sheathed with enamel, not growing from persistent pulps, and altogether unlike those of rodents; cheek teeth in lower jaw reduced to two small styliform rudiments inserted immediately behind the large incisors; upper cheek teeth unknown. Metacheiromyidæ.

One to three pairs of incisors in the lower jaw, with central pair enlarged, having distinct roots, and with crowns sheathed in enamel; premolars never less than two in lower jaw; molars tritubercular above, with fourth cusp rudimentary; anterior cusp of trigon present in lower molars; fourth premolar becoming molariform above and below. Microsyopsidæ.

Family Metacheiromyidæ fam. nov.

Metacheiromys Marshi gen. et sp. nov.

The remains upon which this family and genus are founded consist of a single specimen of a fragmentary skeleton, which includes the two upper incisors, with a portion of the premaxillary attached; portions of the back and base of the skull, including an otic bulla; one mandibular ramus, with the entire tooth-border preserved; the bodies of nearly all the cervicals; a few dorsals and caudals; some ribs; the glenoid cavity of the scapula; the proximal and distal ends of a humerus; the proximal and distal ends of an ulna; the distal end of a radius; a portion of the pelvis, and the proximal and distal ends of a tibia.

* American Eocene Primates, etc., Bull. Amer. Mus. Nat. Hist., June 28, 1902.

The superior incisors, figure 105, more nearly resemble the upper canines of *Hapalemur griseus* than any other teeth with which I have been able to compare them. They are, however, less pointed, somewhat thicker in front, and have a decided twist. The office of this torsion was doubtless to bring into apposition flatwise the points of the two teeth implanted by diverging roots. Both the crowns and the roots are considerably compressed from side to side, the crown terminating behind in a sharp cutting edge. In cross section, therefore, the tooth gives an elliptical outline, pointed behind. There is a worn surface upon the front face of the crown, showing the point where it most frequently impinged upon the lower incisor. The crown is completely invested with enamel, and the tooth was implanted by a distinct root and was therefore of limited growth. The remaining cranial fragments furnish little information of the general skull structure further than that there was a well-ossified tympanic bulla more or less filled with cancellous tissue.

105

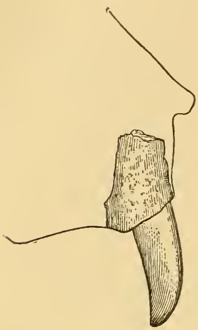

FIGURE 105. — Superior incisor of *Metacheiromys Marshi* Wortman; side view; natural size. (Type.)

107

106

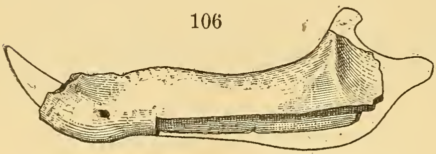

FIGURE 106.—Lower jaw of *Metacheiromys Marshi* Wortman; side view. (Type.)
FIGURE 107.—The same jaw; viewed from above.
Both figures are one and one-half times natural size.

Although not complete, the lower jaw, figures 106 and 107, exhibits some remarkable characters. Posteriorly the lower edge is broken away, as well as the coronoid, condyloid, and angular regions. The front third, however, is entire, and in this part the ramus displays an unusual lack of depth, but is of normal transverse thickness. This latter dimension is considerably augmented in the region of the implantation of the single enlarged incisor. The crown of this tooth is not preserved, being broken away at the level of the alveolus. The root is suboval in cross section, with a rounded angular part internal. Projecting the contour of the broken part of the jaw from that which is preserved, the horizontal ramus is seen to be rather shallow and slender. There was a well-developed masseteric fossa, the anterior portion of which is shown in the specimen. That which may be regarded as the most extraordinary feature of the jaw is the practical absence of cheek teeth. The dentinal border is preserved entire and in this are to be seen two shallow sockets, the first of which is situated immediately posterior to the enlarged incisor. After a short interval behind, a second similar alveolus occurs, and it is perfectly evident that these served for the implantation of two single-rooted styliform teeth, which were apparently caducous. The remainder of the tooth border was entirely edentulous. The mandibular symphysis is not rugose, and there is no trace of any tendency to coössification of the two rami.

The characters of the bodies of the cervical vertebræ are of an indifferent nature, and furnish little or no information of the affinities of the species. They are rather broad and depressed, and are without inferior keels, as in the rodents and certain lemurs, notably *Nycticebus*. The caudal vertebræ denote that there was a long tail. The ribs, as indicated by a few heads, are likewise of the usual pattern and wholly uncharacteristic.

108

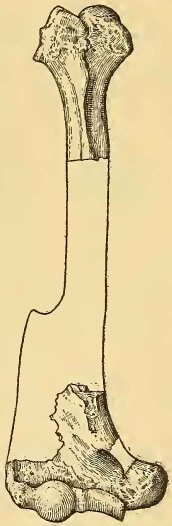

FIGURE 108.—Right humerus of *Metacheiromys Marshi* Wortman; front view; natural size. (Type.)

The glenoid cavity of the scapula has a form usually seen in the living lemurs, perhaps more resembling that of *Propithecus* than any of the other existing species. It will, however, answer quite as well for that of a squirrel. The humerus, figure 108, is more characteristic, and it is in this bone that the Primate affinities begin to manifest themselves. The head is globular, somewhat pointed behind, and overhangs the shaft but slightly. The greater tuberosity rises to the level of the head, and is of considerable fore and aft extent. It equals slightly more than one-half the antero-posterior diameter of the articular portion. The lesser tuberosity is also prominent and separated from the greater tuberosity by a distinct bicipital groove. The deltoid crest is moderate, but the extent to which it descends upon the shaft can not be determined on account of the imperfect condition of the bone. Upon the whole, its proximal end presents a very strong likeness to that of *Cheiromys* and *Propithecus* among the Primates, and differs from that of the rodents. The distal end is noteworthy for its great proportional breadth. The internal condyle is prominent, as in all early mammals. There is an entepicondylar foramen and an unusually broad supinator ridge. On account of the incompleteness of the latter, it is impossible to state whether it terminated abruptly above, as in *Cheiromys*, or sank gradually away into the shaft, as in *Propithecus* and the other lemurs. The distal articular extremity presents the usual divisions into trochlear and capitellar portions. A characteristic feature of this part of the Primate humerus is a ridge descending from the shaft in front, to become continuous with the external raised edge of the ulnar articular surface. No trace of this ridge is found in the humerus of the Rodentia, but in the fossil it is present, although not so strong as in existing lemurs and monkeys. The trochlear portion for articulation with the ulna is well rounded and terminates behind in a moderately deep olecranon depression. The capitellar portion is unusually globular and displays upon its outer side a distinct groove which extends somewhat more than halfway around the articular extremity.

Among living forms, the only case in which this groove is so well developed is in *Propithecus*. *Cheiromys*, *Galago*, and *Cheirogaleus* exhibit distinct traces of it, but it is confined to the upper outer edge of the capitellum. In *Propithecus* it is associated with a characteristic shape of the articular head of the radius, which consists of a central depression surrounded by a more or less flat ringlike area around the edge. The head of the radius is not preserved in the fossil, but the similarity in the structure of the corresponding humeral articulation leaves little doubt that its form was like that of *Propithecus*. The distal end of the humerus is thus seen to be like that of the lemurs and entirely different from that of *Paramys* and *Sciurus*, with which I have compared it.

The olecranon of the ulna is unusually long, and in this respect differs from all the modern lemurs, as well as from *Sciurus*. It is deeply grooved upon its outer side and presents an extensive, flattened, subcutaneous area upon its under side. In the first of these characters it resembles the ulna of *Propithecus*, and in the second that of *Cheiromys*. The similarity to these two genera also extends to the distal ends of both the ulna and radius.

The tibia, figure 109, is the most characteristic part of the skeleton preserved, and in the absence of the feet this bone, especially in its distal end, may be said to be one of the most distinctive of the entire Primate skeleton. The chief characteristics of the tibia in the lemurs and monkeys may be briefly stated as follows: The proximal surface is divided into two subequal articular facets, which are separated by a relatively high, pointed tibial spine. The long, straight shaft is much compressed from side to side and marked at the lower part of its upper third in front by a roughened tubercle for the attachment of the *semitendinosus*, one of the chief inner hamstring muscles. The distal extremity is relatively narrow transversely and limited internally by a large pointed malleolus. The articular surface which it offers to the astragalus is slightly concave from before backward, but in a transverse direction is almost plane and slopes outward toward the fibula. This arrangement is associated with a highly characteristic form of the astragalus, which in turn is indicative of a prehensile pes. Among the Rodentia, on the other hand, the tibia and astragalus are equally characteristic and distinctive of another type of foot. In the fossil under consideration, the tibia has every mark and feature of the Primate so unmistakably stamped upon it that I have no hesitancy in referring the species to this order, in a position not far removed from *Cheiromys*.

109

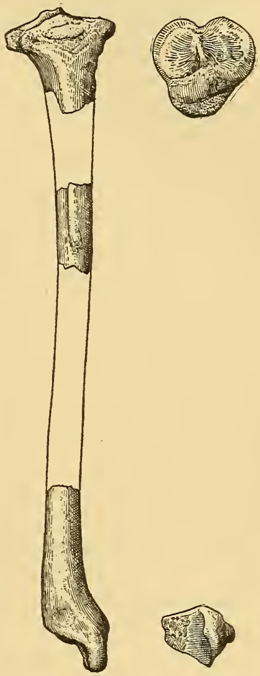

FIGURE 109.—Right tibia of *Metacheiromys Marshi* Wortman; front and end views; natural size. (Type.)

Discussion.—We have already seen that in *Cheiromys* we have an undisputed Primate, in which the incisors have undergone modification exactly similar to that of the Rodentia. We have further seen that the presence of these teeth in this animal is associated not only with a peculiar modification of the third finger of the hand, but with a grub-eating habit and a tendency to degeneration of the molars and premolars. Now in the extinct creature before us, we have, if the evidence derived from its osteology can be trusted, an equally unmistakable Primate undergoing the same modification of the incisors, and in which the cheek teeth had almost completely disappeared. We have no information of the structure of the hand; but whether or not any of the fingers were modified in a manner corresponding to that of the Aye Aye, the practical loss of the molars and premolars can be accounted for on no other supposition than that the nature of the food upon which the animal subsisted was so soft as to require no crushing power on the part of the grinders. From what we know of the habits of the Aye Aye, the inference is both logical and natural that this food was also soft larvæ, which the animal was doubtless accustomed to seek in a similar way. From the comparative slenderness and weakness of the lower jaws, we may even further suggest that the animal captured these grubs in soft or decayed wood.

If the facts of structure have been correctly interpreted and our hypothesis in regard to the habits is well founded, what shall we say of the relationship between *Metacheiromys* and *Cheiromys?* Is it possible to suppose that these modifications, so profound and unique among the Primates, have originated twice in the same group entirely independently of each other? *Metacheiromys* can not be placed directly in the ancestral line of *Cheiromys* for the reason that by the loss of the grinders it had, in the Eocene, already reached a more advanced stage of evolution than the living genus. But to deny that the two were descended from a common ancestral stock would, it seems to me, involve such a tremendous assumption as to lay a heavy burden upon our powers of belief. Such assumption becomes all the more onerous in the complete absence of any evidence in its support. If one had no proofs upon which to base an opinion respecting the community of origin and distribution from a common center other than that afforded by these two animals, so widely separated in space and yet so closely connected in structure, he could still feel amply assured of the security of his foundations. This evidence of the relationship between the Madagascar and Wyoming species, therefore, adds but another link in the chain of proof already set forth, that both forms were migrants from a common boreal home.

Family Microsyopsidæ.

Microsyops Leidy.

The next family of this group to be considered is the Microsyopsidæ. The type genus *Microsyops* was separated and described by Leidy in April, 1872.* In June, 1871, Marsh had previously described a species, *Hyopsodus gracilis*,† which

* Proc. Acad. Nat. Sci. Phila., 1872, p. 20 (published April 16).
† This Journal, vol. ii, 1871, p. 42.

Leidy, at the time he proposed the genus *Microsyops*, thought to be identical with the specimens he had in hand, and adopted Marsh's specific name *gracilis*. Marsh, however, in the same paper in which he described *Hyopsodus gracilis*, had proposed another species, *Limnotherium elegans*. From an examination of Marsh's types, Leidy afterward concluded that it was to *L. elegans* that his specimens were to be referred, and that *Hyopsodus gracilis* was a different species. His exact words are:* "The specific name of *M. gracilis* was originally given under the impression that the remains referred by Professor Marsh to *Hyopsodus gracilis* pertained to the same [species of] animal. A specimen exhibited to the writer by Professor Marsh would indicate that *M. gracilis* is the same as the animal named by him *Limnotherium elegans*. As *Microsyops* is generically distinct from *Limnotherium* as characterized from the typical species, *L. tyrannus*, the specific name of the former would be *Microsyops elegans*."

A careful examination of the types confirms Leidy's conclusions as given above, and establishes the further important fact that *Hyopsodus gracilis* of Marsh is not only distinct specifically, but represents an apparently undescribed genus of the Microsyopsidæ. The oldest members of this group come from the second stage of the Lower Eocene, or Torrejon beds, of New Mexico. The first species of this group found was described by Cope as *Mixodectes*.† Quite recently Osborn has added a second genus *Olbodotes*.‡ The chief characters of *Mixodectes*, which is known almost exclusively from lower jaws, are the following: There are eight teeth in the jaw, of which three are molars, three are premolars, one is a canine, and one an incisor; the last premolar is much simpler than the molars in structure; the two incisors, representing the central pair according to Osborn, are moderately enlarged.

Olbodotes has a full incisor dentition in the lower jaw, with a tendency to enlargement of the central pair. The premolars are reduced to two and the fourth premolar is simpler than in *Mixodectes*. It is therefore the most primitive species of this group thus far known, if correctly referred to this series.

From the succeeding Wasatch, Cope has described another genus under the name of *Cynodontomys*. This species, while very much like the Torrejon *Mixodectes*, differs from it in having lost either the canine or the second premolar and in the greater enlargement of the incisors.

In the Wind River, we have the first appearance of the genus *Microsyops*, which differs from *Cynodontomys* in the

* Extinct Vertebrate Fauna of the West, 1873, p. 84.

† Amer. Philos. Soc., 1882–1883, p. 550.

‡ American Eocene Primates, etc., Bull. Amer. Mus. Nat. Hist., 1902, p. 206.

more complex and perfectly molariform character of the fourth premolar. In the Bridger, from which the type of the family was derived, there are at least four well-marked species now known. The characters of the genus, as understood almost exclusively from the dentition, are as follows: There is but a single pair of incisors in the lower jaw and presumably a like number in the upper jaw; the enamel is not limited to the anterior face of the tooth, as in the Rodentia, but completely invests the crown, and the teeth are not of continuous growth; a small canine and two premolars are present, or no canine and three premolars, according to the way in which we interpret the first small tooth behind the enlarged incisor to be a premolar or canine; except, perhaps, in one species, the fourth premolar above and below is completely molariform; the superior molars are tritubercular in structure, with a faint beginning of a fourth cusp and a slightly developed mesostyle, which becomes stronger in the later species; the two rami of the lower jaws are not coössified.

I know of no remains of other parts of the skeleton that with certainty can be referred to any species of the genus. I have seen, however, some skeletal fragments which I strongly suspect belong to a species of this genus, but I lack the evidence to make the necessary connections.

Microsyops elegans Marsh.

Limnotherium elegans Marsh, this Journal, January, 1871, p. 12; *Microsyops gracilis* (in part) Leidy, Proc. Acad. Nat. Sci. Phila., 1872, p. 20; *Mesacodon speciosus* Marsh, this Journal, September, 1872, p. 205; *Palæacodon verus* Leidy, Proc. Acad. Nat. Sci. Phila., 1872, p. 20; *Microsyops elegans* Cope, Tertiary Vertebrata, 1883, p. 217; *Microsyops gracilis* Osborn, American Eocene Primates, Bull. Amer. Mus. Nat. Hist., 1902, p. 210.

Description of the Type.—The type of this genus and species consists of a fragment of a left mandibular ramus bearing the first and second molars, together with the fourth premolar, and the roots of the last molar. The anterior and posterior parts of the jaw are not preserved, so that it is impossible to determine the full dentition. The molar crowns may be described as consisting of an anterior, tricuspidate, elevated portion, usually termed the trigon, and a posterior, wider, less elevated part, or heel. The three cusps of the trigon are conical, and are placed in the form of a more or less perfect equilateral triangle, with the apex directed forward. Of these, the anterior is much the smallest of the three, the two posterior cusps being subequal in size and standing nearly opposite each other. The heel is considerably wider than the anterior, or trigonal, part of the crown and bears three distinct cusps enclosing a basin. Of these, one is external, one internal, and one posterior. The external cusp is the largest and has a V-shaped pattern. One arm of the V extends forward and inward to join the base of the trigon and the other inward and backward to the posterior cusp. The internal cusp is relatively small and conical, and situated directly opposite the large external one. In front of this, between it and the internal cusp of the trigon, is a deep notch through which the valley opens internally. The posterior cusp of the heel is small and indistinct; it is situated upon the posterior rim of the central valley, more to the inner than to the outer side; it is connected with the outer V-shaped cusp by a low ridge, and is separated from the inner cusp by a notch. The crown of the fourth premolar is nearly like that of the true molars, the only noticeable difference in its structure being the absence of the anterior cusp of the trigon, together with the smaller size and more posterior position of the interior trigonal cusp. The chief characteristics of these teeth are seen in the broad heel as compared with the trigon, as well as the slight elevation and distinctness of the cusps of the latter.

Description of the Type of Mesacodon speciosus.—The specimen upon which this genus and species were founded

110

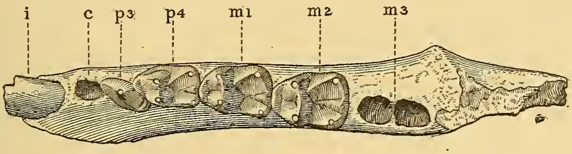

FIGURE 110.—Lower jaw of *Microsyops elegans* Marsh (type of *Mesacodon speciosus* Marsh); viewed from above; two and one-half times natural size.

consists of a well-preserved lower jaw, figure 110, of the right side, lacking the condylar, coronoid, and angular portions. The last molar is missing, as well as the canine or second premolar and the crown of the large incisor. After careful comparison with *Microsyops elegans*, I can not discover any difference between the two. The teeth are very nearly of the same size and, as far as ascertainable, the crowns of the molars and premolars are constituted in exactly the same way. I do not hesitate, therefore, to refer them to the same genus and species.

The additional information furnished by this specimen permits an accurate determination of the entire dentition of the lower jaw. The enlarged incisor is implanted by a distinct root and was not, therefore, of persistent growth; its position is procumbent, being directed much forward and a little upward. Most of the crown is broken away, but enough remains to show that the enamel was not limited to the anterior face of the tooth, as in *Cheiromys* and the Rodentia, but invested it posteriorly as well as in front. The canine or second premolar follows without diastema, and judging from the size of its alveolus was relatively large. An indistinct ridge upon the inner side of the socket indicates that the root was grooved in this situation, a fact which is against its interpretation as a canine and in favor of its being a premolar. The third premolar had not been fully erupted at the time of death, and is only partly protruded from the jaw; it is implanted by two roots somewhat diagonally to the long axis of the ramus and has a pointed crown, with a small, though distinct, heel. The fourth premolar is identical in structure with that of the type of *M. elegans* already described, as are also the molars. The last molar is not preserved in either specimen. The ramus is deepest in front at the posterior border of the symphysis, narrowing considerably behind. The tooth line does not pass behind the coronoid to such an extent as in *Cheiromys* and the Rodentia. The anterior border of the masseteric fossa is prominent and, as in both *Cheiromys* and the Rodentia, toward its upper posterior portion forms the root of the coronoid, which therefore has a position much external to the tooth line. The opening of the inferior dental canal lies considerably below the level of the tooth crowns—a character in which it agrees with *Cheiromys* and differs from both the modern squirrels and *Paramys*. It may be further noted that the symphysis is roughened, but not coössified with the opposite ramus.

Description of other Material.—There are in the Marsh collection six other specimens of more or less complete lower jaws, which I refer to this species. Among these specimens there are several examples of a last molar. This tooth very closely resembles the other molars in structure, differing only in the elongation of the heel by reason of the greater size and prominence of its posterior cusps. In no case do any of the upper teeth accompany these lower jaws, but in another species to be described later, there are upper and lower teeth in association, so that the form of the upper molars is known with certainty. In my own collection there is a well-preserved upper jaw of a small form of *Microsyops*, bearing all the molars and the last premolar, which accord so well in size with what the upper teeth of *M. elegans* should be, that I have no hesitancy in attributing it to that species. I obtained this proportional size by measurement of the teeth of many living species of lemurs, as well as of those of the one known *Microsyops* above referred to.

There should be also mentioned here, the species described by Leidy under the name *Palæacodon verus*, from a superior molar. According to Leidy's figure, this tooth, figure 111, is identical with the upper teeth which I refer to *Microsyops elegans*, and it therefore becomes a synonym of that species—

a conclusion which has been already reached by Osborn. The more important features of the upper teeth of this species may be stated as follows: There are three molars, of which the first and second are subequal, with the third smaller; the crown has three main cusps and a faint indication of the fourth; the two outer cusps are more or less crescentic in structure; there is a small though well-marked mesostyle; both intermediates are present in the first and second molars, but the posterior is absent in the last; the fourth premolar is molariform, but lacks any trace of the posterior intermediate. I give herewith a reconstruction in outline of the dentition, figure 112, as derived from several specimens.

111

112

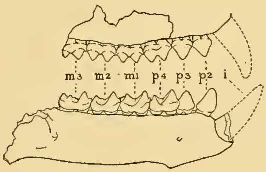

FIGURE 111.—Upper molar of *Microsyops elegans* Marsh (type of *Palæacodon verus* Leidy); crown view; twice natural size. (After Leidy.)
FIGURE 112.—Upper and lower jaws of *Microsyops elegans* Marsh; side view; natural size; composed from several individuals.

The measurements of the type of *Microsyops elegans* are as follows:

From base of posterior root of last molar to anterior extremity of crown of fourth premolar	16·0mm
From base of posterior root of last molar to anterior extremity of crown of first molar	11·0
Length of fourth premolar and first and second molars	11·0
Length of first and second molars	7·5

The measurements of the type of *Mesacodon speciosus* are:

Length from posterior root of last molar to base of incisor	20·0mm
From base of incisor to posterior extremity of fourth premolar	7·5
Depth of jaw at posterior border of symphysis	8·0
Depth of jaw at last molar	7·0

Measurements of the last lower molar and upper teeth of other specimens:

Length of upper molars	10·5mm
Length of upper molars and fourth premolar	14·5
Length of last lower molar	5·0
Length of second and third lower molars	8·5

The type specimen was found by Professor Marsh, at Grizzly Buttes, Bridger Basin, Wyoming. The type of *Mesacodon speciosus* was also found by Professor Marsh at the same place. Other specimens are recorded from this locality; also from Dry Creek, and from Millersville. The single specimen which I obtained is from the same horizon as that in which the type was found.

Microsyops gracilis Leidy.

Microsyops gracilis Leidy, Proc. Acad. Nat. Sci. Phila., April 16, 1872, p. 20; *Bathrodon typus* Marsh, this Journal, August, 1872, p. 19, Separata; *Microsyops typus* Osborn, Bull. Amer. Mus. Nat. Hist., 1902, p. 212.

As already noted, Leidy, in his final description of *M. gracilis*, believed it to be the same as *M. elegans*. This is undoubtedly true of the first specimen mentioned, but a second lower jaw was associated with the latter, with the expression of some doubt as to its specific identity. There are in the Marsh collection four specimens, exclusive of the type of *Bathrodon typus*, figure 113, consisting of the upper and lower jaws of a form which agrees in every way with the figures and descriptions given by Leidy of his second specimen. These are supplemented by three more examples of upper teeth obtained by myself in the type locality last summer. The additional material enables me to determine that this series of specimens is not only larger than the typical *M. elegans*, but

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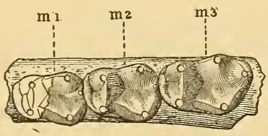

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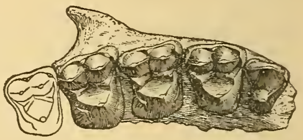


FIGURE 113.—Lower jaw of *Microsyops gracilis* Leidy (type of *Bathrodon typus* Marsh); viewed from above; two and one-half times natural size.
FIGURE 114.—Upper jaw of *Microsyops gracilis* Leidy; crown view; twice natural size.

presents other constant differences which I think impossible to account for on the basis of differences in age or sex. In no case are the upper teeth, figure 114, associated with those of the lower jaw, but as in the preceding species, the size and character of the two correspond so closely that there can be virtually no doubt of their relations. The more important distinctive characters are the following: The teeth are slightly larger than those of *M. elegans*, and the jaw is appreciably heavier and deeper; the last upper molar has a distinct mesostyle and a posterior intermediate cusp, both of which are absent in the same tooth of *M. elegans;* the fourth superior premolar has a mesostyle and the posterior intermediate distinct; the external cusps of the superior molars are apparently less flattened and crescentic than those of *M. elegans.*

In one specimen of an upper jaw, the second and third premolars are preserved, although the tooth which I take to be the second is not in place. The third is implanted by three roots, two of which are external and one internal. The crown is composed of a single large external and a smaller internal, or lingual, cusp. The second is a two-rooted tooth, much smaller than the preceding; its crown is a simple, transversely flattened cone, with a slight indication of a heel, and is very much like the corresponding tooth in many of the modern lemurs. No other parts of the skeleton are known, but I here call attention to an unassociated calcaneum, figure 115, which is not only Primate, apparently, but is about the right size for this or the preceding species and may possibly pertain to one of them. The Primate characters of the bone are seen in the short and incurved tuber, as well as in the arrangement of the facets, which are much like those in *Lemur catta.* The chief peculiarity, however, is in the elongation of the part below the astragalar facet, recalling at once the elongated calcaneum of some of the modern Madagascar species. I mention this matter for the reason that there is no other known Primate in the Bridger to which, as regards size, it could pertain. If this supposition is sustained, these animals are certainly Primates.

115

FIGURE 115. — Calcaneum of *Microsyops (?)*; dorsal view; twice natural size. *af*, astragalar facet; *st*, *sustentaculum tali.*

The measurements of the type of *Bathrodon typus* are as follows:

Length of second and third molars	8·25mm

Measurements of other specimens:

From base of last molar to base of incisor	22·00mm
Length of first and second molars	9·00
Length of fourth premolar and first and second molars	12·50
Depth of jaw at posterior border of symphysis	9·00
Depth of jaw at anterior border of third molar	10·00
Length of upper molars	11·00
Length of upper molars and fourth premolar	15·00
Length of third and fourth premolars and molars	18·00

The type of *Bathrodon typus* was found by Mr. F. Meade, Jr., at Grizzly Buttes; other specimens were obtained at Church Buttes and Millersville. I secured specimens on Cottonwood Creek and at Church Buttes. The calcaneum was found on Dry Creek.

Microsyops annectens Marsh.

Bathrodon annectens Marsh, this Journal, vol. iv, August, 1872, p. 19, Separata; *Microsyops annectens* Osborn, Bull. Amer. Mus. Nat. Hist., June, 1902, p. 213.

The type of this species, figure 116, consists of a fragment of a lower jaw of the left side, bearing the last molar. The only character by means of which it can be distinguished from the two preceding species, at least as far as the type is concerned, is that of size. This distinction, however, is so pronounced that the validity of the species can not be questioned. The crown of the last molar has identically the same structure as that of *M. elegans* and of *M. gracilis*. The trigon is slightly elevated above the heel and the anterior cusp is not very distinct. The heel displays its characteristic breadth, with the large external lunate cusp and the smaller external and posterior cusps. The posterior cusp is not situated at the center of the posterior border, but very much to the inner side, in a position almost behind the internal—an arrangement which gives an imperfect quadrilateral outline to the heel. This is highly characteristic of the genus *Microsyops*, and insures its recognition at sight.

116

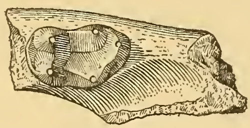


FIGURE 116. — Last lower molar of *Microsyops annectens* Marsh (type of *Bathrodon annectens* Marsh); crown view; two and one-half times natural size.

In the present collection, there are four other specimens represented by lower jaws alone, which give the lower dentition in its entirety. The form, proportions, and relations of the other teeth are very like those in the two species already described.

The measurements of the type are as follows:

Length of last molar	5·8 mm
Depth of the jaw at anterior margin of third molar	11·0

Measurements of other specimens:

Length of molar series	16·0 mm
Length of second and third molars	10·0
Length of molars and premolars to base of incisors	30·0

The type specimen was found near Henry's Fork, by Mr. F. Meade, Jr., of the Yale party, in September, 1871. Additional specimens from the same locality were obtained by Mr. Harger and others.

Microsyops Schlosseri sp. nov.

This species is founded upon a fragment of a left mandibular ramus, figure 117, bearing the second and third molars, together with two fragments of the upper jaw containing the first and second molars in one, and the second molar in the other. There is also an anterior portion of a jaw, bearing a part of the incisor and the premolars much worn, which I likewise refer to this form.

117

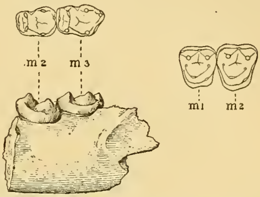


FIGURE 117.—Upper and lower molars of *Microsyops Schlosseri* Wortman; side and crown views; one and one-half times natural size. (Type.)

The chief difference between this species and *M. annectens* is one of size. It exceeds *M. annectens* to about the extent that the latter exceeds *M. gracilis*. Another feature of importance is seen in the wrinkled surface of the enamel, especially in the valley of the heel, where it is quite rugose. The anterior cusp of the trigon is small, though distinct, in the crown of the first molar, but consists of little more than a thickened cingulum in the second. The internal cusp of the trigon is broken, but apparently had about the same degree of elevation as is usual in the other species. The jaw is notably heavier than that of *M. annectens*.

Associated with the type lower jaw is a second upper molar which seems to be too much worn to belong to the same individual. The specimen, however, was collected by Professor Marsh himself, and knowing his great care in such matters, there must have been in the manner of their occurrence very good reason for putting the two together. A second isolated fragment of an upper jaw includes the first and second molars. The chief characters of these teeth are as follows: The outer cusps are moderately flattened externally; the mesostyle is distinct, though small; the intermediates are as in the other species; the postero-internal cusp is represented by little more than a cingulum in the second, but is more distinct in the first; the enamel is rugose.

The following are the chief measurements of the type and of the upper molars referred to this species:

Length of second and third lower molars	12·0 mm
Length of last lower molar	6·5
Depth of jaw at anterior border of third molar	10·5
Antero-posterior diameter of first and second upper molars	10·5
Transverse diameter of second upper molar	6·0

The type specimen was found by Professor Marsh, at Henry's Fork of Green River, August 9, 1873. The other specimens were obtained at the same locality.

In addition to the species herein described, there are probably at least two others indicated by fragmentary specimens. One of these consists of an upper molar tooth of a small species about equal in size to *M. elegans.* It comes from the upper horizon of Henry's Fork, and differs from the upper teeth which I have attributed to *M. elegans* in the absence of the mesostyle, absence of intermediates, and the greater prominence of the postero-internal cusp. It apparently belongs to *Microsyops*, but I refrain from proposing a specific name for so fragmentary a specimen.

In like manner, there is a fragment of an upper jaw containing two molars, from the lower horizon. The structure of these molars differs from all other species of *Microsyops* from the Bridger beds in the more distinctly conical shape of the external cusps, as well as in the prominence of the intermediates. I suspect that the form may be the same as one of the Wind River species in which the upper teeth are entirely unknown.

Smilodectes gen. nov.

This genus is founded upon the specimen originally described by Professor Marsh under the name of *Hyopsodus gracilis.* Osborn in his synonymy refers it to *Sarcolemur*, but the structure of the teeth distinctly forbids its reference to either of these genera. In certain respects the dentition, as far as known, resembles that of *Microsyops* more than that of any other genus, but in others it exhibits distinct relationship to that of *Notharctus* and *Limnotherium.* The number of teeth in the lower jaw is eight, as against seven in *Microsyops*, of which the most anterior is an enlarged incisor. Just as in *Microsyops*, the succeeding tooth may be rated either as a canine or an incisor; if a canine, there are then three premolars and if a premolar, there are four. The fourth premolar is not molariform. The single enlarged incisor distinguishes the genus from *Notharctus* and *Limnotherium*, and the more complex fourth premolar from *Mixodectes.*

Smilodectes gracilis Marsh.

Hyopsodus gracilis Marsh, this Journal, July, 1871, p. 42.

The type of this species and genus consists of the anterior part of a left mandibular ramus, figure 118, containing the fourth premolar, first molar, and a portion of the third premolar. Parts of the alveoli for all the remaining teeth in front are also recognizable, so that the number of the teeth can be accurately determined. With this I associate three other specimens, in two of which the last molar is well preserved.

The jaw has about the same depth as that of the larger species of *Microsyops*, which it otherwise resembles in its general form. The symphysis is deep and rugose, projecting somewhat below the level of the lower border of the ramus, but exhibits no traces of coösification. The alveolus of the enlarged incisor lies close to the symphysis, and unlike that of *Microsyops* indicates an almost vertical position for this tooth. Immediately behind the incisive alveolus is a medium-sized socket for the first premolar or canine. Behind this comes a two-rooted tooth, with the larger of the roots posterior. The third premolar is likewise two-rooted. A portion of the crown denotes that there was a slight indication of a heel. The rest of the crown is broken away. The fourth premolar is in about the same stage of evolution as that of *Limnotherium* or *Notharctus*. The internal cusp, however, is smaller, but the heel is broader and provided with two cusps instead of one. The first molar also closely resembles that of *Limnotherium tyrannus*, lacking the great transverse breadth of the posterior part of the crown seen in *Microsyops*. The arrangement of the cusps is very similar to that seen in *Limnotherium*.

118

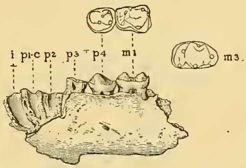


FIGURE 118. — Anterior portion of lower jaw (type of *Hyopsodus gracilis* Marsh) and last lower molar of *Smilodectes gracilis* Marsh; side view of jaw, and crown views of teeth; one and one-half times natural size.

I also place in this species three specimens in which the last lower molar is preserved, but which do not show the number of teeth. The association may be therefore incorrect. In one specimen, part of an upper molar is preserved which exhibits a structure like that of *Microsyops*, and not like that of *Limnotherium*. The last lower molar, on the other hand, resembles the same tooth in *Limnotherium* more than that of *Microsyops*, from all of which, in connection with the characters of the type, I conclude that the specimens must be referred to the species under consideration.

The last molar differs from that of *Microsyops* in the central position of the posterior cusps. In *Microsyops*, as we have already seen, this cusp stands almost directly behind the internal one. In this respect the tooth resembles the last molar of *Limnotherium*, but the cusp is not so large and is more distinct from the posterior rim of the heel. Again this molar differs from that of *Limnotherium* in having a distinct internal cusp of the heel, as in *Microsyops*. Associated with one of the specimens containing the last lower molar is a portion of an upper molar. Enough is preserved to show that there were three main cusps, together with a rudimentary fourth, very much as in *Microsyops*.

The type specimen was found by Professor Marsh, at Grizzly Buttes, Bridger Basin, on September 5, 1870; other specimens were obtained at the same locality.

The Relationship of the Microsyopsidæ.

There is as yet no absolutely conclusive evidence by means of which the position of this group can be determined with certainty. The species had always been considered, without good reason, to belong to the Primates, until Matthew, from an associated astragalus of *Mixodectes pungens*, put forth the view that these forms are rodents. Osborn following Matthew, placed them in a primitive suborder of the Rodentia, which he called Proglires. He says:* "*Relationship to the Rodentia* is now found to be indicated by: (1) progressive elongation of median incisor; (2) disappearance of lateral incisor; (3) reduction of canines; (4) disappearance of the anterior premolars and reduction of third premolar; (5) transformation of fourth premolar into molar forms, thus foreshadowing a homodont molar-premolar series; (6) width and extension of talonid (as in Eocene *Paramys*); (7) rodent form of astragalus. *Against* the *Rodent relationship* are: (1) Persistence of the canine; (2) absence of diastema; (3) absence of any evidence (except the levelling of the premolars) of adaptation for antero-posterior or orthal motion of the jaw."

If the astragalus which Matthew associates with the lower jaw of *Mixodectes* really pertains to the same animal, there is then strong presumptive proof that this species, at least, is not a Primate. From long personal experience in collecting in the Torrejon beds, however, I have found that only too frequently the fossils are washed out of their original matrix and badly mixed. Without a full knowledge of the circumstances under which these particular specimens occurred, and in the absence of reasonably conclusive evidence which would tend to preclude the possibility of a mixture, I should not feel inclined to attach any very great weight to this association. At all events, I should wish some stronger evidence upon which to rest so important a generalization. As for Osborn's alleged additional evidence of relationship to the Rodentia, attention may be called to the fact that he seems to have overlooked *Cheiromys* and left it out of account entirely. With the

*American Eocene Primates, etc., Bull. Amer. Mus. Nat. Hist., 1902, p. 204.

exception of the character of the astragalus, which, as we have just seen, is open to question, all the characters cited, save one—the molariform fourth premolar—are evidence of relationship with, and apply equally to *Cheiromys* as well as to the Rodentia. The molariform fourth premolar is not an especially rodent character. It occurs among the Lemuroidea in *Hapalemur griseus*, *Otogale Monteiri*, *Galago Alleni*, and *Hemigalago Demidoffi*. In like manner, the evidence against rodent relationship, as given by Osborn, can be quite as well considered to be evidence against relationship to *Cheiromys*, for Owen has long since conclusively demonstrated that this species is a Primate, with a highly modified rodent-like dentition. Altogether, I fail to see wherein Osborn has given any reasons, beyond those already well known, for regarding the Microsyopsidæ as members of the Rodentia. On the contrary, to my mind, there is fairly conclusive proof that these animals are not rodents. I shall now proceed to a statement of this evidence.

In Part I of the present series of papers (p. 96, Separata), I have presented my views at some length upon the theory of "Cusp Migration," as originally propounded by Osborn.* I have likewise dissented from the use of the terminology of the mammalian molar cusps proposed by him, on the ground that their homologies were incorrectly determined and the names applied inappropriate and misleading. I have further expressed the opinion that, as far as any nomenclature is applicable to these cusps, which would convey any information of their homological relationship, that proposed by Scott is preferable because based upon ascertained and undisputed facts in the history of the premolar series. By far the most important principle embodied in Scott's determination of the order of appearance and homological position of the cusps of the premolars, although never expressed nor stated by him, is that by means of which we are provided with the key to a proper interpretation of the molar cusps and the determination of their history. All theoretical considerations, as well as all the evidence obtainable, point with such directness and definite precision to the conclusion that the molars and molariform premolars have passed through identically the same changes and have been subjected to precisely the same influences, that it may be accepted as one of the basic and fundamental truths of dental morphology. Credence in any other view would be equivalent to believing that the corresponding teeth on the opposite sides of the mouth have had different histories. This principle or law has not as yet been ocularly demonstrated, for the reason that no Eutherian mammals older than those from

* Jour. Acad. Nat. Sci. Phila., 1886, p. 242.

the Tertiary are known. In the earliest Eocene, the molars, with a few notable exceptions, had already assumed such a degree of complexity as practically to obliterate all traces of the order of appearance and manner of development of the cusps. When, however, the ancestors of the Puerco fauna are found, and the more primitive stages of their tooth development obtained, I look forward with the utmost confidence to the production of all the evidence necessary to a complete and final demonstration of the truth of this hypothesis.

While this principle, enunciated by Scott, may be made to include any given group of mammals, and the history of their molar cusps thus determined, yet at the same time I feel well assured that no general law can be framed nor can any terminology be devised which will be applicable to all the Mammalia, unless it is confined strictly to the position of the cusps, without any reference whatever to their homologies. The reason for this difficulty is, that different groups of mammals have adopted different plans for increasing the complexity of their molars. In many divisions, the order of appearance and position of the cusps, as outlined by Scott, undoubtedly obtains; but in others, as I shall presently show, it has been different.

Taking as a starting point a transversely flattened conical crown, a complicating premolar of the inferior series, in a large number of groups of the Mammalia, passes through the following stages: (1) The posterior edge or slope of the crown elongates and develops a second or posterior root; (2) this slope of the crown becomes thickened transversely, and flattened from before backward, so as to present a triangular area with the apex at the summit; (3) this area looks upward and backward, and is bounded by a descending ridge on each side; (4) a thickened ledge is formed at its base, foreshadowing the heel; (5) on the *inner* descending ridge, bordering the posterior triangular area, appears a new cusp, small at first, which is *posterior and internal to the main cusp;* (6) concomitantly, the heel broadens and its posterior edges grow up in such a way as to form a basin; (7) at the same time a cusp may or may not be developed, at the anterior slope of the crown; (8) the heel develops two cusps, one of which is external and one internal in position.

Thus, it will be seen that all the elements necessary to the formation either of the quadritubercular or of the so-called tuberculo-sectorial crown are present, and further growth of the new elements is all that is required to effect a complete molariform transformation. That the evolution and development of certain premolars has taken place in this manner, is supported by a great abundance of evidence from many well-known phyla whose history has been determined with considerable exactness. In connection with teeth having this developmental history, one important point to remember is, that the antero-internal cusp, or the one which originates upon the inner ridge of the posterior triangular area, is always slightly posterior to the antero-external or main cusp. And it is also of the *utmost importance* to recall that the apex of the original single-pointed premolar corresponds to, and is homologous with, the antero-external cusp. This has been determined as true of the Ungulata, Carnivora, Insectivora, Primates, and probably of other orders.

In the case of the Rodentia, however, it is different. If a perfectly unworn, lower fourth premolar of a member of the Sciuromorph division is examined, figure 119, it will be seen that the new cusp, instead of originating upon the internal, is an outgrowth of the *external*, descending ridge bordering the posterior triangular area. It thus happens that the cusp which corresponds to, and is homologous with, the apex of the original single-pointed premolar *is the antero-internal and not the antero-external cusp, as in the orders just referred to.*

a 119 *b*

FIGURE 119.—Fourth lower premolar of a species of *Paramys;* outside (*a*) and crown (*b*) views; three times natural size.

Further proof of this is found in the fact that the antero-internal cusp has a position in advance of that of the antero-external, which should be the case if the new element had arisen upon the external instead of upon the internal ridge. The ancestral type of the Sciumorphs is represented by the genus *Paramys* of the Eocene, figure 119, and in this group the manner of origin of the premolar cusps is clearly shown. Distinct traces of this succession are still visible in the squirrels and spermophiles of the present day. The genus *Mysops* of the Bridger beds (*Eomys* of the European Eocene), while closely allied to *Paramys*, without much doubt represents the beginning of the Myomorph division of the Rodentia, and it is interesting to note that this same plan of origin of the cusps of the lower premolars is true of this group as well. No sufficiently primitive stages of the teeth of either the Histricomorphs or the Lagomorphs have to my knowledge as yet been found, which would enable one to say with absolute certainty whether or not the complication of their teeth has followed this plan or some other,* but I think there can be little doubt that it is a rule of very general application and a fundamental character of the entire order.

From this it follows that no names can be given to these cusps unless we wish merely to indicate their position. Professor Osborn, in reply to my strictures upon his cusp nomenclature, says that "although wrong the names should still stand." His terminology was proposed to supersede the old names then in vogue, which attempted nothing more than to indicate position. This proposal was elaborately made, and its adoption has been strenuously insisted upon, on the ground that the homologies of the cusps had been determined and that Osborn's system thus expressed something more than the mere fact of position. The names themselves carry with them the significance of this alleged homology, which, according to the oft-repeated and many-times-published statements of its author, constitutes one of its chief merits. In view of the facts above set forth, however, I am more firmly than ever of the opinion, that all such attempts are foredoomed to failure, and I believe they should be abandoned as utterly useless and confusing; that of Professor Osborn, being doubly erroneous, is therefore the most open to objection in this regard.

The Microsyopsidæ, as we have already seen, follow the Primates in the plan of addition of the cusps to the premolars and presumably to the molars also, which, to my mind, effectually disproves Osborn's suggestion that they are members of the Rodentia. If further evidence is required, we have only to refer to the great dissimilarity in the structure of the molars in the two groups. In no living rodent does the molar pattern approach that of *Microsyops*, except, perhaps, in the squirrels and their extinct forerunner, the Eocene *Paramys*, but even here the differences can be readily detected. Among the Lemuroidea, on the other hand, the great similarity in the constitution of the molar crowns to those of the Microsyopsidæ is apparent at a glance. Add to this, the completely transitional molar pattern afforded by *Smilodectes*, together with the strong evidence that the contemporary *Metacheiromys* was a Primate, and the proof of their relationship is all but demonstrated.

* *Sciuravus* Marsh, of the Bridger, which in many respects is closely related to *Paramys*, furnishes the beginning of a modification leading directly into such types of molar crown as those seen in *Steneofiber*, *Palæocastor*, and *Castor*. In like manner, *Mysops* and *Sciuravus* afford the stem types from which both the Histricomorphs and Myomorphs were in all probability derived. This subject will be more fully treated in a subsequent part of the present work.

[To be continued.]

Art. XXXVI. — *Triadenum Virginicum* (L.) Rafin. *A morphological and anatomical study;* by Theo. Holm. (With figures in the text.)

There are said to be at least thirty generic synonyms of *Hypericum*, of which Spach is the author of nineteen; *Hypericum* L. is, however, the only one recognized by Bentham and Hooker, while the other genera are treated merely as sections of two large groups: in accordance with the presence or absence of hypogynous glands in the flower. The suppression of these proposed genera may in some instances seem justified, since not a few of the writers who have dealt with the segregation of genera, and especially of small ones, have perhaps gone too far in their discrimination, or they have not always expressed their reason for making these segregations as clearly as might be desirable. But whatever the case be, a renewed study of several of these segregations may lead to their reëstablishment, especially after careful observations in the field, rather than by continued research in herbaria.

Moreover, in late years the anatomical method has rendered great assistance by the supplementing of characters derived from the internal structure. The actual value of such anatomical characters is, however, only to be perceived when the structure of most of the species of a given genus is known, and we believe that, for instance, the *Hypericaceæ* have been studied thoroughly from this point of view to enable us to draw certain distinctions between the genera.

In presenting a study of the genus *Triadenum*, it is the writer's intention to demonstrate the validity of one of the obscure genera of Rafinesque, which has, as it appears, been imperfectly known heretofore, and ignored by most authors, even by Bentham and Hooker. The history of the genus is very brief. Rafinesque removed Linnæus's *Hypericum Virginicum* from the genus and referred it to a new genus *Triadenum*, on account of the presence of three glands in the flower, alternating with the stamens. *Triadenum Virginicum* (L.) Rafin. is also known under the name *Elodes* or *Elodea Virginica*, but this genus, established by Adanson, does not include plants of habit or structure like that of *Triadenum*. Finally, *Hypericum Virginicum*, as described in the Synoptical Flora,* is our plant, and it so happens that we have not reached a single step farther in regard to the classification of this plant than at the time of Linnæus.

It is true that Rafinesque founded his genus *Triadenum* on no other characters than the floral glands and reddish flowers,

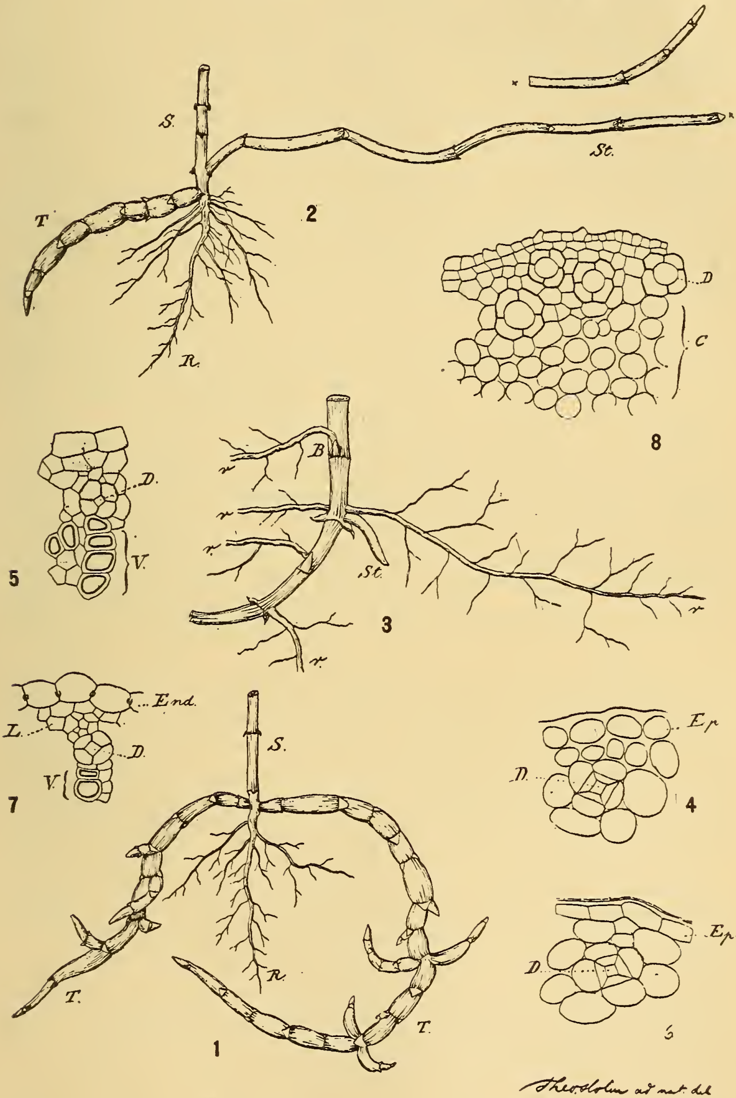
* For references consult the Bibliography appended to this paper.

remarkable, however, in the genus *Hypericum*, but to a critical student it would appear as if there might be some good reason for suspecting additional, and perhaps more valid, characters to accompany those, already pointed out by Rafinesque ; and from the writer's observations upon this plant in a living state through several seasons, *Triadenum* has proved to be quite an interesting plant and undoubtedly a good genus.

The flesh-colored flower attracted our attention when we saw the plant for the first time, growing in a swamp in company with *Rhexia*, *Asclepias*, *Eriocaulon* and others, and when we examined the parts underground, we found a rhizome, which was very different from that of other species of "*Hypericum*," as far as known. A continued study of the plant from seedling and of the subterranean organs in connection with an anatomical investigation of the vegetative organs compared with those of other members of *Hypericaceæ*, and quite especially of *Hypericum*, has convinced us that *Triadenum* possesses sufficient morphological and anatomical characters to entitle it to a genus. In presenting the results of our study, we will begin with some notes upon the morphology of the plant which have not been hitherto recorded.

In the seedling stage, *Triadenum Virginicum* does not differ from most of the species of *Hypericum* except in the very characteristic glaucous hue of the leaves. There is a primary root, a short hypocotyl and a pair of small cotyledons above ground. The seedling reaches the flowering stage commonly in the first summer, and ripens the seeds late in the fall, while the main axis dies off during the winter. Nevertheless the plant is perennial, for during the flowering period the basal stem-portion has commenced to ramify, and shows from one to two pair of horizontal branches, stolons, which are developed in the axils of the cotyledons and the subsequent pair of leaves. The former, those that arise from the axils of the cotyledons, are characteristic by their somewhat swollen and short internodes, and small, membranaceous, scale-like leaves ; they ramify freely, but are rootless for several months (T in figures 1 and 2); their color is crimson or yellowish brown. The other stolons (St. in figure 2), which develop further up the stem, have longer internodes, and are not swollen, and as a rule they do not ramify. When we examine the plant in the succeeding early summer, the main axis, including the main root (R in figs. 1 and 2) has died off altogether, while several vegetative or already flowering shoots have developed from the stolons; and when these aërial shoots finally die off during the fall, the remaining part of the tuberous stolon is able to continue its ramification for at least another year.

Triadenum Virginicum thus possesses an underground rhizome of more or less tuberous stolons with scale-like leaves, which, to our knowledge, is not met with among the species of



Hypericum proper. If, for instance, we examine the perennial *Hypericum maculatum* during the winter, we observe the presence of numerous green shoots above ground at the base of the withered flowering stem, and these shoots are also developed from the axils of the lower stem-leaves, perhaps even from the cotyledons. But they are not subterranean; they bear only green leaves and have no swollen internodes, and a like manner of propagation is met with in other species, for instance *H. perforatum* and *H. tetrapterum*. The rhizome of *Triadenum* is especially characteristic, by the fact that while the underground portion of the main axis stays alive for some time, it never shows the swelling of the internodes as do its lateral branches, at least those from the axils of the cotyledons. Tuberous rhizomes are common, as we remember, but they are mostly of two kinds: either is the main axis very slender and develops equally slender, horizontally-creeping stolons of which the outermost internodes become swollen so as to form a tuber, "tuberiferous stolons," or the main axis is already at the seedling stage visibly swollen, the swelling being moreover observable in all the subsequent internodes, that stay underground, as we remember from *Sanguinaria*, *Podophyllum* and many others; such rhizomes are called "tuberous."

Now in regard to the root-system, *Triadenum* possesses a main root, as shown in figures 1 and 2 (R.), which persists for about two seasons, when the stolons break off from the mother plant and develop adventitious roots at the nodes (*r* in figure 3), or more correctly just above these. The position of these adventitious roots is quite singular since they break out in a very short distance above the axillary buds, one above each, and when the buds stay dormant, the roots appear as if they were axillary; these roots are endogenous. This position of adventitious roots is not frequently met with, and we might recall some of the earlier observations upon this subject. Most frequently secondary roots develop at the nodes of stems, and when the leaves are opposite (and the stem quadrangular?) there may be observed four such roots at each node, one on each side of the leaf-base, or there may be several, as in a number of *Gramineæ*, *Juncaceæ*, *Ranunculaceæ*, *Umbelliferæ*, etc. Irmisch found from one to four secondary roots above the axillary bud in certain species of *Pyrola;* Professor Warming observed a similar position of such roots in *Hottonia*, *Dentaria*, *Cardamine*, *Sedum*, various species of *Campanula*, etc. In *Pyrola aphylla*, which we have described in a previously published paper, the adventitious roots do not break out exactly above the buds, but a little to the right or left of these.

But in *Triadenum* we observed only one root above each bud, two at each node, although the leaves are opposite; we must not forget, however, to state that the stem is cylindrical in this genus.

While thus the subterranean organs of *Triadenum* offer several points of interest, and by which the genus shows a marked deviation from the genus *Hypericum*, the organs above ground are of no less importance. We need only refer to the floral structure, as already indicated by Rafinesque. But besides this the leaves show a character by which they may be readily distinguished from those of broad-leaved species of *Hypericum*, not including *Androsæmum*, which is evidently a distinct genus; this character consists in the venation: the veins in *Triadenum* being very prominent on the lower face of the blade, and the secondaries being more numerous, but shorter and proceeding from the midvein under an angle that is much broader than is observable in the leaves of *Hypericum*. In the latter the secondaries proceed, as a rule, from below the middle of the midvein, while in *Triadenum* they are noticeable almost to the apex of the blade. These are the points which we observed in the external structure of our plant, and which ought to be mentioned in the diagnosis, whether it be accepted as a genus or not.

The observation of these characters induced the writer to extend the study to the internal structure, and to compare this with what is known, so far, about the general anatomy of the order. Moreover, *Triadenum* has not hitherto been examined from this point of view, and, as will be seen in the following, it possesses certain structural peculiarities which, together with the morphological, seem to entitle it to generic rank. The anatomy of the vegetative organs is as follows:

The root.

On the almost capillary, lateral roots developed upon the main one, hairs occur in abundance; there is a narrow cortical parenchyma, which is quite solid, and of which the cells are arranged radially towards the thin-walled endodermis, in which the spots named after Caspary are plainly visible. The pericambium consists of two layers outside the leptome, but of only one outside the hadrome. The root is diarchic with, in all, four vessels in two groups separated from each other by a few strata of thin-walled conjunctive tissue, and alternating with two groups of leptome. Ducts of rhombic cross-section are developed in the pericambium, one outside each of the two groups of leptome. Roots that are slightly thicker show the same structure, but are triarchic. But if we examine one of the thicker, lateral roots, we notice the structure to be somewhat different; the cortex, consisting of seven layers, shows a tangential collapsing of the innermost five; the endodermis shows a number of radial divisions, while the pericambium exhibits the same structure as in the thinner roots, though with a larger number of ducts outside the broad groups of leptome; these ducts are, also, rhombic in transverse section and have four secretory cells; the hadrome consists of many vessels with a few strata of thick-walled conjunctive tissue.

The secondary roots developed upon the rhizome are quite thick and show the same collapsing of the cortical parenchyma; the pericambium has commenced to divide itself tangentially with the large ducts still persisting, and, moreover, similar ducts are, also, observable in the leptome; a small cambium is developed and the hadrome occupies the greater portion of the central cylinder. In other words, these secondary roots show the structure of the perennial type. Van Tieghem, who studied the root of *Hypericum calycinum* (evidently "lateral roots"), observed two ducts in the pericambium, one on each side of the leptome, but none in the leptome itself.

The aërial stem.

This is glabrous and cylindrical with a thick-walled epidermis, which covers some five or six layers of cortical parenchyma with distinct intercellular spaces, but without lacunes; there is a thin-walled endodermis surrounding the leptome, cambium and hadrome, and the innermost part of the central cylinder is occupied by a pith, which soon becomes hollow. No stereome or hypoderm was observed. Two kinds of ducts occur in the stem; some with the four secretory cells very narrow (fig. 6), which traverse the cortex close to the epidermis, and of which there may be until twenty, and others with wide secretory cells (fig. 7) which are developed in the leptome and which are very numerous. In the uppermost portion of the stem, where the pith was unbroken, a single duct, rhombic in cross-section, was observed in the center. The occurrence and arrangement of the ducts in the stem seems very variable, and has been described by Van Tieghem in species of *Hypericum*, *Tridesmis*, *Haronga*, etc., but they do not seem to be frequent. When present in the pith the ducts are said to occur to the number of four, evidently corresponding with the four angles of the stem; the single and central duct observed in the pith of *Triadenum* seems thus to correspond with the circular outline of the stem.

The rhizome.

The stolons, slender and tuberous alike, have several layers of cork underneath the epidermis; the cortex forms a broad, but very open, tissue, and there is an endodermis of the same structure as observed in the above-ground stem. The leptome and hadrome enclose a central pith of rather small cells. Ducts are quite numerous in the internodes and we counted about forty in the cortex near the periphery, which were round, not rhombic, in transverse section (D in figure 8); besides these there were twelve others, of the same shape, in the leptome. No ducts were found in the pith. The structure of the tuberous rhizome of *Triadenum* is so different from that of *Hypericum calycinum*, that a comparison seems unnecessary; we might only state that Van Tieghem found four ducts in the pith, corresponding with the four rows of leaves.

The leaf.

The aërial leaves are glabrous and very glaucous; the structure is bifacial. Very characteristic is the marked difference in the lumen of the epidermal cells, when we compare the upper face with the lower, the cells of the upper being much the larger. Stomata occur only on the lower face; they are surrounded by three to four cells and are sunk below the epidermis; the cuticle is smooth.

The palisade tissue consists of but one layer and is quite solid, in contrast to the open pneumatic tissue. The midrib is prominent on the lower face, where it is supported by a collenchymatic tissue, but without any stereomatic layers. The translucid spots, so very characteristic of the order, are, also, noticeable in *Triadenum*, but the dark spots are entirely wanting. Ducts like those described in the stem occur, also, in the leaves and are of two kinds: Rhombic (in cross-section), with narrow secretory cells (D in fig. 4), were observed in the collenchyma and close to the epidermis; these, five in all, accompany the midrib to about the middle of the leaf-blade, but not any further. The other kind are, also, rhombic, but the lumen of the secretory cells is much wider; these, five in all, are located in the leptome (D in fig. 5) and may be followed throughout the length of the midrib.

So far as known, the stomata in the *Hypericaceæ* are only surrounded by two or three cells, thus *Triadenum* forms an exception; and the presence of ducts in the leaf seems to be exceedingly rare, and usually restricted to the petiole alone. The disposition of the ducts in the vegetative organs of *Triadenum* seems characteristic of the genus, when compared with the other *Hypericaceæ*, and four systems may be recognized:

(1) The medullary, only observed in the stem above ground; (2) those of the cortex in the stolons, the stem and the leaf-blade; (3) those of the pericambium of the root; (4) those of the leptome in the root, the stem, the stolons and the leaf.

There is, still, another species of *Triadenum* in this country, *T. petiolatum*, and we regret to say that we have been unable to secure fresh material of this for comparison. Judging from the structure of the flower and the venation of the leaves, it appears to belong to this genus, but, as is often the case, the parts underground are but seldom preserved in herbarium-specimens. We hope that future observers may study this species, and make a comparison between the two. But whatever the result may be, Linnæus's *Hypericum Virginicum* can no longer be considered as a species of this genus, and even if Rafinesque did not give but a mere hint as to its probable validity as a genus, *Triadenum*, nevertheless, appears tenable and indeed quite distinct from *Hypericum* and the other "generic synonyms."

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EXPLANATION OF FIGURES, p. 371.

Triadenum Virginicum (L.) Raf.

FIGURE 1.—Rhizome of a specimen, collected in October; natural size. S = base of fruitbearing stem; T = two tuberous stolons, developed from the axils of the cotyledons; R = the primary root.

FIGURE 2.—Rhizome of another specimen, collected at the same time; natural size. St. = a slender stolon, developed from the axil of one of the lower stem-leaves; the other letters as above.

FIGURE 3.—Rhizome of a specimen, collected in June; natural size. This rhizome represents a tuberous stolon, of which the terminal bud has developed into an above-ground stem. B = an axillary bud, still dormant; St. = the beginning development of an axillary stolon. *r* = secondary roots, developed above the axillary buds.

FIGURE 4.—Transverse section of a leaf. Ep = epidermis of the lower face; D = a duct. × 320.

FIGURE 5.—Transverse section of a leaf; the duct (D) is here located in the leptome; V = vessels. × 320.

FIGURE 6.—Transverse section of stem. Ep. = epidermis. D = a duct, located in the cortex. × 320.

FIGURE 7.—Transverse section of stem. End = endodermis. D = a duct; L = leptome; V = vessels. × 320.

FIGURE 8.—Transverse section of a tuber. C = cortical parenchyma; D = duct, of which four are visible in this section. × 75.

ART. XXXVII.—*Ephemeral Lakes in Arid Regions;* by CHARLES R. KEYES.

THE bolson plains—those broad mountain-locked basins which occupy so large a part of the high plateau regions of both Old and New Mexico—present certain geographic peculiarities that many writers have taken as evidence of their lacustrine origin. Their Spanish name signifies a purse. This they certainly are. From the immediate piedmont zone there is a gentle slope from all sides towards the middle. Drainage-ways there are none. And the central depression has no outlet. The reported remnants of old terraces on the mountain slopes, so far as personal examination has gone, all seem to be mistaken interpretations.

Since the flat-bottomed intermontane basins assumed their present attitude as slightly warped surfaces of an old destructional plain, they have been modified by fluviatile rather than lacustrine conditions. The old surface, formed on the beveled edges of Paleozoic and Mesozoic strata, has been covered by deposits which, though they are stratified gravels, sands and clays, must be now regarded as of subaërial origin.

The coarse materials covering the bolsons are readily seen to be composed of the same kinds of rocks that are found in the adjoining mountains. The arroyas in flood time carry out into the plain immense quantities of bowlders, gravel and finer materials. These produce great alluvial fans which become confluent and form marginal conglomerates of great thickness. For example, in the Sandoval bolson at the foot of the Ortiz mountains, the conglomerates are 150 or more feet in thickness. Shumard* reports their thickness in the Jornada del Muerto at 500 to 600 feet. Powell,† Dutton,‡ Hill,§ and others have described these bolson gravel deposits and consider them to have a subaërial genesis. This evidence is sufficient to clearly indicate that for the great part at least the later deposits of the bolsons cannot have ascribed to them a lacustrine origin.

There are some of the bolson plains in which limited deposits occur giving undoubted evidences of the existence of old lakes. The Sandoval bolson, south of Santa Fe, contains traces of a comparatively recent lake of considerable size. At the present time the remnants are found in a group as small salt ponds, the chief of which is Laguna del Perro.

There is a class of lakes which occur in connection with the bolsons which appear to have escaped the notice of writers on the arid regions. For want of a better title they are here called ephemeral lakes. They originate under abnormal though frequently recurring conditions.

* Trans. St. Louis Acad. Sci., i, p. 341, 1858.
† Geology of Unita Mts., p. 170, 1876.
‡ Geology High Plateaus, p. 219, 1880.
§ Occurrence of Artesian and Underground Waters, etc., p. 140, 1892.

On the Jornada del Muerto and many other similar basins there are slight depressions in the surface, which during the rainy season collect the storm waters in sufficient quantities to last several months. These ponds, which are frequently half a mile across, are welcomed by the stockmen.

Of similar character, but on a much grander scale, are certain ephemeral lakes which are known to have been formed at a comparatively recent date. From the local reports concerning some of these, there seems to be something of the mythical. There are, however, several instances, which are well authenticated, of the sudden formation of such lakes and their existence through a period of years.

One of these is located on the Mexican Central Railroad near the station called San José, about 75 miles south of El Paso in the state of Chihuahua, Mexico. This depression in the plain had been reported in the past to have contained water at times. The Rio Carmen, which runs west of Chihuahua and about 100 miles from San José, loses itself in the plain. Whenever there are excessive rains, which are said to occur at rare intervals along this stream, the waters form a lake often of considerable size. When recently a lake of large size made its appearance in a night, it was the first time in 15 years, according to the railroad officials, that the phenomenon had occurred.

Near Laguna station on the same line of railroad, 160 miles south of El Paso, similar conditions obtain. A short time ago the railroad company was compelled to move its track for a distance of seven kilometers on account of the water rising in the central depression in the bolson. Unusually heavy rains in the mountains suddenly brought the water of the Sanz river down in a body never before known. When the railroad was located it was believed that it was at an elevation far above the level of any possible "lake" waters, and far enough away from any future shore line.

In the famous Elephant Butte case which was fought through the United States courts for so many years, some interesting data bearing upon the subject in hand were brought out. One instance is especially worthy of note. The state of Tamanlipas is crossed by the Rio San Juan, a stream of considerable size which flows into the Rio Grande at the city of Camargo. Many years ago, according to the old man who was a witness in the legal case, occurred a great flood in the San Juan valley. It filled full the valley of the Rio Grande, broke over the foot hills and made a long chain of large lakes, from which navigation of the Rio Grande lower down was carried on for a number of years. These lakes, which were formed in dry desert basins in the course of a few days, lasted for a period of 80 years.

New Mexico School of Mines, Socorro,
July 1st, 1903.

ART. XXXVIII.—*Note on the Identity of Palacheite and Botryogen;* by ARTHUR S. EAKLE.

UNDER the name *palacheite*,* the writer recently described crystals of a deep red ferri-magnesium sulphate, found at the old Redington quicksilver mine, now known as the Boston mine, Knoxville, California. A later investigation of the chemical composition and crystallization of botryogen shows that palacheite is probably very pure and well crystallized botryogen, and therefore not new as supposed. On noting the similarity in composition of the two sulphates, the analogy of the two in crystallization and physical properties was at once apparent.

Owing to the variations shown in the composition of botryogen, different formulæ have been assigned to the mineral, and the one given by Hockauf† and quoted in Dana's System of Mineralogy, namely, $MgFeS_2O_8+Fe_2S_2O_9+18H_2O$, led to the error of overlooking botryogen as being the same substance. Cleve‡ later deduces from his analyses of botryogen the formula $Mg(FeOH)(SO_4)_2.7H_2O$ or $2MgOFe_2O_3.4SO_3 + 15H_2O$, which latter is the same formula given to palacheite.

The analyses of botryogen show varying amounts of other oxides, namely FeO, MnO, CaO and ZnO, which have been regarded as impurities, replacing the MgO or FeO, but the small amount of material spared for the analyses of palacheite did not show the presence of any of these impurities.

The writer collected an abundance of beautiful specimens of the sulphate this summer, during a visit to the mine, and Professor Blasdale of the Chemical Department kindly made special qualitative tests on larger amounts for impurities, with the result that a small amount of manganese, probably less than one-tenth per cent, is present, but no zinc. The material is, therefore, the purest botryogen that has been found.

The axial elements for botryogen and palacheite are as follows:

Botryogen $a:b:c=0·6521:1:0·5992$; $\beta=117°\ 34'$ (Haidinger)
Palacheite $a:b:c=0·6554:1:0·3996$; $\beta=117°\ 9'$

The short vertical axis for palacheite was calculated by assuming the most frequently occurring clinodome as {011}. The corresponding form on botryogen is {023}, which practically gives the same length of *c*-axis for botryogen as for palacheite. The only orthodome observed was {$\bar{2}$01}, but it is

* Bull. Dept. Geol. Univ. of Cal., iii, 231–236, 1903.
† Zeitschr. Kryst., xii, 240–254, 1887.
‡ Idem, xxviii, 510, 1898.

exceedingly small and seldom occurs. Assuming it as {$\bar{1}01$}, the vertical parameter for palacheite would become 0·7992, which corresponds to the *c*-axis of botryogen, calculated by Hockauf from Haidinger's measurements. Most of the crystals are worthless for the determination of the elements, because of striated and vicinal faces; but the axial elements for palacheite were calculated from the measurements, with the two-circle goniometer, of several very minute crystals which gave good reflections, and it seems probable they are nearer the true values for botryogen than those given by Haidinger.

The excellent cleavage parallel to the clinopinacoid seems not to have been observed on botryogen. This cleavage is more prominent and better than the prismatic cleavage. Very little has been done on the optical properties of botryogen. Hockauf states that the plane of the optic axes lies nearly normal to the prismatic faces. As a matter of fact it is nearly parallel to the edge $110 \wedge 1\bar{1}0$. The analogy of the interfacial angles to those of anorthite, which he mentions, probably means little, as the crystals are undoubtedly monoclinic.

The crystals remain unchanged in ordinary dry air, as the original specimens, exposed in the laboratory, for over a year, have suffered no alteration. Much yellow earthy sulphate, however, accompanied the material recently obtained, which may have been derived from the crystals by exposure to dampness. This yellow coating has a strong astringent taste, like coquimbite, while the taste of the fresh crystals is barely perceptible or none. The yellow coating must be a different sulphate, although Hockauf states that the analyses of the ochre yellow substance and of the red crystals were essentially the same.

An unsuccessful attempt was made with a small amount of the original substance to recrystallize the mineral; with the large amount of material now at hand, further experiments will be made in the hope of obtaining good crystals. The main difficulty is perhaps in keeping the mineral into solution in pure water without the precipitation of the basic sulphate, which so readily forms.

While the name palacheite should be recalled, although the name botryogen is a misnomer for these crystals, the work will stand as a more complete study of the rare sulphate botryogen than has heretofore been possible.

University of California.

Art. XXXIX.—*On Colloidal Gold: Adsorption Phenomena and Allotropy*; by J. C. Blake.

[Contributions from the Kent Chemical Lab. of Yale University—CXX.]

Red and blue colloidal gold solutions have long been known,* the red being changed to blue by the action of electrolytes. Hence, in order to study all of the concurrent phenomena, it is necessary to begin with a red solution. All of the red solutions heretofore described, however, have either contained objectionable impurities, like the acids of phosphorus, or have been very dilute and hard to prepare in stable form with constant properties. I have found that a concentrated red gold solution, free from all these objections, may be prepared by pouring into acetylene water containing ether an ethereal solution of gold chloride dried at 170°. The resulting garnet-colored solution of colloidal gold is exceedingly stable, though quite strongly acid. It is scarcely turbid in ordinary light, but gives the Tyndall effect when a beam of light is thrown into it with a lens. This solution has been investigated with regard to the adsorption phenomena of the gold when precipitated by electrolytes, an investigation attended by some interesting observations on the apparent allotropy of gold.

It should be rememberd that Linder and Picton† and Whitney and Ober,‡ working with colloidal solutions of arsenious sulphide, have found that when such solutions are coagulated by electrolytes, part of the basic radical of the electrolyte is retained by the coagulum, with the liberation of the corresponding amount of free acid in the filtrate. The base thus retained by the coagulum cannot be washed out with water. Since the suspended particles of which the colloidal solutions are made up are known to be negatively electrified, whereas the basic radicals or ions carry a positive charge, the question arises whether the basic radical retained by the coagulated colloid may not be held by reason of the mutual neutralization of these charges, with the formation of a chemical compound or pseudo-chemical compound, thus perhaps affording an indication of the nature of chemical union and proving that the phenomena of the permanent suspension of solid particles in liquids and their subsequent precipitation by electrolytes are essentially electrical, as is assumed in Whetham's§ hypothesis. It was thought that the

*Faraday, Phil. Trans., cxlvii, 145; Pogg. Ann., ci, 313. Zsigmondy, Lieb. Ann., ccci, 29, 361; Zeit. phys. Chem., xxiii, 63.

† Jour. Chem. Soc., lxvii, 63.

‡ Jour. Am. Chem. Soc., xxiii, 842.

§ Jour. of Physiol., xxiv, 288; Phil. Mag., xlviii, 474.

results to be obtained with colloidal gold solutions would be especially interesting in this connection, both because of the great improbability of ordinary chemical union between the gold and the basic radicals, and because of the ease and thoroughness with which the precipitated gold could be washed.

Red colloidal solutions of gold prepared according to the method just described were precipitated by solutions of barium compounds, and the coagulum was analyzed for gold, barium, and carbon, derived from the acetylene. Except when otherwise stated, all the filtrations and weighings were made on asbestos felt contained in a perforated platinum crucible. The mixed coagulum, either washed or unwashed, was ignited in a porcelain crucible and then treated with aqua regia in small amount either at the ordinary temperature or on the steam bath, the carbon being nearly all dissolved in the latter case. After dilution, the undissolved carbon was filtered off, washed, dried at 200°, weighed and ignited. The gold was determined as the metal in the filtrate from the carbon by precipitation with magnesium ribbon. The barium was precipitated as sulphate in the filtrate from the gold and weighed after standing twelve hours on the steam bath.

It was found that if the colloidal gold solution contained a little unreduced gold chloride, the coagulum was coherent, spongy, opaque, insoluble in water, and reflected brownish yellow light. If, however, the gold chloride had been completely reduced, the coagulum was blue-black, non-coherent, readily soluble in pure water to a blue colloidal solution, the color being due to transmitted light.

I. *The Spongy Form of Gold.*

In the following experiments the gold chloride used in preparing the colloidal gold solution was not quite all reduced, and the colloidal gold, precipitated with a solution of a barium salt, came down in the spongy form. The coagulum was either washed in succession with the amounts of water given in the table, the included liquid being finally pressed out of the spongy precipitate as much as possible, or the coagulum was not washed, but merely dried between filter papers. For purposes of comparison the amounts of the barium compounds (calculated as hydroxide) which were present in $0{\cdot}5^{cm^3}$ of the supernatant liquid are also given in the table.

TABLE I.

Vol. of gold sol. cm³.	Precipitant.	Wash water cm³.	Mixed coagulum, ignited. grm.	Gold found. grm.	$Ba(OH)_2$ found. grm.	Calc. amt. of $Ba(OH)_2$ in 0·5 cm³ supernatant liquid. grm.	Error of analysis. grm.
550	50 cm³ $\frac{n}{10}$—$Ba(NO_3)_2$	300, 50	0·4151	0·4151	0·0000	0·0003	0·0000
1200	100 cm³ n—$BaCl_2$	500, 100, 100	2·2668	-----*	0·0020	0·0033	-----
610	10 cm³ $\frac{n}{10}$—$BaCl_2$	Not washed. Dried between filter papers.	0·7569	0·7566	0·0000	0·0001	0·0003—
610	100 cm³ n—$BaCl_2$	Not washed. Dried between filter papers.	0·6499	0·6417	0·0066	0·0060	0·0016—†

From the foregoing results it is plain that very little of the barium compound is held by the gold under these conditions, and that the traces thus retained cannot readily be washed out—a condition agreeing exactly with what would be expected if the barium were held as nitrate or chloride dissolved in the liquid mechanically retained by the spongy gold. The obvious physical properties of this spongy gold proved to be identical with those of the gold thrown out from strong solutions of gold compounds by ferrous sulphate or oxalic acid, which is known to be crystalline.‡

II. *The Blue Form of Gold.*

In the following experiments the gold chloride used in preparing the colloidal gold solution was all reduced, and the colloidal gold, precipitated with a solution of a barium compound, came down in the non-coherent blue form. In the experiments given under A (p. 386), the coagulum was washed successively by decantation with the given amounts of hot water without the use of a filter, part of the finely-divided gold thus temporarily re-suspended being washed away. In the experiments given under B, the coagulum was thrown upon an ashless filter (or asbestos felt) held in a large platinum cone, the mother liquor was exhausted by suction, and the barium compound held by the unwashed gold and the filter was determined.

* Gold lost by explosion, presumably owing to the formation of a hydride during reduction by magnesium.

† This error becomes 0·0003— if the barium held by the gold be calculated as the chloride.

‡ Roscoe and Schoelemmer, Treatise on Chemistry, 1898, ii, p. 399.

By comparing the amounts of the barium compounds thus found with the amounts of the barium compounds held by the filter in blank experiments similarly conducted, and with the amounts of the barium compounds held by 1^{cm^3} of the supernatant liquid, a very fair estimate of the amount of the barium compounds held by the gold can be arrived at. In these experiments the amounts of carbon left with the gold after ignition, not readily dissolved in the subsequent treatment with *aqua regia*, first became noticeable, indicating that in the former experiments most of the carbon had been lost by decantation. In the experiments given under C (p. 387), a freshly prepared solution of barium hydroxide, containing about 20^{grm} per liter, was used as the precipitant, the supernatant liquid being still slightly acid; while in the experiments given under D, the barium hydroxide was added to alkaline reaction. The wash-water was neutral to litmus.

The results of Table II (pp. 386, 387) show that as long as the solution is even slightly acid only insignificant amounts of barium are held by the gold, whether washed or unwashed. Other colloidal (blue) gold solutions, prepared by the action of hydrazine hydrate on a water solution of gold chloride, in which the free acid was nearly neutralized by the hydrazine hydrate before the gold was precipitated by barium chloride, gave similar results. When the supernatant liquid becomes alkaline, on the other hand, the amount of barium retained by the gold becomes appreciable. It is probable that none of this amount was due to the presence of barium carbonate, although there was doubtless some barium chloride (formed by the reaction) present with the hydroxide in experiment (12) of the table, owing to the insolubility of the chloride in alcohol. There is, however, no reason to suppose that the amount of barium hydroxide retained by the gold precipitated from alkaline solution is greater than that which would have been retained, owing to the well-known tenacity of free alkalis for solid substances, by any finely-divided insoluble substance under similar conditions of concentration.* In fact, the absence of adsorption phenomena in acid solution and the presence of such phenomena in alkaline solution is in full accord with Van Bemmelen's functional equation for absorption from solution by porous solids

$$C''_{KOH} = f(C'_{K_2SO_4}, C'_{SO_3})$$

where C''_{KOH} is the concentration of the base in the liquid retained by the solid, and C' represents the concentrations of the given substances in the supernatant liquid. C'' increases as $C'_{K_2SO_4}$ increases, and decreases as C'_{SO_3} increases.

* Cf. Van Bemmelen, Zeit. anorg. Chem., xxiii, 364.

Hence, it appears that adsorption phenomena are not pronouncedly concerned, if at all, in the color changes brought about in red gold solutions by electrolytes, or in the subsequent precipitation of the blue or of the spongy gold. Some interesting results might be obtained in this connection by working with neutral red gold solutions, such as might have been prepared by dialysing the ones here described; but it is difficult to see how any such results could be intelligible unless differentiated by a series of parallel experiments from the effects due to the hydrolysis of neutral salts and absorption of the basic radical by porous solids. If these two effects are identical, as suggested by Whitney and Ober, then Whetham's hypothesis can receive no support from the results to be obtained with them.

The "blue gold" precipitated in these experiments is amorphous and has a dark bronze appearance when viewed in reflected light. The three apparently allotropic forms of gold here noted, named according to the colors most readily observed, as in the case of silver,* are the following:

Form of gold.	Color in reflected light.	Color in transmitted light.
"Yellow gold"	Golden	Blue
"Blue gold"	Dark bronze	Blue
"Red gold"	Light golden†	Red

* This Journal [4], xvi, 282 (1903).
† Well seen in the Tyndall effect.

TABLE II.

A. Coagulum washed.

No.	Vol. of gold solution cm^3.	Precipitant.	Treatment of moist coagulum.	Coagulum, ignited. grm.	Gold found. grm.	Carbon found. grm.	$Ba(OH)_2$ found. grm.	Calc. amt. of $Ba(OH)_2$ in supernatant liquid. grm.	$Ba(OH)_2$ in blank. (aver'ges) grm.	Error of analysis. grm.
1	600	100 cm^3 $n-BaCl_2$	*Water.* { 500, 100 }	0·3216*	0·3200	------	0·0013	0·5 cm^3 0·0071	----	0·0003—
2	1400	100 cm^3 $n-BaCl_2$	{ 1000, 150, 20 }	0·5691	0·5690	--- --	0·0003	0·0030	----	0·0002+
3	1100	50 cm^3 $2n-BaCl_2$	{ 500, 100, 100 }	0·8439†	0·8435	------	0·0004	0·0037	----	0·0000

B. Coagulum unwashed.

No.	Vol. of gold solution cm^3.	Precipitant.	Treatment of moist coagulum.	Coagulum, ignited. grm.	Gold found. grm.	Carbon found. grm.	$Ba(OH)_2$ found. grm.	Calc. amt. of $Ba(OH)_2$ in supernatant liquid. grm.	$Ba(OH)_2$ in blank. (aver'ges) grm.	Error of analysis. grm.
4	760	25 cm^3 $\frac{n}{10}-BaCl_2$	Collected on asbestos felt without washing.	0·9271	------	Considerable amounts.	0·0009	1 cm^3 0·0003	0·0005	------
5	880	25 cm^3 $n-BaCl_2$		0·8875	------		0·0027	0·0024	0·0023	------
6	1000	25 cm^3 $\frac{n}{10}-BaCl_2$	Collected on filter paper without washing.	0·3520	0·3503	Dissolved with the gold, by digestion.	0·0002	0·0002	0·0005	0·0015—‡
7	980	25 cm^3 $n-BaCl_2$		1·3239	1·3161	0·0027	0·0037	0·0022	0·0023	0·0013—‡

* Loss above 80°=0·0032 grm. † Loss above 120°=0·0027 grm. ‡ Attributed to carbon dissolved by the *aqua regia*.

TABLE II—*Continued.*

C. $Ba(OH)_2$ not in excess.

No.	Vol. of gold solution. cm^3.	Precipitant.	Treatment of moist coagulum.	Coagulum, ignited. grm.	Gold found. grm.	Carbon found. grm.	$Ba(OH)_2$ found. grm.	Calc. amt. of $Ba(OH)_2$ in supernatant liquid. grm.	Error of analysis. grm.
8	1000	25 cm^3 $Ba(OH)_2$ sol.	*Water.* {500, 200, 100}	0·1465	0·1463	0·0003	0·0002	0·5 cm^3 0·0003	0·0003 +
9	1000	25 cm^3 $Ba(OH)_2$ sol.	Collected on filter paper without washing.	0·4159	0·4125	0·0022	0·0006	1 cm^3 0·0005	0·0006 —
			D. $Ba(OH)_2$ in excess.						
10	1000	50 cm^3 $Ba(OH)_2$ sol.	{500, 100, 100}	0·2545	0·2524	0·0006	0·0019	0·5 cm^3 0·0005	0·0004 +
11	1000	125 cm^3 $Ba(OH)_2$ sol.	{100, 20}	2·4610	-----*	0·0014	0·0104	0·0013	------
12	1000	100 cm^3 $Ba(OH)_2$ sol.	Alcohol {100, 100, 100, 5}	0 8447	0·8306	------	0·0168	0·0010	0·0027 + ‡

* Gold lost by explosion.

† This error becomes 0·0009 + if the barium held by the gold was present as the oxide after ignition, protected from the carbon dioxide of the air by the surrounding gold. Cf. Gmelin-Kraut, Anorg. Chem. II (1), 259.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The Utilization of Atmospheric Nitrogen for Agricultural and Industrial Purposes.*—In an address before the recent International Congress for Applied Chemistry at Berlin, Dr. Frank stated that we are now in a position, by the help of electric power, to combine the hitherto passive nitrogen of the air and to make it useful for the fertilization of land and for the production of nitrogenous chemical products. The particular process described depends on the fixation of nitrogen by calcium carbide, a product of the electric furnace which is now extensively manufactured. The product of this reaction is not calcium cyanide, as might be expected, but calcium cyanamide :

$$CaC_2 + N_2 = CaCN_2 + C.$$

From this product cyanamide itself is readily prepared, and both substances yield ammonia when heated with water under high pressure :

$$CaCN_2 + 3H_2O = CaCO_3 + 2NH_3$$
$$CN_2H_2 + 3H_2O = (NH_4)_2CO_3.$$

Experiments with plants have been made which indicate that the crude calcium cyanamide will serve very well when used directly as a fertilizer. The substance contains from 14 to 22 per cent of nitrogen, according to the process used for its manufacture, so that it approaches Chili saltpeter and ammonium-sulphate in its richness in this fertilizing element. As an indication of the availability of these substances for plant-food, it may be mentioned that cyanamide, by simply taking up water, is converted into urea :

$$CN_2H_2 + H_2O = CH_4N_2O.$$

The importance of a cheap method of fixing atmospheric nitrogen can hardly be over-estimated, in view of the fact that about three-quarters of the Chili saltpeter and ammonium sulphate are used for agricultural purposes. It may be expected also that the supply of Chili-saltpeter would otherwise soon be exhausted, since the export of this salt from the western coast of South America increased from 68,500 tons in 1860 to 1,453,000 tons in 1900. The world's future food-supply largely depends upon the supply of nitrogenous fertilizers.—*Zeitschr. angew. Chem.*, xvi, 536. H. L. W.

2. *The Use of Calcium Cyanamide for Producing Alkaline Cyanides.*—The production of calcium cyanamide has been described in the preceding notice. At the recent International Congress for Applied Chemistry at Berlin, Dr. G. Erlwein has explained the use of this new material in the manufacture of cyanides. He states that calcium carbide, with proper treatment, can be made to take up from 85 to 95 per cent of the theoretical amount of

nitrogen when heated in a muffle with fuel instead of being heated in an electric furnace. The black product, containing lime and carbon as impurities, impure calcium cyanamide with 20 to 23½ per cent of nitrogen, can be treated for the production of cyanides in various ways. It has been found possible, however, to produce the calcium cyanamide by a single operation in the electric furnace according to the equation,

$$CaO + 2C + N_2 = CaCN_2 + CO.$$

This direct process is more economical than the indirect one by means of calcium carbide, and it will be of great practical importance not only for the production of cyanides, but also for the preparation of the substance for fertilizing purposes.

It was found that calcium cyanamide, by a simple leaching process, yields crystallized dicyandiamide :

$$2CaCN_2 + 4H_2O = 2Ca(OH)_2 + (CNNH_2)_2.$$

The latter salt, then, by a simple fusion process, gives pure alkaline cyanides :

$$4CNNH_2 + 2Na_2CO_3 + 4C = 4NaCN + 2NH_3 + H_2 + 6CO + N_2$$

Another important result is the production of a substitute for potassium cyanide, to be used in gold extraction, by fusing crude calcium cyanamide with common salt. The product corresponds to 30 per cent potassium cyanide, is extraordinarily cheap, and answers the purpose as well as the pure salt.—*Zeitschr. angew. Chem.*, xvi, 533. H. L. W.

3. *The Separation of Gaseous Mixtures by Centrifugal Force.*—In the preceding number of this Journal a process for separating gases of different density by centrifugal force was noticed. It seemed necessary, therefore, to mention here the fact that Claude and Demoussy have reached the conclusion that this method produces only very slight results, if, indeed, there is any separation at all. These experimenters used a strong steel tube about 50^{cm} long and 3^{cm} in internal diameter, provided with stopcocks at the ends and with interior spring-valves near the ends. The tube was charged with gaseous mixtures under pressure, so that the differences in density were augmented, then it was rotated about an axis perpendicular to its center at the rate of 3600 revolutions per minute. It did not seem prudent to exceed this speed, which was greater than that used in the industrial machines that have been referred to. The internal valves were adjusted by springs in such a way that they opened by the action of centrifugal force, and closed tightly after the speed became slower. Analyses showed that the gases collected beyond the valves after rotation did not differ appreciably from the original mixtures in the cases of air, oxygen and carbon dioxide, and even hydrogen and carbon dioxide.—*Comptes Rendus*, cxxxvii, 250. H. L. W.

4. *Investigations on Double Salts by Physical Means.*—Dr. H. W. Foote of the Sheffield Laboratory has devised a method for determining what double salts are formed by two single salts with a common ion. The method depends chiefly on well-known

principles of solubility. At a given temperature there will be but one saturated solution possible when both salts are present in excess, provided the salts form no double salts with each other. If one double salt forms, there will be two definite saturated solutions, one when A and AB are both present as solids, the other when AB and B are present. The single salts alone or a double salt alone can exist in contact with a series of saturated solutions containing A and B. It follows that when two salts, either simple or double, are present in the solid state the composition of the solid will change as the relative proportion of the two salts changes, but the composition of the saturated solution will remain constant. When, however, only one salt, either simple or double, is in the solid state its composition must remain fixed, while the composition of the saturated solution varies within certain limits. By making a series of saturated solutions with a pair of salts, therefore, and determining the composition of the solutions and the residues, it is possible to determine the composition of every double salt that is formed. Dr. Foote has applied the method in several cases with entirely satisfactory results; for instance, he has shown that five cæsium mercuric chlorides, and no others, exist at the temperature of the experiments. These salts, $3CsCl.HgCl_2$, $2CsCl.HgCl_2$, $CsCl.HgCl_2$, $CsCl.2HgCl_2$ and $CsCl.5HgCl_2$ were described by Wells in this Journal in 1892. The method, which is an application of the Phase Rule of the late Professor Gibbs, promises to be exceedingly serviceable in the investigation of double salts, for by its use every double salt, whether well-crystallized or not, can be detected, while by the old method some members of a series might easily be overlooked.—*Amer. Chem. Jour.*, xxx, 330, 339.

H. L. W.

5. *Ausgewählte Methoden der Analytischen Chemie;* von Prof. Dr. A. Classen. Zweiter Band, 8vo, pp. xvi, 831. Braunschweig 1903 (Vieweg und Sohn).—The first volume of this excellent reference-book for practical analysts has already been noticed in this Journal. The present second volume deals with the non-metallic elements, and it need only be repeated here that every analytical chemist should have access to this valuable work.

H. L. W.

6. *Physical Chemistry in the Service of the Sciences;* by Jacobus H. van't Hoff. English version by Alexander Smith. 8vo, pp. 150, Chicago 1903. (The University of Chicago Press.)—This book comprises a series of nine lectures delivered in June, 1901 at the decennial celebration of the University of Chicago. The subjects discussed, after an introductory address, are the relation of physical chemistry to pure chemistry, industrial chemistry, physiology and geology. In view of the eminence of the author it is hardly necessary to say that these lectures give an excellent account of the more important achievements of physical chemistry.

H. L. W.

7. *Penetrative Solar Radiations.* — M. R. Blondlot believes

that he has discovered new radiations from the sun which he terms the *n*-rays. A fine glass tube containing sulphide of calcium exposed to the sun for a very short time continued to glow, but the glow diminished when a plate of lead was interposed between the shutter and the sulphide, and increased when the lead was removed. When an oaken joist 3^{cm} thick, a piece of cardboard, and several sheets of aluminum were successively interposed there was no diminution in the glow. A layer of pure water entirely arrested the *n*-radiations. The radiations could be concentrated by a quartz lens. They are regularly reflected by a polished glass surface, and diffused by an unpolished surface. —*Comptes Rendus*, 24. *Nature*, July 9, 1903. J. T.

8. *Spectra of the Cathode light in Gaseous Compounds of Nitrogen and Carbon.*—M. H. DESLANDRES states that the cathode light gives the same spectrum as the anode light in the luminous part of the spectrum and also between $\lambda = 400$ and $\lambda = 300$, but from $\lambda = 300$ to $\lambda = 200$ a new band spectrum is observed having a remarkably simple relation between its bands. —*Comptes Rendus*, Sept. 14, 1903. J. T.

9. *The Dark Cathode Space.*—Numerous papers have appeared on the analogy between conduction in gases and electrolytic conduction in fluids. G. C. SCHMIDT extends the analogy to a consideration of the phenomena in the dark cathode space and founds a theory upon Nernst's theory of the electrolysis of certain water solutions. A soluble electrode is one which sends electrons or ions into the gas; an insoluble one which cannot. White hot electrodes and electrodes from which cathode rays are emitted are considered soluble; also light electric metals that emit electrons on exposure to light. This theory is borne in mind in the author's experiments. The dark cathode space is regarded as a space poor in ions. The fall in potential is also considered from the view of the poverty or affluence of ions. The poverty extends to the cathode itself, while the anode possesses the abundance. The cathode dark space behaves as a dielectric, and does not screen electric waves.—*Ann. der Physik.*, No. 11, pp. 622–652. J. T.

10. *Observations of Slow Cathode Radiations with the help of Phosphorescence.*—P. LENARD contributes an exhaustive paper on this subject, and also upon secondary excitation of cathode rays. He gives his reasons for preferring the employment of phosphorescence to the use of the electrometer. The former serves to individualize the phenomena, while the latter gives the integral effect. He introduces the new term *Quanten* to denote the corpuscle or portion of negative electricity. The path of the *Quanten* is a cathode ray. Electrically laden atoms he terms bearers of electricity or *Träger*. Ultra-violet rays pass into a suitable tube, where they are submitted to varying differences of electric potential, and the spreading out of the rays is observed on a phosphorescent screen, contained in the same tube. Various phenomena are described and theories of absorption of energy

are discussed. It was found that the secondary excitation of cathode rays is not due to a splitting up of the molecule in an electrolytic sense. The question is discussed whether the bearers of electricity are bound to the material gas particles, and whether the light electric phenomena are due to double layers on material in air which subsist for a long time in a vacuum.—*Ann. der Physik.*, No. 11, 1903, pp. 450–490. J. T.

11. *Discharge of Electricity from Hot Platinum.*—HAROLD A. WILSON, of Trinity College, Cambridge, finds that the presence of traces of hydrogen in platinum wire enormously increases the leak of negative electricity from it. The presence also of traces of phosphoric pentoxide greatly increased this leak. The variation of the negative leak with air pressure and potential difference is due to the ionization of the air by collisions of air molecules with the negative ions leaving the wire.—*Roy. Soc.*, June 18, 1903; *Nature*, July 16, 1903. J. T.

12. *Penetrating Radiation from the Earth's Surface.*—Mr. H. LESTER COOKE of McGill University, Montreal, working under the direction of Prof. Rutherford, gives as the results of his investigation:

"(1) The proof of the existence of a very penetrating radiation, present everywhere under ordinary conditions. This radiation is similar in properties to the radiation from radium, and is comparable to it in penetrating power. This radiation is accountable for between 30 and 33 per cent of the natural ionization observed in ordinary testing vessels, 33 per cent being the greatest reduction obtained by the use of massive lead screens. This penetrating radiation may have its origin in the radio-active matter which is distributed throughout the earth and atmosphere. It was not found possible to obtain sufficient excited activity on a wire charged negatively in the open air to show the presence of a very penetrating radiation due to it. The effect observed is too large to be accounted for by the excited activity distributed on the walls of the laboratory.

(2) That all substances examined give forth a radiation of a not very penetrating character: that this is probably the cause of all the residual ionization in the electroscope when surrounded by heavy metal screens; and that this activity varies with different substances, being very low in the case of brass.

(3) The reduction by the experimental arrangements of the number of ions produced per c.c. per second in air under atmospheric pressure from 14 to 5."—*Phil. Mag.*, Oct., 1903, pp. 403–411. J. T.

13. *Mathematical Papers of the late George Green.* xii + 336 pp. Paris, 1903 (A. Hermann).—This is a fac-simile reprint by photographic process of Ferrers' edition of Green's Papers and is to be welcomed as increasing their accessibility to students of mathematical physics. There is no better introduction to the theory of electrostatics and the Newtonian potential in general than the celebrated paper of 1828 in which the name potential

was first used and in which the great utility and preëminent importance of this function was first made plain. Few, if any, improvements in the presentation of the general theory have been made in the seventy-five years since its publication, and it has all the advantage of being the original work of a great genius and of showing in a measure the processes by which he reached his results. That such a work should have been produced by a young man without any mathematical training except what he could gain for himself is one of the most interesting chapters in the natural history of genius. Some of the other papers are of less direct interest at the present day; that on the propagation of light in crystallized media, however, is still the foundation of the theory of the elasticity of æolotropic solids and cannot be neglected by the student who desires a comprehensive knowledge of the history of this important subject.

H. A. B.

14. *Electric and Magnetic Circuits;* by Ellis H. Crapper. xi+379 pp. New York, 1903 (Longmans, Green and Co.).—The plan of this elementary text-book for students of electrical engineering is not unlike that of the school arithmetics in which a large number of numerical examples are propounded for solution by the student, each collection of problems bring prefaced by a brief statement of the "rules" necessary for solving them, and by two or three worked-out examples. The explanatory portions leave much to be desired especially in the more elementary sections. The definitions are often inaccurate and sometimes quite meaningless, as on p. 3 where the ampere is defined as "the time rate of change of the coulomb per second." The explanations often give entirely wrong ideas of the relations between electrical quantities and of the laws which express them, as in the discussion of E.M.F. and P.D. on pp. 34 and 35 and the curious statement on p. 39 that the constant ratio of the E.M.F. to the current "was discovered by Ohm to be equal in all cases to the total resistance of the circuit". Most of the formulae used for solving the problems are introduced as depending directly upon experiment with no indication that they might easily be deduced from preceding ones ; it is hard to believe that there is any very large number of students of electricity so deficient in logical memory as to find this method easier and more "practical" than an orderly and logical presentation. A still more serious defect, in a book primarily intended to teach engineers to calculate, is that no attention is paid to the limits of accuracy in data and results. In the illustrative examples, currents and resistances are calculated to six or seven significant figures, the cost of incandescent lights per candle-hour is determined to the ten-millionth of a penny, and in one case (p. 306) the torque exerted by a motor is calculated to eleven figures from data given to four figures. Such calculations cannot be regarded as good models for imitation by future engineers. H. A. B.

II. Geology and Mineralogy.

1. *United States Geological Survey:* C. D. Walcott, Director.—The following publications have recently been received:

Folios No. 92. Gaines Folio, Pennsylvania-New York.

No. 93. Elkland-Tioga Folio, Pennsylvania; by Myron L. Fuller and William C. Alden.

These folios are specially interesting as an expression of the revision of classification of the terminal Devonian formation of the New York-Pennsylvania area based on recent surveys. The classification adopted is as follows:

Carboniferous	Pennsylvanian	Pottsville	30′–200′
		Sharon conglomerate	60–100′
		Mauch Chunk	0–100′
	Mississippian	Oswayo	1000′
Devonian		Cattaraugus	500′
		Chemung	600–2000′+.

The definition of the formations is based upon lithologic characters. In describing the Chemung on the Gaines quadrangle the author says: "It should be clearly distinguished from the paleontologic division called Chemung which includes both the marine fauna of the lithologic Chemung and the fresh and brackish water fauna of the overlying Cattaraugus and lower portion of the Oswayo formations." In other words, the Chemung fauna may be regarded as ranging above the Chemung formation and as high as the lower part of the Oswayo formation.

Lithologically the Chemung is limited below by the bluish shales of the Portage, not reached in these quadrangles, and above by the red shales of the Cattaraugus. Soft laminated shales predominate; limestones predominate in upper part; the thickest beds in the upper 100 or 200 feet. A single bed of bright red shale is reported? 300 feet down in the Tioga quadrangle, and a thin lens of iron ore at same level, with dull reddish brown shales still lower. A bed of gray cross-bedded sandstone of Cattaraugus type is reported 60 or 100 feet below the top. Vertical worm borings, concretions of sand, and a few thin lenses of conglomerate are seen in the upper part of the formation. Two horizons of iron ore beds are seen, one "close to the top," the second 300 feet or more down. The upper is the "Mansfield" ore beds a few feet below the first red bed of the Cattaraugus. Chemung character of rock and fossils are said to occur for 50 to 100 feet after the reds of the Cattaraugus first appear.

The limits of the Cattaraugus are given as from the first pronounced red beds upward for 500 feet, the upper limit arbitrarily drawn. The red beds are thicker in the southeastern portion of the area and are thinner and more widely separated by more pronounced beds of other kinds to the west and northwest. Cross-bedding is conspicuous. This corresponds in general to the formation which has been called the red Catskill.

Oswayo is characterized by green and gray sandstones and shales with occasional thin beds or lenses of red shale from the arbitrary top limit of the Cattaraugus to a point at which decidedly red beds begin to appear about 1100 feet higher up. These beds are also more or less cross-bedded.

The Mauch Chunk includes from the lowest recognized red bed overlying the Oswayo for 100 feet upward or less, and is terminated above by an unconformity.

The Pottsville formation is described in the text as including the Sharon conglomerate member at the base, 60 to 100 feet in thickness, almost entirely quartz, "and is frequently a coarse sandstone rather than a conglomerate." The upper portion is more sandy and shaly than the lower and with one or more coal seams; the fossil plants in which have been identified with those of the Mercer horizon of the Pottsville.

It is evident from these definitions that the limits set for the formations are both local and arbitrary ; and as the characters used in drawing the lines are recognized as varying across the area mapped in these two contiguous folios, it is not probable that formations based on the same criteria of discrimination will agree in stratigraphic position for many miles either side of this area. H. S. W.

2. *Geological Survey of Canada:* ROBERT BELL, Director.—The following reports have recently been issued :

No. 797. Report on the Cambrian Rocks of Cape Breton; by G. F. Matthew. 246 pp., 18 pls.

No. 821. Report of the Section of Chemistry and Mineralogy; by G. Christian Hoffmann, pp. 1 R to 67 R.

No. 822. Catalogue of Canadian Birds, Part II. Birds of prey, woodpeckers, flycatchers, crows, jays and blackbirds, including the following orders : Raptores, Coccyges, Pici, Macrochires, and part of the Passeres ; by John Macoun. 413 pp.

No. 827. Mesozoic Fossils, Vol. I, Part V (and last). On some additional fossils from the Vancouver Cretaceous with a revised list of the species therefrom ; by J. F. Whiteaves, pp. 309–416, and pls. 40–51.

In the first of these reports Dr. Matthew gives details of the Coldbrook and Etcheminian terranes, and the fossils found in them and of their relation to the Laurentian upper series. The results of an interesting investigation of the orientation of brachiopod shells are reported from which the direction of the current during their burial is estimated, based upon a large number of observations upon the shells of numerous genera. The shells of *Acrothyra* furnish the most satisfactory evidence. Mr. Macoun contributes a second part to his catalogue of Canadian birds ; the third is announced as almost ready for printing.

Doctor Whiteaves completes, in the contribution here listed, his valuable Memoir upon the Cretaceous Rocks of Vancouver.

The present volume contains the detailed description of collections made from these rocks since 1871. H. S. W.

3. *Elements of Geology:* A text-book for colleges and for the general reader; by JOSEPH LECONTE, revised and partly rewritten by HERMAN LEROY FAIRCHILD. 5th edition, revised and enlarged. 667 pp., 1002 figs. 1903. (D. Appleton & Co.)—The revising author makes special mention of the adoption in this volume of Professor Chamberlin's Planetesmal Hypothesis of the Origin of the Earth, stating that "recent studies discredit the nebular hypothesis" which has long held a prominent place in geology. Other new points of view resulting from the general progress of science are noted, and the illustrations are augmented by a number of original views reproduced by photography of typical geological features, and, as is stated in the reviser's preface, "the spirit and style of the revered author have been held as the model," and successfully. H. S. W.

4. *Chemical Analyses of Igneous Rocks; Published from 1884–1900, with a Critical Discussion of the Character and Use of Analyses;* by H. S. WASHINGTON. U. S. Geol. Surv. Prof. Paper 14, Washington, 1903, 4°, 495 pp.—This is a publication whose appearance will be gladly welcomed by petrographers, chemists and geologists interested in the chemistry of rocks. Since the time of Roth, whose collected tables were so long an invaluable aid in petrographic investigations, no such adequate collection as the one before us has appeared. The work begins with a discussion of the methods of making analyses and a just emphasis is laid upon the considerable amount of poor or incomplete work which is often done in this direction. A basis for the rating of analyses according to their completeness and accuracy is described and all of those in the tables are rated according to the standards adopted. Following this method the whole number is divided into two sets of tables—"superior analyses," of which 1987 are given, and "inferior analyses," of which there are 984. The superior analyses are classified according to the new quantitative system recently proposed by Cross, Iddings, Pirsson and Washington, and thus serve as a most complete exposition of this system. In all these cases the calculated "norm" of the system is given with each analysis. The inferior analyses are classified according to prevailing systems, that is they are grouped under the names with which they have been published. With all analyses the locality of the rock, the name of the analyst and the reference in the literature are given, and usually some appended remarks containing useful information. The accompanying text contains also an interesting discussion of the information thrown on the new system of classification by the generalized facts which the collection affords. The whole evinces the results of a vast amount of patient and unwearied industry in the search through the literature and in the collating and reducing to form of the material collected. Its value is greatly enhanced by a very complete system of indexes, to new rock names, to old rock names, to localities, to the text, and there is

also a glossary of the terms of the new classification. The work cannot fail to exert a permanent influence on the advancement of petrographic science. L. V. P.

5. *Californite* (*Vesuvianite*),* — a new ornamental stone; by GEORGE F. KUNZ. (Communicated.) — A discovery has been recently made in California of a mineral which promises well as an addition to the increasing list of semi-precious or ornamental stones found in the United States. It is not indeed a new mineral species, but a compact massive variety of vesuvianite (idocrase). The discovery was first announced in the report of the U. S. Geological Survey for 1901, by the writer.† The mineral was found by Dr. A. E. Heighway, on land owned by him on the South Fork of Indian Creek, 12 miles from Happy Camp and 90 miles from Yreka, in Siskiyou County. Here a hard and handsome stone, varying from olive- to almost grass-green, and taking a fine polish, outcrops for some 200 feet along a hillside about 100 feet above the creek, and large masses have fallen into the bed of the creek below. It was at first supposed to be jade (nephrite), but proves upon analysis to be vesuvianite. The fallen pieces were in some cases as much as five feet square and two feet thick, of excellent quality for polishing, and of varying shades of light to dark green. The associated rock is precious serpentine.

This substance closely resembles a mineral from the south side of the Piz Longhin, in the Bergellthal, also found in rolled pieces in the bed of the stream called the Ordlegna, near Casaccia, in the Upper Engadine. These were at first taken for jadeite,‡ but were positively identified as vesuvianite by the analysis of Berwerth.§ It seems at first remarkable that the same mistake should have been made in both cases as to this massive vesuvianite, but its whole aspect is so jade-like that it is not surprising. The rich translucent green color, fine-grained subsplintery fracture, and brilliant luster when polished all strongly suggest jade. The polished surface shows minute pale streaks or flocculi, which still further heighten the resemblance.

The following analysis was made through Prof. F. W. Clarke, chief chemist of the U. S. Geological Survey, by Mr. George Steiger, in the spring of the present year.

ANALYSIS OF VESUVIANITE, FROM SISKIYOU CO., CALIF.

SiO_2	35·85	TiO_2	0·10	
Al_2O_3	18·35	P_2O_5	0·02	
CaO	33·51	H_2O	0·29	below 100° C.
Fe_2O_3	1·67	H_2O	4·18	above 100° C.
FeO	0·39			
MgO	5·43		99·85	
MnO	0·05			

* N. Y. Acad. Sciences, Oct. 19, 1903; N. Y. Min. Club, Oct. 20, 1903.
† Mineral Resources of the U. S. (extract), p. 30.
‡ Fellenberg, Jahrb. Min., vol. i, 1889, p. 103.
§ Ann. Mus. Wien, vol. iv, 1889, p. 87.

The analysis is essentially that of a normal vesuvianite, though the percentage of water is unusually high; the lime and the iron are below the average; the titanium and phosphorus are exceptional occurrences.

The mineral is compact, of remarkable toughness, and readily admits of a fine polish, quite as high and beautiful as that of nephrite (jade), with which it was at first confounded. It is subtranslucent to faintly translucent, with very weak double refraction. The hardness is 6·5, and the specific gravity (from two determinations) 3·286. The luster is vitreous, often inclining to resinous, and the streak white. The color is a yellow leek-green, with inclusions of a darker green, generally more translucent than the surrounding mass.

This interesting mineral exists in large quantity, and could be cut into a variety of ornaments, in the same way as jade, nephrite and chrysoprase. It is a form of vesuvianite distinctive enough to warrant giving it a special variety name,—which, if appropriate and euphonious,, would undoubtedly aid the sale of the stone in the arts. I therefore propose the name "*Californite*" for this massive, translucent mineral,—which occurs in quite a range of colors, from almost white to pale green, leek-green, even dark grass-green shades.

What appears to be the same mineral has recently been announced from two other localities quite remote from the first. One of these was reported by that indefatigable prospector, Mr. M. Braverman, of Visalia, as existing in Burro valley, in Fresno County, a mile and a half from Hawkins school house, and 32 east of Fresno city. The material is pale olive-green, translucent, with darker spots in a paler mass. It breaks with an uneven fracture, slightly splintery and partly crystalline, and hence much resembles the Siskiyou County material.

The other locality is apparently not very distant from the last mentioned; it is said to be in Tulare County, near the town of Selma, which though in Fresno County, is not far from the Tulare line. Here the mineral is of even a richer color, at times resembling the tint of apple-green chrysoprase for which it was at first mistaken.

6. *Native Bismuth and Bismite from Pala, California;* by George F. Kunz. (Communicated.)—The remarkable locality at Pala, San Diego Co., California, noted for its colored tourmalines and other lithia minerals, has now been found to yield also native bismuth in considerable abundance, and likewise the oxide, bismite. Specimens have lately been received by me through the courtesy of Mr. W. H. Crane, of the American Lithia Co., of New York. Overlying the great mass of amblygonite at the lepidolite mine (described in this Journal for September, 1903) is a heavy capping of coarse granite, throughout which both metallic bismuth and bismite are present in more or less profusion. The latter appears as a coating of an orange-yellow to grey color, permeating the quartz and associated minerals, and between the

crystalline platy masses of the bismuth, from which it is unquestionably derived. The native bismuth is generally in long irregular crystals, always forming a capping over another mineral, evidently tourmaline; it also appears in platy crystalline masses, several millimeters in length and breadth, up to 12 or 15. The characteristic pinkish tin color is well shown in a cut section, and on the pronounced *c* faces of cleavage. One bismuth crystal, an inch in length, was evidently a pseudomorph or replacement of bismuth after a feldspar (?). The hardness is a little above 2.

7. *The Production of Precious Stones in 1902*; by GEORGE F. KUNZ. Extract from Mineral Resources of the United States, U. S. Geological Survey, Washington, 1903.—This report gives an interesting summary of the production of the various gems and ornamental stones throughout the world with particular reference to this country. The total importation of precious stones into this country amounted in 1902 to nearly $25,000,000. The comparative table for the years 1896 to 1902 shows that in that period the production of sapphire in this country increased from $10,000 to $115,000; of tourmaline from $3,000 to $30,000; of turquoise from $40,000 to $130,000. No diamonds have been found in this country during 1902, but the production in South Africa was large, aggregating upwards of four million pounds sterling. It is noted as a matter of curiosity that a cubic meter of diamonds from the De Beers Mine was found to weigh 11,976,000 carats and had the approximate value of about $76,000,000.

An interesting account is given of the production of diamonds and carbons (carbonado) in Bahia, Brazil, and a description is given of some very large masses of carbon found there. The largest of these, found in 1895, weighed 3,078 carats; another, found in 1894, weighed 975 carats and a third was found in 1901 weighing 750½ carats.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Report of the U. S. National Museum under the direction of the Smithsonian Institution for the year ending June 30, 1901.*—This volume gives the reader a good knowledge of the activity in the work of the National Museum at Washington, the conduct of which is one of the important functions of the Smithsonian Institution. It contains the report of the Assistant Secretary in charge of the Museum, Mr. Richard Rathbun, with also those of W. H. Holmes, Curator in the Department of Anthropology, of F. W. True, Curator of Biology, and of G. P. Merrill, Curator in Geology. Among the special papers accompanying the volume is one giving a full account of the exhibit of the Museum at the Pan-American Exposition illustrated by many plates; another on flint implements and fossil remains from a Sulphur Spring at Afton, I. T., by W. H. Holmes; on archæological field work in northeastern Arizona by Walter Hough; a

narrative of a visit to Indian tribes of the Purus River, Brazil, by J. B. Steere.

The Afton Sulphur Spring is remarkable for the fossil remains discovered in its immediate neighborhood. These are chiefly the teeth of the mastodon and the mammoth, also teeth of the fossil bison and horse ; with them occur bones of some recent animals. Stone and bone implements were also found in large numbers in the spring. The conclusion is reached that these deposits owe their existence for the most part to the superstition of the Indians who by their offerings sought to propitiate the spirits of the spring.

2. *The Fauna and Geography of the Maldive and Laccadive Archipelagoes ;* edited by J. STANLEY GARDINER. Vol. II, Part I, pp. 492–588, 9 pls. (See this Journal, xiii, 321 ; xiv, 74 ; xv, 240, 488.)—This part includes the results of the studies of some of the smaller collections of the expedition: Alcyonarians, Nudibranchs, Sponge-crabs, Land Planarians, and Lagoon Deposits; these are by Professor S. J. Hickson, Miss Edith M. Pratt, Sir Charles Eliot, Messrs. L. A. Borradaile, F. F. Laidlaw, J. Stanley Gardiner, and Sir John Murray. Professor Hickson found the alcyonaria to be of more than ordinary interest, as the specimens were obtained from a considerable number of dredgings made in several localities over an extensive area, thus affording an opportunity for a study of the variation in form, color, and other features ; hitherto a species often having been founded on a single specimen or on a few from a single locality. Miss Pratt gives valuable results of anatomical investigations and comparative studies of four genera of the group: *Sarcophytum*, *Lobophytum*, *Sclerophytum*, and *Alcyonium*. K. J. B.

3. *Catalogue of the Collection of Birds' Eggs in the British Museum (Natural History)*, Vol. III ; by EUGENE W. OATES, assisted by Capt. SAVILLE G. REID. Pp. xxi, 349 with x plates. London, 1903.—This third volume includes 907 species belonging to the Carinatæ (Psittaciformes-Passeriformes) ; it corresponds to volumes II and III, already issued, of Dr. Sharpe's Hand-list of the Genera and Species of Birds.

4. *A Hand-list of the Genera and Species of Birds ;* by R. BOWLDER SHARPE. Vol. IV, pp. xii, 391. London, 1903.—The list of known species of Passeriformes down to the end of the Certhiidæ are included in this volume. It is announced that the whole work will be completed with the issue of a fifth volume, which will probably be published in the course of a few months.

5. *Cold Spring Monographs, Nos. I and II.*—These monographs give the results of work done at the Biological Laboratory of the Brooklyn Institute of Arts and Sciences at Cold Spring Harbor, L. I. No. I, by Mabel E. Smallwood, is on the Beach Flea, *Talorchestia longicornis*, with three plates and three text-figures. No. II, by C. B. Davenport, is on the Collembola of Cold Spring Beach with special reference to the movements of the Poduridæ, with one plate.

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Art. XL.—*Polar Climate in Time the Major Factor in the Evolution of Plants and Animals;* by G. R. Wieland.

The long period of physical evolution which preceded and made possible the appearance of life on the globe forms a subject with which the physicist, the chemist, and the astronomer must deal in common. For the history of these changes is an inferential one based on the physical properties, constitution, and relative position of the materials of the globe in space. And indeed the same is largely true of the immense period of time which doubtless elapsed from the appearance of whatever was the most primitive form of protoplasm to the evolution of the oldest organisms now found fossilized. From this crucial period onward, the paleontologist can decipher the main facts in the story of life on the globe, although he can at no point dispense with the mathematical sciences. Especially is this true when it is attempted to gain a knowledge of climate in time, certainly the most tangible and readily understood, and doubtless the fundamental factor in evolution. To make this latter statement clear let the extent to which organic growth and life-processes involve chemism, be recalled in the light of the more recent experiments of such investigators as Loeb and Matthews. Now chemism refers solely to those properties of matter which are unchangeable and eternal. On the other hand, chemical change is governed by the conditions of electrification, and of heat, light, and moisture, which are none other than the elements of climate, or weather conditions. Life then, as far as we have succeeded in scrutinizing it, is a function of variable mechanical factors combined with chemism, which is fixed, and of climate as dependent mainly on the manner of terrestrial reception of the solar radiant energy. Climate, although following a fairly fixed trend, in itself subject in so far as the globe is concerned to an evolutionary course, is at all times in given localities subject to the accidence of countless movable conditions.

Thus it is that in any attempt to reach a general idea of the course of life on the globe, the scene of its origin, the location of dispersion centers, and the more active factors in the changing of organisms and evolving of new species, it at once becomes necessary to consult first of all the astronomical and physical records. Secondly, it becomes a subject of the highest interest when we are able to consult both the physical and biologic record in those later periods of the earth's history where these overlap. Each then supplements the other. In taking a glance, however, at the subject of climate in time, and particularly polar climate, I shall, leaving the consideration of the pre-fossil period to the geo-physicist, mention but briefly several associated theories of an astronomical or physical nature, and then confine myself mainly to biologic data. And I hold that the evidence taken in its entirety indicates as most probable the polar origin of life, and the development throughout more especially later geological time of the great groups of animals and plants markedly possessing invasive power, mainly in boreal regions. Secondarily these northern forms dispersed themselves southward over the V-shaped continents, and there appears to be but little likelihood that austral forms ever played as conspicuous a part in the great faunal and floral movements of the past. In a word, that the great evolutionary *Schauplatz* was boreal is possible from the astronomical relations, probable from the physical facts, and rendered an established certainty by the unheralded synchronous appearance of the main groups of animals and plants on both sides of the great oceans throughout post-Paleozoic time. Moreover, the efficient cause of this origin in high latitudes of hardy and effective colonizers is to be sought for in the vicissitudes of polar climate as compared with the more equable and static conditions of the tropics.

Climate in time, or geological climate, may be considered as the resultant of two sets of factors, both of which are subject to an evolutionary process which is in the one set more or less irregular and subject to cataclysm, and in the other more purely differential or secular. The first set includes chiefly altitude, emergence and stability of the land masses, deflection of the winds and tides, and probably reception of meteoric material. The main possible differential factors of geological climate are: Change in obliquity of the ecliptic, axial fixity, internal heat reaching the surface, rate of solar radiation, length of day, composition of the atmosphere, seasonal distribution of light, and orbital eccentricity.

Now a point of prime importance when we come to the consideration of such topics in connection with the fossil record is the vivid impression we get of the general stability of the globe, and of the main features of climate throughout very long periods of time. The facts of the fossil record lend much of reality to our ideas of the relative or the actual permanence of matter. But it would only be presumption on the part of one who has interested himself almost entirely with biological studies to attempt an arbitrament of the results of research on fundamental physical and astronomical subjects. It will, however, doubtless suffice for the purposes of the present argument if but two of the above climatic factors subject to secular change,—namely, *axial fixity*, and *orbital eccentricity*, be here mentioned at any length.

Axial Fixity.—Variations of latitude due to motion of the poles are theoretically due to mountain making, denudation, and glacial ice caps, and though slight, have with increasing refinement of astronomical measurement become determinable. As the result of prolonged calculation Dr. S. C. Chandler of Cambridge finds evidence of polar shifting in all reliable observations since 1750. From the available data he finds the motion of the pole to be a much varying component arising from an annual revolution in a narrow ellipse about 30 feet long, but varying in form and position, and a revolution in a circle about 26 feet in diameter with a period of about 428 days.

According to Croll, the shifting of the southern ice caps to the north would move the earth's center of gravity from 500 to 1000 feet, but this would in part be compensated by oceanic shifting. It is evident that the change from this cause must be slight. And Lord Kelvin holds that the equatorial bulge is such that no geologic changes of surface could have possibly altered the position of rotation sufficiently to sensibly affect climate.

Nor is it likely that accumulations of extra-terrestrial material in some one quarter of the globe could ever have had such an effect. If so, there should be some stratigraphical evidence of occasional local large aerolitic deposits. But none are known and the facts indicate that in the long run the surface of the globe has as a whole received accretions from without about equally. Beyond the slight movements above given there is, therefore, no evidence of departure from a relatively fixed position of the earth's axis, and until direct evidence has been adduced, it is both legitimate and necessary to set aside as valueless all mere speculations to the contrary.

Orbital Eccentricity.—At times of high eccentricity of the earth's orbit, secondary climatic changes are set up which have been the subject of profound discussion ever since the publication of James Croll's "Climate and Time," in which he contends strenuously that periods of high eccentricity are causes of climatic change sufficiently great to produce a glacial epoch in the hemisphere passing through aphelion winter.

Let us recall that according to Croll's theory the causes of glacial periods are physical, not astronomical. That is to say, solar radiation remaining approximately constant, orbital eccentricity does not in itself produce any diminution in the sum total of solar heat received each year by the entire surface of the globe, or at any latitude. This follows from three causes; 1st, by Kepler's second law the radius vector sweeps over equal areas in equal periods of time; 2d, the amount of heat received is inversely as the square of the distance from the sun; and 3d, the orbit of the earth is constant in the long run as regards its *major axis* and the length of the year, the increase of heat with eccentricity being, according to Sir John F. Herschel, less than ·005 of the total solar heat received now, an amount too slight to markedly influence climate.

When eccentricity is high, therefore, summer is shorter and hotter and winter longer and colder, or *vice versa*, depending on the change in perihelion and aphelion due to the precession of the equinoxes, but the actual yearly amount of solar heat received will be fairly constant for any given latitude.

The argument of Croll is that the true causes of glaciation following eccentricital variations result from the entailed disturbances in the ocean currents, the winds, the rain and snowfall, atmospheric humidity, and (first suggested by Newcomb) increased radiation of heat into space, as temperature rises during the short perihelion summer.*

In addition, A. R. Wallace† has pointed out that these climatic factors have been profoundly affected in the polar regions by changes in the land masses resulting in much modification in the warm and cold currents, and, especially, altitude and the winter storage of cold, which is not offset by any similar storage of summer heat. Now to go into this question at great length, nor can it be fully discussed short of this, is hardly within the scope of the present thesis. And to announce a mere opinion is of course not argument. But it does seem to me that the contention of Croll (pp. 57-66 of "Climate and Time") that the low temperatures of the Antarctic regions are due in considerable measure to the cumulative cooling effect of

* On Some Points in Climatology. A Rejoinder to Mr. Croll. This Journal, vol. xxviii, No. 157, 1884.

† Island Life.

great bodies of ice and snow there found, and that such effects would be heightened if the orbital eccentricity were now much higher, is fairly sustained. It is doubtless true that the great mountainous area of Antarctica is mainly responsible for a condition which is in a lesser degree paralleled by the Greenland ice cap,* and that a much heavier Arctic ice cap would be present were it not for the deep polar sea discovered by Nansen.

But there are no known facts invalidating such impressive testimony as that afforded by the conditions at Sandwich Land, as so graphically described by Capt. Cook. He says, "We thought it very extraordinary that an island between 54° and 55° south latitude should in the very height of summer be almost covered with frozen snow several fathoms deep, . . . masses of ice were continually breaking off and dropping into the sea with a sound like a cannon . . . . . the savage rocks raised their lofty summits till lost in the clouds and the valleys were covered with seemingly perpetual snow." On the other hand, depending on the course and source of the prevailing winds and currents, low-lying lands with fairly equable summers are often found in close proximity to glacier covered regions. Indeed snow and ice seldom accumulate in Arctic lowlands. According to Lieutenant Payer, during the short summer in high latitudes under the influence of dry winds and the sun the ice fields diminished four feet in thickness, or the equivalent of 45 inches of rain. And most northern travelers have noted the sudden burst of luxuriant herbaceous vegetation on the Tundras as soon as the cold winds cease to blow in from the snow fields and ice packs, and thus blanket the winter store of cold with a fog, sleet, and snow-laden atmosphere. Moreover, F. W. Harmer has shown, in one of the most important contributions to the subject of climatology made in recent years,† that many of the phenomena of the "Great Ice Age" may be accounted for in a simple manner on the basis of alterations in the course of the Gulf Stream, in the prevailing winds, and in the shifting of the areas of prevailing high and low barometer, with respect to the land masses surrounding the polar area. It is not, however, the purpose to pass any final judgment, or formulate a theory as to glacial epochs.

* From what was previously known of temperatures and of ice and snow conditions, Nansen had supposed that his great difficulty in crossing the Greenland ice cap would be due to melting snow during the long summer day. But to his great surprise he found mid-winter conditions on the ice cap, and he and his men suffered from well-nigh uncontrollable thirst during their entire journey over it, in the month of August being dependant for drinking water on small quantities of snow melted against their bodies.

† The influence of winds on climate during the Pleistocene epoch; a Palæometeorological explanation of some geological problems.—Quar. Jour. of Geol. Soc., August, 1901.

From the great mass of facts, only the few just given are selected, because they rivet attention to the true nature of Arctic climates as we find them now, and help us to better call to mind the extent of the changes which the geological and paleontological record, and this is the main point, shows them to have undergone. Let us note further, that the several Greenland, New Siberian Island, and Spitzbergen plant beds show that secular diminution of heat had steadily proceeded from the Mesozoic on, until, in the later Tertiary, moderately sharp winters like those of the present temperate zone ruled in the north polar area, which at this critical juncture presumably took on for the first time in its history the land-locked condition and rigorous Arctic climate such as we see to-day. Then simultaneously, possibly with a brief period of low solar radiation, maximum obliquity of the ecliptic, a highly eccentric orbit, changed position of the Gulf Stream, and also mayhap the emergence of boreal mountains, the glacial period set in. But whether or not this was preceded after the same manner by an earlier Miocene glaciation is a topic I shall not need to take up.

The fundamentally important point is, that extensive Arctic explorations taken together with the fossil plant record, preclude glacial periods in the north polar area previous to Miocene time. And as we go back in time, periods of high eccentricity with changed position of the ocean currents and areas of barometric pressure, tended less and less to produce glaciation at either pole. *They must rather have resulted in prolonged hot, or frosty, or cool, or rainy, or dry seasons.* Each return of high eccentricity thus witnessed, speaking comparatively of the general or average conditions of the epoch in which it occurred, the most profound climatal modifications, these always being greatest at the poles and diminishing toward the equatorial regions where they would be scarcely felt. As eccentricity is always fluctuating with a tolerable frequency of maximum periods, and as these always last long enough for equinoctial precession to reverse the maximum effects, the polar areas have hence been throughout geological time the scene of a steadily increasing and finally stupendous shuttle of climatic change.

Nor need we, so far as the main question is concerned, carry this general statement further. It does not affect, unless in its favor, the force of the present argument, for instance, that there is increasingly abundant evidence of Permian glaciation in the southern hemisphere. The fact is that in the north all the known evidence is against pre-Miocene glacial epochs and in favor of mild climates throughout the early Tertiary, and of more and more tropical climates in all of the Mesozoic and

Paleozoic, though subject throughout, let it be repeated, to the shuttle of seasonal change due to orbital eccentricity. But let us now turn to the biologic record.

Theoretical early polar life, and the generalized conditions of the Paleozoic.—If it were permissible to accept the suggestion made by Chamberlain* and others that the early history of the globe was mainly one of quiet meteoric aggregation without the fusion of all its mass at any time, the period during which the origin, or introduction, of life could have taken place might be considered as greatly lengthened, and extending back into very novel conditions. But although this idea may have very important elements of truth in it, it is one requiring much further elaboration, and as we shall see need not here be taken up. The hypothesis of the early nebular constitution of the solar system and of the molten globe, as formulated by Kant and by Laplace, and as supported by most of the every-day facts of geology, astronomy, physics, and chemistry, as well as rigid mathematical interpretation, must as yet afford the main basis of speculation. One cannot but admire the confidence with which Lord Kelvin speaks of the first formed crust of the molten globe a few centimeters thick, and says that, "All the reckonings of the history of the underground heat . . . . are founded on the very sure assumption that the material of our present very solid earth all round its surface was at one time a white-hot liquid."

Now in the face of concrete facts, bare suggestions to the contrary cannot have a very great weight. If the molten globe is to be accepted as a reality, it is then clear that perhaps in part owing to the equatorial bulge, but mainly because heavy tides and currents must long have continued to break up the initially formed crust in the equatorial regions, there must first have appeared at the poles sufficient crustal stability to make hot water life possible. It is also to be recalled that as strongly indicated by G. H. Darwin's hypothesis, the moon must have been at this early period much closer to the globe than now. If so there must long have been produced lunar tides of tremendous power sufficient to break up crusts of many meters in thickness in the equatorial regions, while at the pole weak tides would rule. A great interval of time must then have elapsed between the first appearance of crustal stability at the poles and at the equator, an interval of time enough for the formation all round an undisturbed molten globe of a crust a sufficient number of meters in thickness to resist the lunar and solar tidal stress. This length of time between the appearance of stable conditions suitable to the

* On Lord Kelvin's address on the Age of the Earth as an abode fitted for life. Annual Report Smithsonian Institution, 1899.

lower forms of life at the poles and their later appearance at the tropics would also be lengthened by the greater heating power of the sun at the equator, a factor doubtless greater then than now. In any case the critical temperature and the stability necessary even to hot water life may well have required a million years to slowly move southward to the equator, after an initial appearance at the poles. And the highly interesting view that the requisite physical conditions of life did actually first appear and inaugurate life itself at the north pole, and that as the result of evolution in the northern circum-polar area new species were continually dispersing from thence southward throughout time down to the glacial period, was ably presented by Mr. G. Hilton Scribner, more than twenty years ago.* When Mr. Scribner wrote, the work of G. H. Darwin had not yet appeared, and while overlooking the part that tides must have played in preventing equatorial stability and thus have been the main factor in preventing early equatorial life, his chief conclusion is regarded as fundamentally correct, and to him belongs the credit of its first enunciation. Though it seems quite clear that life could as reasonably have had a similar beginning at much the same time at both the poles.

The causation of this assumed early polar origin of life, has of course a direct bearing on the view of climate here presented. But without indulging at present in speculations however interesting, I shall only say in passing that we cannot admit that the properties of primal protoplasm, whether of mundane or extra-mundane origin, depend on anything else than the physical, electrical, chemical, *vital* and other properties of matter. "*Ex nihilo nihil fit.*"†

* Where Did Life Begin? New York: Charles Scribner's Sons, 1883.

† The theory that the origin and entire course of life is wholly based on the properties of matter must be held as the most comprehensible, even if life was actually transplanted from some other sphere, for thus pushing its origin back a stage leaves us in precisely the same position as before. But that life may have originated very remotely and have reached this globe, perchance, from other celestial bodies is not utterly without the bounds of reason, as suggested by the experiments of Professor Dewar and Sir W. T. Thiselton-Dyer, showing that seeds (and spores) have wonderful resistant power to cold. These experimenters placed the seeds of flowering plants in vacuo at —250° to —253° C., a condition approximating outer space, without greatly affecting their vitality,—a good proportion of the seeds which had been thus passed through a sub-crystalline state afterward growing when planted. Other seeds were soaked in liquid hydrogen and afterward germinated, as did yet others after immersion in liquid air contained in a red hot platinum dish!

It is above all things conceivable in the light of such experiments that virile spores and resting stages of lowly organized forms may have reached this globe from the outer space at any time in its history, or indeed may still be reaching it for aught we can say, in the vastest numbers. The "red

With regard to the period of an assumed polar origin or implantation of life, needless to say little can be said from the purely historical view in so far as now known. In general the all sufficient assumption is that consolidation of the continents went on apace, and that there was a continuous dispersion of increasingly diverse forms from the slowly enlarging and more equable polar areas towards the borders of the lessening tropical belt over-hot for life. *Even though the globe was never in the white hot condition*, this was still doubtless the case, and the presumption is strong that coupled with eccentricity the same progressive climatic changes already mentioned played their part even in the ancient period, culminating in the universal tropical conditions of the Paleozoic to which the unimpeachable geophysical and paleontological record carries us back. But it is, of course, not possible to now trace out the actual march of events in the Paleozoic, abundant though its fossil forms may be. It may only be remarked that the great preponderance of aquatic animals and spore-bearing plants made the distribution of Paleozoic life easy, and rapid, and general, facts which aside from the scanter record render it very difficult to reach conclusions concerning any invasion of polar forms so far as recorded in fossil floræ and faunæ.*

In general it may be said that in the Devonian and Lower Carboniferous most plant forms are, so far as present, more or less ubiquitous. During these periods the Equisetales, Lycopodiales, Filicales, Sphenophyllales, Cycadofilices, and Cordaitales appear to reach a high degree of specialization and for the greater part a cosmopolitan distribution. These generalized floral conditions were, however, interrupted in the Permo-Carboniferous by the appearance in the southern hemisphere, mainly below the tropic of Capricorn, of a new and simpler type of flora than that continuing to flourish and develop in

snow" (*Sphærella nivalis*) of the Arctic regions shows us that in the old worn out and frigid stage of a planet life may still be present.

The life of hot springs affords an example of low organization at the opposite temperature extreme.

* It is true that many large seeded plants existed, but their seeds would readily be carried from island to island, when not too distant, bearing in mind the much freer circulation of ocean drift among the Paleozoic islands. An excellent example of the ease with which the ferns make their way is afforded by the isolated occurrence of *Adiantum Cappillis Veneris* along a stream fed by thermal waters in the Southern Black Hills, far beyond its utmost normal north-limit. This shows how readily spore-bearing plants transplant themselves to great distances and to strange places. Nor may the new station for the "Adder's Tongue," *Ophioglossum Vulgatum*, recently found in Iceland, mean that at this point a last stand is being made against the cold that has driven this fern from its original boreal home, but just as readily that it has long since during glacial times been pressed far to the south, and that its spores have again been wafted northward from either Eurasia or America.

the north—the so-called *Glossopteris*—flora. In this the genus *Glossopteris* was so extraordinarily abundant as to have suggested to Seward in his eloquent presidential address* the idea that it must have monopolized wide areas over large parts of southern South America, Africa, and Australia to the exclusion of other plants, just as the Bracken to-day covers sunny hillsides with a carpet of green. The southern origin of the *Glossopteris* flora is certainly a legitimate assumption, and was doubtless connected in some way with climatic changes culminating in the glacial conditions of the southern Permian. But whilst the *Glossopteris* flora in reality thus furnishes the first suggestion of the breaking up of ancient generalized tropical conditions by an invasion from the far south, there remains the fact of the immense extent and distribution of more varied northern forms, as well as the return and long persistence of wide-spread uniform conditions during the Trias and Jura. The vertebrates of the later Paleozoic are not as yet understood to indicate any differentiation into zoological realms, although a much fuller knowledge of the Permian faunas of Texas, South Africa, and Northern Russia may yet furnish evidence of such.

Although doubtless increasing in force, polar influences due to eccentricity during Paleozoic time must hence from the nature of the record long or always remain more or less obscure. It is, however, from this period on that the facts of polar origins become clearer and clearer. As soon as we get in the Mesozoic, the fortuitous combination of fairly numerous freshwater strata on the Continental mainlands and the early representatives of the more highly organized vertebrates and plants, which by reason of their organization are easily liable to displacement and extinction, and hence constitute delicate horizon-markers, we become more and more aware of a vast procession of similar series of both animals and plants from north to south on both sides of the Atlantic. To this main line of our discussion let us now yield attention.

The Argument for Polar Origins as Based on the Vertebrates.—The earlier expression of the north to south movement of types originating in the high north consists in the fact that the small and delicate so-called mammals of the Jurassic are much alike in beds on both sides of the Atlantic presumed to be of about the same age. In the Cretaceous the same general fact is true, but in an accentuated form. And throughout the Tertiary the completer the record the greater the parallelism displayed between synchronous faunæ of the various European and American horizons yielding vertebrate fossils.

* British A. A. S. meeting at Southport, 1903, Address to the Botanical Section.

Now all the divisions of the Tertiary, the Eocene, Oligocene, Miocene, and Pliocene were markedly periods of great inland lakes and flood plains, which on the whole favored the deposition of far more extensive freshwater beds than those of earlier times when the continents were rather smaller. Moreover, these periods witnessed the expansion of the primitive mammalian stocks into the existing mammalian orders, as well as the rise and extinction of many striking forms. As a consequence, the mammals being from size, habit, and frequency of preservation among the best of all horizon-markers, the Tertiary record, unlike the older and more imperfect Mesozoic record, is often quite complete. The North American Tertiary strata are more than a mile in total thickness, and contain imbedded at intervals, which of course depended on local conditions, a score or more of successive faunæ. When closely studied these are found to possess many peculiarities of their own. Many of the genera and families of each are new and unheralded in preceding groups. No vertebrate paleontologist would consider these new elements as direct local derivatives from preceding faunæ. That is to say, there is throughout the series an ever-recurring lack of precursor forms, if we except the later stages of certain groups like the horses which evolved many successive species in the great mid and late Tertiary American plains. In short, most of the groups come suddenly with a large proportion of new elements scarcely or not at all related to preceding forms and they go as suddenly, as if by a succession of "waves" or "impulses." In Europe there are not such extensive Tertiary deposits as in America, but there is a reasonably complete record, and it shows the same history of new faunal influxes. But this is not all. The series of unheralded faunal influxes forming so prominent a feature in the European Tertiary was made up of much the same successive elements, possessing the same peculiarities as well as many of the same genera and closely related species, and appearing in the same order, and at essentially the same time as in America. In fact, essentially the same new complex faunæ appear, as explained, at about the same time on both sides of the Atlantic so often and so continuously as to make this mode of appearance the rule, not the exception. And such differences as do present themselves are explicable on the basis of the known great imperfections of the fossil record, on some climatal differences, and because of the unlikelihood that all the elements of faunæ, including diverse orders and families, could in any case whatsoever reach such widely separated regions.*

* These facts of similarity become more and more striking with exacter methods of study and the multiplication of known forms with each added year of exploration. Thus Charles Depéret in a recent study of the *early*

How best explain this extensive faunal parallelism? As the deep oceans and the continents, though slowly increasing in area as the result mainly of delta formation, have occupied relatively the same position as now far back in geological time, there have been no means of horizontal dispersion back and forth. Although this view has been at times called into requisition it appears to be utterly unsound. The great antiquity of the principal elements of the life of the Hawaiian Islands, Australia, New Zealand, Madagascar, bears unmistakable testimony to the difficulty of dispersion of the higher types of life across ocean barriers in any direction, and indeed shows such dispersion of the vertebrates to be nearly impossible. Nor is it conceivable that there was a *constant* exchange of American and European monkeys, ganodents, cumbrous ungulates, horses, dogs, rodents, bears, etc., etc., back and forth by way of the polar regions. The difficulties of the enormous distances, doubtless in most of Tertiary time increased by mountain ranges, of the Behring's Strait, or the Aleutian Island route, for such interchange between the Tertiary basins of Wyoming and France are obvious enough. The shortest nearly all land route that may by any possibility have existed so nearly as may be judged from present shallow ocean depths, would have been by way of the transverse submarine plateau marked by Iceland, the Faeroes, and Shetlands, the average depth between these islands, exclusive of the deep waters off the Greenland coast, now being some 250 fathoms. The remaining possibility lies almost directly in line with the north pole and would be a route by way of Melville Peninsula and Cockburn Land, North Devon, Ellesmere Land, Grinnell Land, Melville Land, The Spitzbergen Group, and Franz Josef's Land, Nova Zembla and Northern Siberia. Even now this route involves but short water gaps. But even if conditions were more favorable than now, it is not conceivable that with the exception of a very few times in the past, if ever, could animals have succeeded

horses (Revision des Formes Européenes de la Famille des Hyracotherides, Lyon, March, 1901) finds as the result of close analysis that *Eohippus* Marsh of the Wasatch is close to *Hyracotherium* Owen and to *Propachynolophus* Lemoine of the Suessonian, that *Protorohippus* Wortman from the Wind River is very similar to *Propalæotherium* Gervais and *Pachynolophus* Pomel, and that *Epihippus* and *Eohippus* Marsh are similar to *Lophiotherium* of Gervais. Depéret shows that the early horses of Europe are most closely allied to those of America in their successive evolutionary stages, or even identical, and Professor Osborn in speaking of this similarity says (Science, p. 674, April 24, 1903): "It is probably premature to establish generic identity between these American and European forms; but it is evident that the time is not far distant when such identity is likely to be established, unless we take the ground that the European and American forms were entirely independent in their evolution from the time of their first appearance." In Europe, as in America, it appears, however, that in the later history of the horses there was mainly an indigenous evolution of species.

in passing by either of these routes. At all times since the earliest Mesozoic either animals (or plants) in so doing would so repeatedly have been forced to change their mode of life and endure new conditions during the reproductive season, especially after sharp winters set in in the northern regions, that one must greatly doubt if any ever accomplished the journey after the later Cretaceous. Likewise that any of the synchronous similar faunæ or elements of faunæ could have come from the south is contrary to the evidence of the fossils themselves, and contrary to what we know of the general north to south movement of animals and plants as so fully and thoroughly demonstrated by Wallace in his Island Life. Again, that the same series of peculiar genera of horses, dogs, camels, etc., were constantly being evolved independently at widely separated points is preposterous.

Taken singly and collectively, the facts of Mesozoic and Tertiary vertebrate distribution in the northern hemisphere explain themselves satisfactorily on no other than the sole remaining hypothesis, namely, that of a common polar origin of the principal ancestral stocks, which then dispersed secondarily outwards in waves or impulses from the polar area and spread over America and Eurasia. The various high northern lands mentioned above then become, instead of mere migratory routes, centers of origin and a means of ready dispersion, the various stocks only passing out uniformly from them in the southward direction—that which always offered least resistance to migration and extension of habitat. In addition a large part of Northern Siberia may be included in this northern area so subject to change, since Cape Chelyuskin lies 600 miles north of the Arctic Circle, while many Tertiary islands must have existed that have since disappeared. It is all the while to be borne in mind that broken land areas at the north are likely to have been important factors in the faunal and floral changes there taking place.

It is to be added that it is not impossible, and even seemingly probable, that the Antarctic area represented a minor dispersion center facing the apices of the triangular continental masses whence certain peculiar elements of the South American, African and Australian faunæ may have originally sprung.

More recently a masterful résume of the facts relating to the impressive synchronous succession of similar vertebrate faunæ in Europe and America has been given by Dr. J. L. Wortman,* and to him belongs the merit of first having pointed out its great extent and bearing on the question of the polar origin of the main ancestral mammalian stocks. Although the

* Studies of Eocene Mammalia in the Marsh Collection, Peabody Museum, this Journal, vols. xi–xv, 1901, 1903.

general idea was vaguely suggested by Saporta, and very definitely by Scribner twenty-five years since, it has never hitherto been seriously entertained, worked out, or applied by vertebrate paleontologists in their discussion of the distribution of fossil faunæ.

As here held because of the following reasons, the north polar area has since the Carboniferous been of relatively *more* importance in the origination of hardy stocks with strong invasive power, and which have mainly followed outwardly lines of longitude, the more readily because of the secular retreat southward of tropical conditions throughout long periods of time:

(*a*) The parallelism between the life of America and Eurasia is apparently greater than that of the more isolated continental areas of the far south—South Africa, Notogæa, and Neogæa.

(*b*) The great land masses lie about and project well within the Arctic area, and have, therefore, afforded the presumably wider geographic range.

(*c*) There is much reason to believe that the lands near the north pole were always much divided into islands and peninsulas, and were thus, as elsewhere explained, a more active scene of plant and animal change than even a much larger and more isolated body of land such as Antarctica may have been.

(*d*) It is reasonably certain that over a large portion of the Antarctic area the continuity of life was interrupted by glacial conditions in the Permian.

But the same physical and ethologic principles apply to both of the polar areas. And it is of much moment to the views here advanced that although the discovery of the first evidence of the ancient vertebrate and plant life of Antarctica is yet to be made, the former presence of abundant life within the austral area has at various times been suggested or claimed. A convenient summary of literature bearing on this subject has been given by A. E. Ortmann.* And Osborn† says very distinctly that, "One of the greatest triumphs of recent biological investigation is the concurrence of botanical, zoological, and paleontological testimony in the reconstruction of a great southern continent to which the name Antarctica has been given."

The discovery of the great horned turtle *Miolania* in Patagonia, Australia, and Lord Howe Island, and as yet nowhere else, is only one of various striking facts that do suggest a former south polar land connection of these now widely separated localities. But not to tarry too long, I shall only remark that the views of Antarctica have come to be much involved

* Am. Nat., vol. xxxv, No. 410, Feb., 1901.
† Ann. New York Acad. Sci., No. 1, pp. 1 to 72, July 31, 1900.

with a belief in extensive lateral intermingling of African, Notogæan and Neogæan life. Crossing and recrossing of either of the polar areas we believe rarely to have taken place, and certainly during periods of polar cold this becomes quite, or wholly impossible.

Now it follows from *a priori* reasons, that since vertebrate stocks originated more and more frequently in the boreal area as time went on, down to the Glacial epoch, there must have been a preceding development of food plants of quite as varied character as the animals themselves, and with one more word we may turn to the plant record. Nothing could at the present time be more satisfactory to paleontologists than the discovery of polar localities yielding fossil vertebrates. As justly remarked by Professor Nathorst in a letter to the writer, "It is very curious that not a single mammalian bone has hitherto been found in any Tertiary deposit within the Arctic area." But this dearth of actual evidence is quite as much due to the unfavorable conditions for the preservation of fossil bones on the exposed surfaces in high latitudes as enumerated by Nordenskjöld and Palander, as to the lack of exploration. One cannot but believe that in the course of time there must be found in the high north evidence in abundance complementary to that of the Jurassic, Cretaceous and Tertiary vertebrate-yielding horizons of America and Eurasia.

The Argument for Polar Origins as Based on the Plants.—In the case of the plants there is both a northern and continental record. Both taken together supplement and confirm the evidence afforded by the vertebrates of the radiation of hardy stocks from the polar area on a grand scale. Indeed it is on the basis of the facts afforded by both the past and present distribution of plants, that more or less well defended theories as to the northern origin of the present temperate flora, and, *a priori*, fauna have from time to time been proposed. A belief in a Scandinavian flora of great antiquity, occupying the polar area and *during the advent of the glacial period* radiating out on every longitude and to every latitude, was held by Forbes and Darwin fifty years ago. It was given a certain basis in fact by Sir Joseph D. Hooker in his Outlines of the Distribution of Arctic Plants in 1861, and later on Saporta in the *Revue de Deux Mondes* (1883), after the discovery of the Cretaceous Arctic fossil floræ, stated his belief in the Arctic origin of the main groups of animals and plants far back in geological time, and including man as well. The definite conception, well fortified by facts, of a universal southward dispersion of plants from the northern polar area during Tertiary time was, however, first conclusively formulated and presented by Asa Gray in his Dubuque Presidential Address before the Botanical Society of America in 1875. In 1883 additional facts were given by Mr. G. Hilton Scribner, who took up the subject from the standpoint of the northern origin of life itself. Moreover, in 1883 Nathorst published a map of fossil Tertiary plant localities in the north polar regions and the hypothetical routes of their migration southwards.

As we have already seen, the point at which the evidence from the side of the vertebrates is most wanting, lies in the entire absence of known vertebrate-bearing horizons within the polar circles, whilst, on the other hand, the American and European record is quite complete in Tertiary time, there being abundant horizons covering this period of rapid mammalian development. Contrariwise in the case of the plants, the northern record from the Cretaceous on, is one of the most interesting within the ken of the paleobotanist. But as the main development of the early Dicotyls and other plants constituting the best horizon markers took place in the late Jurassic, at a time when there is a considerable dearth of freshwater beds in close succession, the plant record also has its serious weak point. The general facts of both records are, however, so entirely complementary that it is a matter of some surprise that they have so little occupied the attention of biologists.

The fact that, as recently shown by Seward,* there are striking similarities in the plants of the Inferior Oölite of Yorkshire, and those of the lower Jurassic of Bornholm (Sweden), Japan, and the Rajmahal series of India, may, so far as present knowledge goes, be considered an early indication of a north to south movement of plants. It is noteworthy that *Gingko* and *Baiera*, so abundant in the Lower Jurassic of England, Japan, and Bornholm, are so far unknown in this horizon in India. Few forms, albeit, have a more striking northern development during Jurassic and Cretaceous time than the Gingkoales.

Following the period of very generalized tropical conditions, the earliest extensive comparison of European and American floræ that can now be made is that between the Jurassic of Portugal and the Trias of America. Notwithstanding this time hiatus, about two-thirds of the Portuguese genera, as has been pointed out by Ward, are present in the American Trias. In the Lower Cretaceous of Maryland and of Portugal the comparison is a much more striking one. There are, indeed, some species of wide distribution common to both. But as Professor Ward has said, "We should not, of course, expect the species to be common to any great extent, and the comparison is practically limited to the genera. Looked at from this point of view, we see that the resemblance is indeed close,

* Occurrence of Dictyozamites in England, with remarks on European and Eastern Mesozoic Floras, Quart. Jour. Geol. Soc., May, 1903, vol. lix.

a great number of the important genera occurring in both floras. There are no less than forty-six of these common to the two, though in some cases the author's individuality is probably alone responsible for slight differences in the names. For example, forms referred to *Baiera* by one would be referred to *Baieropsis* by another, and so with *Ctenis* and *Ctenidium*, *Myrsine* and *Myrsinophyllum*, *Oleandra* and *Oleandridium*, *Salix* and *Saliciphyllum*, *Thuya*, and *Thujites*, etc."*

Moreover, Professor Ward finds that the proportion of species of the similar genera bears some relation to the relative size of the two floræ, about 1 to 4 (200 species being known from Portugal to about 800 in Maryland). Thus the proportion of Portuguese to American species is respectively for the genus *Aralia* 2 to 11, for *Brachyphyllum* 5 to 9, for *Cladophlebis* 12 to 25, for *Frenelopsis* 2 to 6, for *Laurus* 3 to 8, for *Myrica* 2 to 11, for *Podozamites* 7 to 15, for *Sphenolepedium* 3 to 9, etc. Of Magnolia, however, there is only 1 species to 12 in Portugal. Professor Ward concludes that, "On the whole it may be considered that the Lower Cretaceous flora of Portugal is, botanically speaking, a very close repetition of that of America; and in view of the fact that in both countries a number of distinct horizons showing the progressive change in the flora throughout that period have yielded fossil plants in such a way that, if the Portuguese beds were as fully developed as are the American ones, each of these florules might be compared, the subject becomes rather fascinating."

To note further the parallelism between continental floræ of Europe and America from the Cretaceous on, is scarcely required. It may be remarked that previous to the discovery of the rich Potomac flora and of various archetypal dicotyls in certain Jurassic strata it was supposed that the Angiosperms, now the predominant type of vegetation, had their origin in the Middle Cretaceous. The sudden and simultaneous appearance at this time in large number of species in Europe and America of the main forest types of to-day with but few forerunners, however, constitutes such a profound phenomenon of American and Eurasian plant parallelism as is scarcely explicable on the basis of lateral distribution. Furthermore, there is indicated a steady decline in temperature and retreat of tropical conditions to the southward. The Dakotas and Wyoming still enjoyed Floridian conditions in the Eocene. From this time on the temperature decline was marked.

But let us take a glance at the northern record. It is of more than passing interest to note that it so happens that the most varied Upper Devonian flora yet discovered is that of the

* XVIth Ann. Rep. U. S. Geol. Survey, 1894–95, pp. 469–540.

Bear Island which lies in 74° north latitude about midway between the North Cape and Spitzbergen. To be exact, it includes, according to Nathorst,* Filices, Sphenophyllales (extinct plants from which have been derived the horsetails and lycopods), Calamites and Lycopods. These plants indicate, needless to say, a decidedly tropical climate, and from their diversity of form and structure "show that vascular plants must have existed for an exceedingly long period previous to Upper Devonian time." As stated above, up to and including this period and the Lower Carboniferous the *Paleozoic represents a generalized tropical period in so far as can now be determined.* Nor is there reason to believe that other than tropical conditions ruled at the north during the Permo-Carboniferous and Trias. Likewise the Jurassic plants from Spitzbergen, King Charles' Island, Franz Josef's Land, Cape Flora, and other far northern localities leave no question of the continuance of these conditions within the Arctic area. Regarding the late Jurassic and the very earliest Cretaceous, or the period covering the origin of the Dicotyls, we as yet have scanty evidence from the north. But from this time on the record of climatic change furnished by the northern plants becomes a striking one indeed.

Greenland is one of the best known of Arctic lands. Though largely an Archaean area of eruptive rocks much too old to shed any light on the character of ancient northern life, and intensely scoured and glaciated, this winter-locked land affords abundant and reasonably connected evidence of the slow decline in temperature that culminated in the Glacial epoch, as well as of the exceedingly rich and varied flora that just preceded this period of decline. About the edges of the great ice cap far to the north on the west coast, and mainly between 69″ 15′, and 72° 15′ N. L. there are numerous outcrops of Sandstone and slate containing intervening layers of coal, clay, and clay ironstone, from which have been obtained some of the finest series of Cretaceous and Tertiary fossil plants known, the best and most numerous localities being on the peninsulas of Nugsuak and Svartenhuk, and on Disco Island. The most northerly locality is in Grinnell Land, 82° N. L. These plant-bearing beds have a total thickness of from 2,000 to 3,000 feet, and are covered by an additional 2,500 feet of basalt, which has protected them from erosion by superimposed ice. Being loose of texture, it is held that they would certainly long since have been completely eroded away were it not for this basalt covering. Although known for nearly a hundred years, the first adequate collections of fossils from these plant beds were made by

* Zur Fossilen Flora der Polarländer, Erster Teil. Dritte Lieferung. Zur Oberdevonischen Flora der Bären-Insel. Stockholm, 1902.

Nordenskiöld and Steenstrup, and studied by Professor Oswald Heer, the chief results being published in his magnificent monograph the *Flora Fossilis Arctica.*

Heer divided the Greenland beds into (1) the *Kome beds*, (2) the *Atane beds*, (3) the *Patoot beds* and (4) the *Tertiary beds.* In all there occur more than 600 species of plants.

In the lower or *Kome beds* (the so-called Greenland Urgonian), twenty or more Cycads, as many Conifers, a number of ferns, five Monocotyls, and one Dicotyl are present. The Cycads are mainly of a quite modern type and also include a species close to *Cycas revoluta*, now native of warmer Japan, but are almost uniformly dwarfish forms. The conifers, sequoias, and pines seem to have formed extensive forests. The single Dicotyl (*Populas primaeva*) was regarded as the oldest of all the dicotyls until the later discovery of primitive dicotyledonous types in the lower Cretaceous of Maryland and Portugal, to be again mentioned. Heer concluded that the mean temperature when the Kome beds were laid down was about 71° to 72°. This is that of Cuba now.*

In number (2) the *Atane beds* there occur at Lower Atanikerdluk more than fifty Dicotyls, including the fig and the bay. There are fewer ferns and a diminishing number of conifers, and the presence in this much changed floral facies of about four Cycads shows them to be a waning group, although no other than very slight decline in temperature is indicated. In (3) the *Patoot beds* the Dicotyls reach a fully established sway, numbering about 70 species with 18 conifers, whilst the Cycads disappear. Oaks and planes are here the most abundant forest trees, and alders, maples, figs, bay, walnuts and birches are present. A secular decline in temperature is indicated. In all these floræ a noteworthy phenomenon often noted amongst Upper Cretaceous plants and eloquent of the origin of the Dicotyls in a moist and hot climate, is the growth side by side of forms whose nearest relatives are now found quite exclusively in either temperate, warm temperate or hot climates. Thus in the Atane beds the bread fruit tree, now only found in the hotter lands, grew side by side with the oak and chestnut.

The Greenland *Tertiary* includes twenty beds containing

* A quite similar climate and forest facies is indicated by the fossils of the "Lower Cretaceous" cycad-bearing horizons of the Black Hills "rim," where large numbers of cycads, possibly in part of a somewhat older general type than those of the Kome beds, formed the underbrush or grew in the open dells of great coniferous (Araucarian) forests. The beautifully silicified trunks with the leaves and fruits of the Bennettitalean cycads and numerous immense Araucarian silicified logs as well as many plant impressions tell the story. It is significant that here as elsewhere the sway of the gymnosperms was very suddenly disputed by the inrush of Angiosperms, with but very few precursor forms.

Eocene and probably Miocene plants, represented by nearly three hundred species. The conifers, Taxodium, Thuja, Sequoia, Gingko, Abies and Pinus are present. Among the Dicotyls are a profusion of oaks and walnuts, with poplars, elms, ashes, planes, maples, chestnuts, alders, beeches, birches. There are, moreover, bays, six species of magnolia, three of ebony, and a soapberry, as well as smilax and other climbing vines. Heer considered the mean temperature indicated by these plants of northern Greenland to have been not less than 55° F.; though Professor Nathorst, the most distinguished living authority on the plants of the polar lands, shows this estimate to be certainly too high for the close of the period, which was, however, warm enough for the ripening of walnuts in 70° 25′ N. L. Moreover, by this time fairly sharp polar winters had set in. Supplementary evidence showing this steady decline in Arctic Tertiary temperature has accumulated from a series of localities fairly girdling the pole. The principal ones are the Sabine Island on the east coast of Greenland, Iceland, Spitzbergen and the new Siberian Islands.

In brief the north polar regions were as yet markedly tropical in Jurassic time, and less so by the close of the Cretaceous; whilst the several northern fossil floræ indicate a steady, persistent, unmistakable secular decline in temperature over the entire polar area, culminating in the late Tertiary in arctic conditions.

That the rich vegetation of the various horizons represented within the Arctic area forms the original source of most of the plant families, which as the evidence shows spread synchronously over Eurasia and America throughout Cretaceous and Tertiary time, is a conclusion which we can scarce escape. But as to the actual first home of the Dicotyls it would of course on the basis of present knowledge be a gratuitous guess to say that this was within the Arctic circle. They may rather be a legacy left over from the later generalized tropical periods, these being characterized, as stated, by easy distribution. The first Mono- and Dicotyls may hence never be assigned to any particular region.

It is, however, to be observed that the early Angiosperms, which appear alike unheralded in the Cretaceous of Maryland and Portugal, may really be younger than the plants of the Greenland Urgonian (Kome beds). I only need note that the belief in the similar age of these beds rests entirely on floral evidence, and that equivalent floræ in such widely separated localities afford very insufficient proof of synchronism. Moreover, in view of what we now know of southern migrations if in the case of two quite similar but widely distant fossil faunæ or floræ, one rests far to the north, it is likely, once the stratigraphic succession is learned in more detail, to be found overlapped and the more ancient. And, conversely, in the case of two such remarkably similar floræ as are found at essentially the same latitude in the Lower Cretaceous of Portugal and Maryland, there is a strong likelihood that they are really of much the same age.

Reasons for the Origin of Prepotent Northern Stocks.—As has been seen, the fact of extensive southern migration for long periods of time is a patent one. It now remains to take up the most interesting enquiry as to why hardy stocks originate at the north, and especially as to how their origin has been governed by the secular decrease in temperature which northern life shows to have taken place, as well as by the shuttle of climatic change, caused by orbital eccentricity, doubtless the most active of all factors producing change in the life of the polar areas. It is trite to say that the enquiry here briefly taken up must largely await future study, involving as it does the fundamental working principles of evolution. But it is possible to mention certain salient elements of the completer answer.

Vegetal and animal forms are often figuratively spoken of as driven south, or east, or west. Now forms of life may be driven out of a region, that is exterminated within its bounds, but unless rarely, in the case of the more intelligent higher forms of animals fleeing from some newly appearing dreaded enemy, they are never actually driven into a new habitat. Nor do they migrate except in a most general sense. They simply make their way aided by or in spite of vicissitudes of climate and season, as if from one side of a stream or one hillside to another, changing more or less all the while, while somewhere to the rear the original stock is also changing into a new one or being directly cut off.

Again the conditions under which the life of a given locality thrives are always in the long run retreating southward, and other and hardier forms are always to be found to the northward, though in less and less number as the secular approach of glacial cold slowly and surely depopulated the Arctic area. Now, only the hardy remnant of the once abundant northern life yet dwelling on the borders of the great ice cap is left. But it is a remnant with the power to invade, and that is still pressing south in the same manner as the more profuse boreal life of the past. Hence, as secular cooling is always going on, and as the general nature of growth is constant, a condition of high northern organic potential resulting in a southward stress and movement must always exist.

The idea here meant to be conveyed can be readily illustrated. According to C. Hart Merriam* nine species of plants brought back from Lady Franklin Bay by Lieut. Greely also occur on the bleak and storm beaten summit of San Francisco Mountain in Arizona, hundreds of miles south of any other known station.† These plants grow at an altitude of 3,500 meters and their seeds were either carried southward by birds, or they are a far southern remnant of a once wider habitat during glacial times, which is more probable. Beneath the summit where these isolated species grow are found on a small scale successive realms of animals and plants recapitulating in a way the great life belts that can be distinguished in passing from the mountain base to the Arctic Ocean. Now it is very clear that in the event of secular or perchance local decrease in temperature the Arctic forms at the top of San Francisco Mountain would immediately step into the places left vacant down the slopes by killing or weakening frost. Conversely, if melior conditions were to begin from any cause to rule at the summit, owing to increased seasonal heat or dryness, overlapping especially the reproductive season, or for other causes, this far southern skirmish line of the advancing northern flora would doubtless be beaten back or destroyed. Every agriculturist knows this principle and avails himself of it. Experience has everywhere taught that for any given locality northern varieties of plants (and animals) are the hardier, and that southern stocks are weaker and even impossible of successful introduction. Hence for any given isotherm as viewed at the present time the maximum of easy conditions of growth always lies *somewhere to the south.* And it appears that among other effects, where forms of life do succeed in holding out against more and more stringent conditions there is especially a resulting increase of fertility, while on the other hand, where such forms after being inured to rigors are transplanted, or naturally make their way into far more favorable conditions, there results a more robust growth and a decrease in fertility. This would be one prime reason why the southward stress due to secular diminution in heat would be the more readily taken advantage of.

Evidently then from the record of the past, the vast majority of southern types are known to have made their way from the north, and at the same time the present organic facies and everyday knowledge shows that life utterly fails to make its way northward again and that southward stress is ever present.

* Biological survey of the San Francisco Mountains, U. S. Dept. of Agriculture. North Americau Faunæ. Bulletin No. 3, Washington, 1890.

† List of plants growing both on the shores of Lady Franklin Bay, and at the summit of San Francisco Mountain, Arizona:

Androsace septentrionalis; Arenaria verna; Cerastium alpinum; Cystopteris fragilis; Saxifraga caespitosa; Saxifraga nivolis; Oxyna digyna; Trisetum subspicatum.

But whilst the constant changes in animal and plant forms, due to the operation of such causes as these, are fairly apparent, the subject of the vicissitudes of the southern movement of life "as it takes its way along the great north and south rivers and is split by the great north and south mountains" of America and Eurasia, is a fairly separate topic. What is plain is that there is and has been a constant stress due to northern prepotency extending all the way to the pole itself, where, as has been repeatedly stated, climatic variation has always been relatively greatest. And this brings us to the consideration of what the mere determination of the nature of the southward organic stress scarcely explains, that is to say to the crux of the entire question, the reason *why* prepotent races tended so constantly to originate at the north. Nor can I hope adequately to deal with this feature of the present subject. However, the ordinary physical environment and the far reaching effects of climatic conditions considered of course in their widest sense, and including in a largely unexplained manner electrical conditions, are the sole and the only evolutionary factors influencing life as such, within the range of my vision.*

From such a view-point quite the first of the elements of polar climate that occurs to me is the peculiar distribution of light. Well might J. W. Dawson, who was not an evolutionist, say in remarking on the varied northern floræ and the fact that the flora of Canada, where growth is arrested by cold nearly six months in the year, is in some respects richer than that of temperate Europe, that,—†

"It is indeed, not impossible that in the plans of the Creator the continuous summer sun of the Arctic regions may have been made the means of the introduction *or at least for the rapid growth and multiplication of new and more varied types of plants.*" The italics are mine. But we have a fund of facts directly bearing on how much of this growth of new species was thus produced, without any extraneous interference

* I am glad that but recently so powerful a thinker as Ward has not hesitated to thus define his view of bathmism—" . . . Motility (or the power of spontaneous molar motion which is the differential attribute of life) in its later stages takes the form of bathmism, and becomes the universal growth force of the organic world. What I wish especially to emphasize here is that motility, with its generalized form, bathmism, is simply a property of protoplasm and of all living organizms, as much so as sweetness is a property of sugar, bitterness of quinine or isomerism of protein. *Zoism is a synthetic creation of chemism.*" (Pure Sociology, p. 115.) I take the liberty of underscoring the last sentence. A simple theory of life may best be founded on the idea of an atomic basis of consciousness as a true property of matter differing in degree in the several atoms just as the several chemical elements differ in their magnetic or their radiant powers, or in any of their *other* fundamental properties, none of which are definable except in terms of themselves.

† The Geological History of Plants, New York, 1888.

or direction other than that based on the properties of matter, including the power of living and undergoing evolution.

Kerner Von Marilaun performed various culture experiments in the powerful light of the Alpine heights of the Tyrol, and his conclusion from these is definite. He says:*

"From these culture experiments two things may be learned: first, that a very brilliant light is able to influence the distribution of plants, and to set up an impassable barrier for many of them; secondly, many plants have the capacity of adapting themselves to various degrees of light intensity, but in consequence they develop such a varying character that they might be mistaken for wholly distinct species." It also is known that certain species with the foliage exposed to the direct rays of the sun have violet or red hairy leaves, and that these same species growing in shady places may have green and nearly hairless leaves. Again, the leaves of one and the same species may have on low ground few hairs and thin cuticular layers, while on high mountains its leaves may be shrouded in thick grey or white fur and have a thick and leathery texture in consequence of strongly developed cuticular layers. And Kerner further states that herbs with vertically directed leaf surface are never to be met with in shady places. The leaves and branches of plants of vertical habit when brought into the shade tend to twist and bend so as to present a broader leaf surface to the diffuse light.

It is obvious that in temperate and tropic regions the vertical position of the young and tender leaves of such plants as the ferns and cycads, is a protection against strong sunlight. Later, when thick epidermal layers have formed, the leaf bends into its normal position and catches the nearly full rays of the sun. Curved young pinnules, like those of *Cycas*, also afford protection from the hot sun. From such facts, and they could be extensively added to, it is very clear that the peculiar light relations of the Arctic regions must always have had great influence on plant, and perforce on animal life. The further minor changes produced during southward migration could only be deduced from extended careful study. The range of light variation lies between the polar perihelion day or night of 200 solar days, and the equal division of twelve hours of daylight and twelve hours of darkness at the equator. When the greatest local variation in length of light succeeding darkness takes place within the Arctic circle, periods of vernation and reproduction must be more powerfully *altered* and *changed* there than elsewhere, reasoning from cause to effect. It would seem also that the hibernation of many animals, including certain forms of such diverse groups as monkeys, bears, and tur-

* Page 394 of Oliver's translation of Pflanzenleben.

tles, now living in tropic or subtropic regions, is a habit acquired in an original boreal home, and never broken.

As bearing on the general effect of light and darkness on plant growth, the elaborate experiments of MacDougal* are of high importance. He shows that etiolated tissues tend to remain in a primitive condition, though there may be transference of light effects to etiolated parts, that light shortens the meristematic period and induces the formation of permanent tissue, and that aplastic material is not so readily laid down in the absence of light. These facts are all suggestive of a chemico-physical basis of growth and development, and in complete accord with the ideas proposed here.

But with regard to the effect of the Arctic night on plants there have been probably no experiments in detail, although it is well known that the women of Disco Island find no difficulty in growing in their homes ornamental plants from far southern latitudes. If it were attempted, however, to demonstrate experimentally the effect of conditions representing hypothetical climates of the past, it would be necessary to use plants which have changed greatly and could therefore yield only relative results. Thus the entire cast of vegetation in the Carboniferous, of course conformed in transpiratory and other delicate functional structures to the moist hot climate, diffuse sunlight, and superabundance of carbonic acid characterizing that period. Hence while duplications of these climatic features may be readily made in the laboratory, their effect on plants now living affords only a general idea of the actual effect of the conditions of Carboniferous vegetation.†

As in the case of *light*, *heat* and *moisture* were also similarly variable to the utmost degree in the polar areas. Even if the

* Memoirs of the New York Bot. Garden, vol. 11, Jan. 20, 1903.

† A series of experiments, apparently requiring further extension—especially with reference to Pteridophytes,—has recently been made by H. F. Brown and F. Enscome (Proc. Roy. Soc., lxx, p. 397–413, pl. 5–10) to determine the probable effects of varying amounts of atmospheric carbon dioxide on the photosynthetic processes of leaves and on the mode of plant growth. These experimenters subjected plants during periods of several months to an artificially conditioned atmosphere containing as much as 11·47 per cent of carbon dioxide, and found that this resulted in diminished leaf surface, increased starch and chlorophyll content, deeper green, and various stem modifications. Fructification was apparently checked. Without attaching undue importance to experiments which leave many categories of inquiry unsatisfied, we may say that it is demonstrated that variations in the amount of atmospheric carbon dioxide do affect plant growth profoundly. And the effect on animals is equally or even greater, considered as either direct or indirect. At the poles, in addition to the direct chemical effect due to increase or decrease in the amount of atmospheric carbon dioxide, there is a further important physical effect. Dr Arrhenius (Philosophical Magazine, S. 15, vol. xli, No. 251, April, 1896, pp. 237–279) estimates that the addition of but two to three per cent of carbon dioxide to the atmosphere would be sufficient to give to the Arctic regions the genial climate indicated by their Tertiary flora.

north polar area had been at times in the past occupied by a continental mass with a but little broken shore line, the general statement that during periods of high eccentricity, this region underwent relatively more change in the distribution of seasonal heat and moisture than the inter-polar portions of the globe, could scarcely be challenged. But there is every reason to believe that the presence of numerous peninsulas and archipelagoes has long characterized the Arctic regions, and that these added very directly to the peculiarities and vicissitudes of northern climate, more especially, too, because of a doubtless not infrequent diversion, as change went on, of ocean currents. At times of high eccentricity there must have been within the limits of the time of the precession of the equinoxes, the most extraordinary changes and diversities in cloudiness, rainfall, dryness, heat and frostiness in the localities about the pole. As in the case of light these changes must have affected the economy of plants and animals profoundly. The possible difference of 36 solar days in the length of the seasons would in many cases produce totally different weather conditions during the periods of reproduction, sometimes favorable, sometimes adverse. Extermination must have been not infrequent, and likewise favorable turns of seasons. But it is scarcely necessary to go into these particular features of polar climate at great length now. This general statement may here suffice as the effect of varying conditions of light, heat and moisture on the lesser scale to be seen in temperate and tropic regions, and therefore their general significance must be fairly well understood. Aside from these factors it only need be remarked that there remain the more conjectural, magnetic, electrical and perhaps other effects included within the idea of climate as the resultant or manner of the terrestrial reception of radiant energy.

Perhaps the most fundamental corollary to the view of northern origins as now dealt with at some length, is that of a rapid origin of new species or even genera of both animals and plants. But the idea that this has been the general rule has been suggested, or even insisted upon by various naturalists. And this rapid origin is especially noteworthy in the vertebrata. The horse, I am told by an eminent authority, accomplished more evolution during the deposition of some 900 feet of John Day and White River Oligocene and Miocene sediments, than in all of previous Tertiary time as represented by far more than a mile of sediments. The same is in fact known to be true of so many vertebrate stocks that it may well be the rule. More recently Cumings in his able study of the Morphogenesis of *Platystrophia** has also found in the case

* This Journal, vol. xv, 1-48, 121–136, 1903.

of this exceedingly well represented brachiopod genus extending quite through the Cambrian, Ordovician and Silurian, that the fundamental difference between its earlier and later history "is the presence of intermediate groups during the former period, and their absence during the latter." In view of his own studies and the testimony of others a summation of the general facts is thus stated:—"Given a new and vigorous stock in a favorable environment, the initiation of new species takes place with great rapidity."

It may of course be added that by any "rapid" evolution I here mean only relatively rapid. Sudden changes of climate, or the transportation from warm to much colder localities and *vice versa*, result in very obvious changes in animals and plants, but such do not usually leave the stock a vigorous one, or end in extinction. I have described an excellent example of this kind in the case of the shutting out of salt water from the Currituck Sound by the closing up of the Currituck Inlet in North Carolina by drifting sands in 1828.* Previous to that year this inlet formed such a passage from the ocean through a narrow outer beach into the waters of Currituck Sound as is now formed by the new or Ocracock Inlet to Pamlico Sound. With the closing of the Currituck Inlet there resulted a conversion of upwards of one hundred square miles of shallow salt or brackish water to a fresh water area; and it is within the memory of men now living that the resultant changes in the life of the sound were immediate and striking. Previously the sound had been a valuable oyster bed. But within a few years after the exclusion of salt water the oysters had all died out, and their shells may now be seen in long heaps where they have been thrown out in dredging for a boat way in the shallow Coinjock Bay, a southwestern extension of the sound. Furthermore, the salt water fishes were driven out, and fresh water fishes took their places, whilst such changes were produced in the vegetation as brought countless thousands of ducks of species that had only been occasional before, thus making this one of the finest hunting grounds on the Atlantic Coast.

Owing to the landlocked condition of the Arctic area, and its numerous peninsulas and archipelagoes, such changes must from the Mesozoic on often have occurred there and by depopulation added to the general tendency to rapid change.

Some idea of the amount of evolution which may be undergone in isolated and favorable areas after a general dispersion has taken place, may be gained by the consideration of island life. The great development of tree-like plants, elsewhere

* This Journal, p. 76, July, 1897.

herbaceous, as seen in the arboreal lobelias, the shrubby geraniums, violets and plantains, and the strange arborescent Compositae of the Hawaiian Islands, affords an instructive example. But the evolution of the main groups of flowering plants having long since taken place, we cannot expect to find in islands, which at most show little more than such changes as have taken place in Tertiary time, evidence of the origin of new orders of plants; though such changes as are observed, or greater, doubtless often take place after the successful invasion of a new area, or in the case of the destruction of competitors in the old home. Moreover, if, as was always the case in the Arctic regions, the period of rigor was quickly followed by one of extremely favorable conditions coming on, nevertheless, at a rate easily taken advantage of by both plants and animals, races of great strength must quite surely be generated; and likewise new species, to an extent and with a rapidity that can scarcely be estimated on the basis of the fairly static conditions of most islands. As polar changes were mainly governed by the precession of the equinoxes, we know that the time scale was one of 12,934 years for the passing from rigorous to melior conditions and *vice versa*, throughout the successive periods of high eccentricity.

Summation.—From the preceding portions of the present consideration and argument, it appears that climatic changes of a character affecting life must in the course of time be of minimum amount at the equator, and increase towards the poles, where the maximum amount of such change occurs. Hence throughout time, the nearer a given locality to either pole, the greater the seasonal vicissitudes to which its life is subjected. Next, the view that the origin of life itself took place at the north (or at both of the poles), was accepted as in all probability the reasonable one, although as mentioned, the bare possibility that there has been a supplementary or an original extra-terrestrial origin of life also requires consideration. In either case, should the globe ever have been molten, the conditions making it probable that terrestrial life appeared at the poles, were not due alone to lesser solar heat there but mainly to the mechanical action of heavy lunar tides in the primitive equatorial lava seas. If the globe was never molten, any excessive equatorial heat whatever in the early geological periods would still leave the polar areas the probable early scene of life as at present understood. Attention was also called to the fact that the Paleozoic must have been because of climatic and other reasons, such as the freer circulation of oceanic waters, and the greater number of aquatic animals, and lowly organized or spore-bearing plants, a period mainly of generalized origins. Hence, there can be slight stratigraphic record of the distributory movements of faunæ and floræ in the Paleozoic, although there are excellent reasons for supposing that even then polar climates were the most important of evolutionary factors. It would seem that from the origin of life down to the Mesozoic the north and south polar areas may have played a well nigh equal part in creating a certain southward and northward stress with, to borrow a term used in different sense by Ward (Pure Sociology), a sort of breaking up or *Karyokinetic origin* of species in the tropics. But beginning with Mesozoic time and extending to the glacial period, overwhelming evidence points to the polar origin and continuous outward dispersion from the north polar area of most of the great plant and vertebrate groups. Whatever minor rôle was played by the south polar area yet remains to be demonstrated. The successive unheralded synchronous appearance of in large part unrelated and complex northern faunæ, leaves us no other alternative hypothesis than that of boreal origin, in spite of the fact that vertebrate fossils of Mesozoic and post-Mesozoic age from the Arctic (and Antarctic) area are unknown. The similarity in successive unrelated and diverse faunæ synchronously appearing on both sides of the fairly permanent Atlantic, as the record shows, cannot be accounted for throughout long periods of time on the basis of lateral interchange. Nor can similar series of changes, and similar genera and even species have so often arisen independently at such widely separated points, as to have produced the parallelism so constantly evident in the fossil vertebrates of Eurasia and America. And these same principles apply to the record of the post-Paleozoic floræ as next reviewed and shown to be in all essentials the complement of the vertebrate record, and far completer. Further, it was recalled that the outward movement especially of Conifers and Dicotyls from the Arctic area for long periods of time, has frequently been recognized by scientists. Some of the traces of this movement are still evident in the present strikingly homogeneous circumboreal flora, although its main development, as in the case of the vertebrates, was obscured and partially checked by the appearance of glacial conditions.

Without attempting to follow out the several lines of evidence of northern origin and of southern migration and displacement any further, it does appear fully conclusive that all the factors of climate and therefore the main alternative potentialities producing organic evolution, have been in the highest degree variant in the polar areas. And this being true, the grouping of the continents about the north pole so that they have come to cover fully 300° of the Arctic circle would make it reasonable to suppose, were there not abundant direct evidence pointing to the fact, that the northern circumpolar area has probably been, ever since the older Paleozoic at least, the main evolutionary center from which animal and plant life have radiated. But the theoretical view is as we see supported by overwhelming proof that such has been the fact, and that it is from the Arctic area that the greatest waves of change have swept out to lessen and disintegrate, though I do not at all mean to infer cease, in the more static conditions of the tropics.

The true nature of the southward organic stress was next illustrated, and some of the peculiar climatic conditions making the origin of new stocks more likely at the north were also pointed out. In particular I have also shown the possible connection between periods of high orbital eccentricity and the origination of the organic "waves or impulses" that students of the fossil record often speak of, or for which there is more or less conclusive evidence, especially among Tertiary vertebrates.

These cognate facts, as thus brought together, it seems to me sustain incontrovertibly our main thesis that polar climate has been the major factor in the evolution of plants and animals.

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Art. XLI.—*Note on the Composition of Bredig's Silver Hydrosols*; by J. C. Blake.

[Contributions from the Kent Chemical Lab. of Yale University.—CXXI.]

In preparing silver hydrosols by passing the electric spark between silver electrodes under water according to the method of Bredig,* it was noticed that the anode was eroded fully as much as the cathode, especially if the current passing was small (four ampères); and the freshly prepared liquid was always distinctly alkaline. The black deposit which at first settles out was dried at 105° or at 140°, and found to lose weight on ignition. The alkalinity of the liquid and the loss on ignition of the deposit were attributed to the presence of silver compounds, formed by oxidation of the anode. Some silver solutions obtained by the action of the current without sparking led to a confirmation of this belief.

Electrodes of specially purified silver consisting of plates 0·5^{mm} thick and 3^{mm} wide, and of convenient length, as well as electrodes of silver wire obtained in the market, were immersed one or two centimeters in water from a tin still, or in "conductivity" water, and connected with the street current having a voltage of 110. On placing the silver electrodes in the water white and yellowish clouds seemed to arise from them and disseminate throughout the liquid, although the electrodes were some centimeters apart. This phenomenon, investigated in open vessels and in U-tubes plugged with asbestos, gave the following results:

Time. hrs.	Distance between electrodes. cm.	Erosion of anode. grm.	Conditions.
2	2 to 7	0·0821—	In an open vessel.
2	2	0·0692—	
2	2	0·0655—	In an open vessel, each electrode surrounded by a filter paper.
2	2	0·0149—	In a U-tube, electrodes separated by two loose asbestos plugs.
7	4	0·3107—	
3	3	0·0488—	In a U-tube, electrodes separated by two tight asbestos plugs.
9	3	0·0184—	

Throughout these experiments the cathode remained unchanged in weight, although a yellowish gray slime of

*Anorganische Fermente, Leipsig, 1901. Zeit. Angew. Chem., 1898, p. 951.

metallic silver collected on it, from which the yellowish clouds were derived; the anode at first gave rise to snow-white clouds (silver hydroxide?), but soon became coated with a brown-red layer of silver peroxide, whereupon the white clouds ceased to be evolved in appreciable amount. On one occasion, when the anode was nearly touching one of the asbestos plugs, a bridge of the snow-white material was formed between the anode and the asbestos. When the current was broken this band soon dissolved, leaving a skeleton of peroxide; but the white band re-formed when the circuit was closed again. The resulting solution was strongly alkaline at first, but became neutral by standing, doubtless because silver hydroxide was originally present in the solution and was changed to the carbonate by the carbon dioxide of the air. Part of the silver derived from the yellowish clouds remained in suspension, forming a hydrosol.* When alcohol is substituted for the water no action takes place without sparking and only the cathode is eroded with sparking, forming a black silver alcosol, thus strengthening the supposition that the erosion of the anode in the presence of water when the spark is not passing is due to oxidation. It would seem very likely, moreover, that the anode would be similarly oxidized while the spark is passing, not to mention the possibility that part of the finely-divided silver torn off from the cathode might also be oxidized when it is carried into the region of the anode.

In Bredig's method of preparing silver hydrosols by sparking between silver electrodes under water, the current is frequently stopped on account of the rapid erosion of the electrodes. During such intervals of stoppage the conditions are the same as in the experiments of which a description has just been given, excepting, possibly, the distance between the electrodes. It seems certain, therefore, that in Bredig's experiments silver compounds must have been formed, thus accounting for the facts mentioned in the opening paragraph of this note, and for the fact, noted by McIntosh,† that the electrical conductivity of the water is greatly increased by the process of sparking. It would seem essential that these facts should be taken into consideration in such extended investigations as the latter author has made on the catalytic properties of the finely-divided silver contained in hydrosols prepared according to Bredig's method, especially when working with neutral or acid solutions.

This inquiry was made at the suggestion of Prof. F. A. Gooch, to whom my thanks are due.

*Cf. Billitzer, Ber. Deutsch. chem. Ges., xxxv, 1929.
† Jour. Phys. Chem., vi, 15.

Art. XLII. — *Behavior of Red Colloidal Gold Solutions toward the Electric Current and toward Electrolytes ;* by J. C. Blake.

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

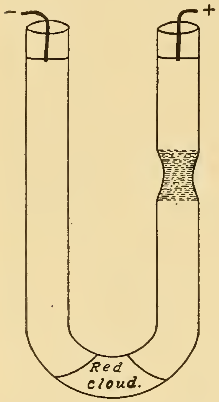
I. *Behavior toward the Electric Current.*

It is generally stated that colloidal gold solutions,* as well as permanent suspensions† and solutions of typical colloids, such as egg-albumen,‡ are coagulated and precipitated by the passage of the electric current, red colloidal gold solutions being simultaneously turned blue. I have investigated the behavior in this respect of completely reduced red solutions of colloidal gold, formed by the action of an ethereal solution of gold chloride dried at 170° on acetylene water containing ether.§ Such solutions contained in an ordinary beaker are apparently unaffected by the passage of the current for hours between gold or platinum wires 1^{mm} in diameter at a potential difference of 110 volts, unless, owing to the proximity of the electrodes, enough chlorine is liberated from the hydrochloric acid present to attack the colloidal gold with the formation of a solution of gold chloride from which ordinary gold is deposited on the cathode. This apparent inactivity toward the current is due to the fact that the conditions favor uniform diffusion of the gold throughout the liquid. When, on the other hand, the colloidal gold solution is contained in an ordinary U-tube, with an electrode in each arm, barely entering the liquid in order to avoid the diffusing effect of the escaping gases evolved by the current (amounting to about 0·005 ampère under the given conditions), electrical migration and concentration of the gold may be observed. Under these conditions, when contact is made, the gold immediately begins to settle from around the cathode with a clear surface of demarcation, leaving a colorless liquid, but never passing the bend of the U-tube; the gold solution around the anode grows deeper in color for about half an hour and then grows lighter in color, until after twelve hours or more only a faint pink tint remains, all the gold being now concentrated in a red cloud at the bend of the U-tube except for a slight deposit of dark-colored slime on the anode. When the U-tube was so constructed as to have a long horizontal portion between the two arms, the phenomena were unchanged, the red cloud forming midway between the

* Zsigmondy, Lieb. Ann., ccci, 29; Bredig, Anorganische Fermente, Leipsig, 1901, p. 28.
† Spring, Rec. trav. chim. Pays. Bas., xix, 215.
‡ Hardy, Jour. of Physiol., xxiv, 292.
§ Cf. this Journal, xvi, 381.

poles, thus showing that the effect is not due to gravity. The red cloud may at any time be readily diffused throughout the liquid by gentle agitation or warming, and slowly diffuses spontaneously when the current is broken. By withdrawing the clear liquid and dissolving the red cloud in pure water a purified red colloidal gold solution may be obtained.

This experiment becomes still more instructive if an asbestos plug be placed in one arm of the U-tube, just below the anode, as shown in the cut. If the plug is tight, the electrical osmosis of the liquid carries the gold with it to some extent. If the plug is loose, no movement of the liquid is observable and the gold moves in obedience to the current.



When the plug is loose the gold moves toward the anode as soon as contact is made, settling from around the cathode in exactly the same manner as in the former experiment; simultaneously a little gold is carried into the lower part of the asbestos plug below the anode, while that above the plug rises a little way, leaving the colorless liquid clearly defined. By the end of half an hour this latter surface of demarcation settles back to the asbestos plug, and thereafter for a long time (a week in one experiment, with interruption of the current over night) the gold solution above the plug remains unchanged, except that a dark-colored slime in slight amount forms on the anode, as in the former experiment. The gold below the asbestos plug not carried into it during the first half hour gathers in a red cloud at the bend of the U-tube as in the experiment where no plug was used. In the one experiment which was continued for a week, this red cloud practically all disappeared, and the gold which it contained was deposited in the lower end of the asbestos plug for a distance of 1^{cm}, coloring the asbestos red.

It was found that when the hydrochloric acid formed in the reduction of the gold chloride was removed from the colloidal gold solution by dialyzing the liquid until it became neutral to litmus, the electrical movements of the gold were not noticeably different from those given above. Also, when a red colloidal gold solution was prepared without the presence of ether, by the action of a dilute aqueous solution of gold chloride on acetylene water, the results were still the same.

These various occurrences may, perhaps, be explained as follows: All of the gold particles are originally negatively electrified and hence start toward the anode. This state of affairs never changes in the arm of the U-tube carrying the cathode. But the gold particles at first concentrated around the anode by the action of the current give up their negative charge to that pole, and, being for some reason unable to remain in contact with it (except to a slight extent in the formation of the dark-colored slime), depart laden with a positive charge. Hence the surface of demarcation at first formed above the asbestos plug soon settles back to its original position, causing the plug to become positively charged, which then acts as the anode to the particles below it. The positively charged particles repelled from the lower end of the asbestos plug, or from the anode if no plug is present, meeting the negatively charged particles from the cathode, form some sort of a union, possibly by mutual attraction without disruption of the water envelopes with which they are surrounded, thus producing the red cloud at the bend of the U-tube. The fact that the gold in this cloud was ultimately carried into the asbestos plug in the one experiment continued for a week shows that the positively charged particles present in the cloud must slowly lose their charge; and both that fact and the fact that diffusion restores the original conditions* indicate that the union of positively and negatively charged particles in the red cloud is very feeble. The fact that the gold above the plug does not settle, on the other hand, is a further indication that some kind of aggregation of oppositely charged particles must take place to form the red cloud in the bend of the U-tube.

The formation of the red cloud midway between the electrodes in these experiments closely resembles the formation of a precipitate similarly situated observed by Lehmann† in his study of suspensions made viscous by gelatine. A dark-colored corona gradually extended from the anode and a light-colored corona from the cathode. Midway between the electrodes the coronas met with the formation of a precipitate and the liberation of heat. So, also, the reverse or "secondary movement" noticed by Hardy‡ in the case of egg-albnmen, as well as the reverse movement of haemoglobin noticed by Gamgee,§ must be closely similar in their nature to the backward movement of the gold here described.

II. *Behavior toward Electrolytes.*

Bodländer‖ and Spring¶ have each insisted that in studying the action of electrolytes on permanent suspensions it is necessary to distinguish two phenomena: (1) Coagulation; (2) Pre-

* Cf. post, p. 441.
† Wied. Ann., lii, 455.
‡ Loc. cit.
§ Proc. Roy. Soc., lxx, 79.
‖ Neues Jahrb. f. Mineral., ii, 156.
¶ Loc. cit.

cipitation. A considerable amount of an electrolyte up to a definite limit can be added to a permanent suspension without causing any appreciable sedimentation within a reasonable length of time. This portion of the electrolyte is concerned in bringing about "coagulation." The further addition of an electrolyte after the above limit has been reached causes sedimentation to take place, the rate of settling varying with the amount of electrolyte thus added. This portion of the electrolyte is concerned in bringing about "precipitation." In working with colloidal gold solutions it is necessary to distinguish five effects:

(1) Coagulation of red gold solutions.
(2) Precipitation of red gold solutions.
(3) Coagulation of blue gold solutions.
(4) Precipitation of blue gold solutions.
(5) Transformation of red gold solutions into blue gold solutions.

Transformation of red colloidal gold solutions into blue colloidal gold solutions, with subsequent sedimentation.

The most obvious change brought about in red colloidal gold solutions by the addition of electrolytes is the change of color from red to blue, with subsequent subsidence of the gold. The change of color was investigated to some extent by Hardy,* who used a dilute red colloidal gold solution produced by the action of phosphorus in ether on an aqueous solution of gold chloride. The difference in the stability of his solution and the one used in these experiments, as indicated by the strengths of the various electrolytes necessary to produce the change of color, is so great that the results here recorded may be found none the less interesting. A red gold solution prepared according to the method already described and diluted to contain 0·0490 grams of gold per liter was titrated with electrolytes of known strength, the change of color from purple to violet which ensues soon after the original red color has changed to purple being taken as the end-point. The time required for titration varied from two to five minutes, but the time factor is not active until the end-point is nearly reached. Consequently only the last portions of the electrolyte were allowed to drop regularly from the burette. The gold solution changed from violet to pure blue in about two minutes after the titration was completed and the gold all settled out in four or five hours—the maximum rate† of subsidence in water noted in any experiment, including the work on absorption.‡ The results are given in the following table.

* Proc. Roy. Soc., lxvi, 110; Zeitsch. Phys. Chem., xxxiii, 385.
† Cf. Durham, Chem. News, xxxvii, 47.
‡ This Journal, xvi, 381.

TABLE I.

Vol. of gold solution cm^3.	Electrolyte.	Amt. of elect. cm^3.	Averages for 50^{cm^3}.	Final concentration of electrolyte in terms of normal strength.
50	$\frac{n}{10}$ — $KAl(SO_4)_2.12H_2O$	0·4	0·4	·0008 of $\frac{1 \text{ gram mol.}}{3}$ per liter.
50		0·4		
50	$\frac{n}{100}$ — $KAl(SO_4)_2.12H_2O$	2·1	2·2	·0004 of $\frac{1 \text{ gram mol.}}{3}$ per liter.
50		2·2		
50		2·2		
50	$\frac{n}{10}$ — $BaCl_2$	2·8	3·11	·0058 of $\frac{1 \text{ gram mol.}}{2}$ per liter.
50		3·3		
50		3·2		
50		3·0		
100		6·5		
50	$\frac{n}{10}$ — $Ba(NO_3)_2$	3·4	3·45	·0064 of $\frac{1 \text{ gram mol.}}{2}$ per liter.
50		3·7		
50		3·3		
100		6·8		
50	n — NaCl	7·7	7·6	·13 of 1 gram. mol. per liter.
100		15·0		
20	$\frac{n}{10}$ — NaCl	100		·083* of 1 gram mol. per liter.

These results are in accord with Whetham's† hypothesis, that the activity of electrolytes toward colloidal solutions is an exponential function of the valency of the basic elements which they contain, the final concentration of sodium chloride necessary to induce the change of color from red to blue being 22·4 times that of barium chloride, which, in turn, is 14·5 that of potassium alum. No amount of a tenth-normal solution of sodium chloride brings about the change of color within a reasonable length of time (see the last experiment of the table), the final concentration required, ·13-normal, being greater than that of a tenth-normal solution. The fact that the change of color takes place suddenly at a given concentration of the electrolytes and that a weaker concentration of the same electrolytes does not produce the change of color even after a considerable lapse of time, tends to disprove the hypothesis of Whetham, since time should be an active factor in bringing

* Solution not turned blue in two days.

† Jour. of Physiol., xxiv, 288; Phil. Mag., xlviii, 474.

about the change of color if it is the haphazard coincidences of gold particles and basic ions which condition the transformation, rather than some uniform and sudden change throughout the entire liquid, such as would be indicated by the observations of Bodländer on the coagulation and precipitation of kaolin suspensions.

That the effect of mixing two electrolytes whose basic elements have different valencies is subtractive rather than additive was shown by Linder and Picton* for colloidal solutions of arsenious sulphide and by Hardy† for colloidal solutions of egg-albumen, and is indicated by the following experiments, in which a red colloidal gold solution containing a known amount of a salt of a univalent basic radical was titrated to the violet color by barium chloride.

TABLE II.

Vol. of gold solution.	Electrolyte No. 1.	Amt. of el. No. 1.	Final conc. of el. No. 1.	Elec. No. 2.	Amt. of el. No. 2.	Final conc. of el. No. 2.
cm³.		cm³.			cm³.	
50	$\frac{n}{10}$—NH_4NO_3	65	·052	$\frac{n}{10}$—$BaCl_2$	9·2	·0074
100	$\frac{n}{10}$—NaCl	100	·047	$\frac{n}{10}$—$BaCl_2$	14·5	·0068
50	[Average from Table I.]			$\frac{n}{10}$—$BaCl_2$	3·11	·0058

It seems impossible to reconcile these results with Whetham's hypothesis. It is evident that a quantitative study of the effects of mixtures of electrolytic substances in various proportions in turning red solutions blue offers an interesting field for the investigation of the properties of electrolytes themselves.

It was thought likely that the remarkable stability of these red colloidal gold solutions was due to the ether present, acting as a non-electrolyte in inhibiting the action of electrolytes after the fashion of typical colloids, such as gelatine—a phenomenon first pointed out by Faraday,‡ and applied by Lottermoser and Meyer,§ Zsigmondy‖ and others. Consequently the following experiments were made on the same gold solution used above, but diluted with four volumes of water. To this diluted solution various amounts of ether were added before titration. The results are given in the following table.

* Jour. Chem. Soc., lxvii, 63. † Jour. of Physiol., xxiv, 182.
‡ Phil. Trans., cxlvii, 145. § Jour. Prakt. Chem., lvi. 248.
‖ Zeitsch. Anal. Chem., xl, 697; Schulz and Zsigmondy, Hofmeister's Beiträge, iii, 137.

TABLE III.
Volume of gold solution, 50^{cm^3}.

Volume ratio of ether added.	$\frac{n}{100}$—KaAl—$(SO_4)_2.12H_2O$ cm^3.	Averages. cm^3.	Final concentration of electrolyte in terms of normal strength.
	1·8 1·7 1·9 1·9	1·8	·00035
1 : 50	2·58 2·65 2·50 2·70	2·61	·00050
1 : 25	3·15 3·05 3·35	3·18	·00060 } of $\frac{1 \text{ gram mol.}}{3}$ per liter
Saturated, exposed to air during titration.	5·00	5·00	·00091
Saturated, titrated under ether.	8·75 9·20	8·98	·00151

In the last two experiments of the table neither aluminium nor sulphuric or hydrochloric acid could be found in the ether. Hence it appears that the presence of the ether tends to inhibit the action of electrolytes to such an extent that a red gold solution kept saturated with ether by a superimposed layer of it required more than four times as great a concentration of the potassium alum to produce the change of color as was required by a solution containing the same amount of gold and acetylene and but very little ether. The effect, if any, of varying the amounts of gold and acetylene is covered up by the simultaneous variations produced by changes in the amount of ether present.

Since it was found impossible to turn red colloidal gold solutions blue in the experiments with the electric current detained at the beginning of this paper, other electrical means of bringing about the change of color were sought; but neither the alternating current from an induction coil, giving an inch spark in air, nor long-continued sparking between gold electrodes with the direct current, as in Bredig's* method of pre-

*Loc. cit. Zeit. angew. Chem., 1898, p. 951; Bredig and Reinders, Zeit. Phys. Chem., xxxvii, 323.

paring gold hydrosols (aqueous colloidal solutions), served to bring about the desired result.† Hence the following experiments were made in order to find out, if possible, whether electrical phenomena were demonstrably concerned in bringing about the change of color. In the experiments given under A of Table IV a red colloidal gold solution containing 0·0193 gram of gold per liter was titrated with electrolytes without the presence of the current, for purposes of comparison; in those given under B the titration was made in the presence of electrodes of platinum wire at a potential difference of 110 volts and $0{\cdot}5^{cm}$ apart. In these experiments the first noticeable change of color of the liquid from red to purple was taken as the end-point. Under these conditions the liquids included under A, as well as those titrated with sodium sulphate under B, assumed a distinct purple or violet color within ten minutes after the titration was completed, but the gold remained suspended for some days, finally settling in the form of a purple or violet powder. The liquids titrate with potassium alum in the presence of the current changed from purple to blue almost at once.

Table IV.

Volume of gold solution, 100^{cm^3}.

A. Titrated without the electric current.

Electrolyte.	Amt. of elect. cm^3.	Averages.	Final concentration of electrolyte in terms of normal strength.
$\frac{n}{100}$ — $KAl(SO_4)_2.12H_2O$	3·19 2·90 2·95	3·01	·00029 of $\frac{1 \text{ gram mol.}}{3}$ per liter
n—Na_2SO_4	15·8 16·4 17·2	16·3	·140 of 1 gram mol. per liter
B. Titrated in the presence of the electric current.			
$\frac{n}{100}$ — $KAl(SO_4)_2.12H_2O$	1·36 1·45 1·25	1·35	·00013 of $\frac{1 \text{ gram mol.}}{3}$ per liter
n — Na_2SO_4	20·4 18·2 21·8	20·1	·167 of 1 gram mol. per liter

These results are sufficient to show that the phenomena involved in the titration of red gold solutions with electrolytes in the presence of the electric current are complex and demand

* Cf. Spring, loc. cit.

extended investigation. Thus the presence of the electric current increased the activity of the potassium alum, but retarded that of the sodium sulphate. Since the acid radicals were the same, it is necessary to attribute the difference in behavior to the basic radicals, thus strengthening the belief that the basic radical is the active factor in causing precipitation when the current is not acting. In one experiment with a hundredth-normal solution of potassium alum, it was found that the amount of electrolyte required to turn the red solution blue was not changed by the passage of the current under the same conditions as before for ten minutes and subsequent titration after the current was broken. This supports the conclusion arrived at above (p. 435) that red colloidal gold solutions are not necessarily permanently affected by the passage of the electric current.

The separate coagulation and precipitation of red gold solutions and the separate coagulation and precipitation of blue gold solutions, as well as the reverse change of color from blue to red with its apparent hysteresis, are being studied further. The fact that these gold solutions show five different effects on the addition of electrolytes, instead of two as in most colloidal solutions, renders them exceedingly interesting from a theoretical standpoint. Until the activity of electrolytes in bringing about each of these effects is better understood and differentiated, it would seem that speculation with regard to the causes which induce them would be idle; for in the process of turning red solutions blue as ordinarily conducted all five phenomena are doubtless involved. Some results obtained by titrating the same gold solution first to the purple color, then immediately to the violet color, are given below. The fact (noted above) that in the former case the gold settles slowly in the form of a purple or violet powder, in the latter case in the form of a blue powder and at the maximum rate, indicates that within the limits between the two readings is included the entire range of concentration of the electrolyte necessary to increase to the maximum the rate of subsidence of the red gold, to complete the change of color from red to blue, and to precipitate the blue gold thus formed.

Table V.

Volume of gold solution, 50^{cm^3}. Electrolyte, $\frac{n}{100} KAl(SO_4)_2.12H_2O$.

Titrated to purple.	Mean	Titrated to violet.	Mean
2·25		3·65	
2·45		3·40	
2·50		3·45	
2·40	2·41	3·45	3·49
2·70		3·55	
2·30		3·50	
2·30		3·40	

Art. XLIII.—*Is the Peak of Fernando de Noronha a volcanic plug like that of Mont Pelé?* by John C. Branner.

It is doubtful whether the writer would have ventured the suggestion made by the title of this note if the idea had not occurred many years ago to no less a person than Charles Darwin. In his "Journal," new edition, New York, 1878, p. 11, Mr. Darwin says of the island of Fernando de Noronha: "The most remarkable feature is a conical hill about one thousand feet high, the upper part of which is exceedingly steep, and on one side overhangs its base. The rock is phonolite, and is divided into irregular columns. On viewing one of these isolated masses at first *one is inclined to believe that it has been suddenly pushed up in a semi-fluid state.* At St. Helena, however, I ascertained that some pinnacles, of a nearly similar figure and construction, had been formed by the injection of melted rock into yielding strata, which thus had formed the moulds for these gigantic obelisks."

The italics (not Mr. Darwin's) direct attention to the chief point of interest in the present connection. In his "Geological Observations," second edition, page 27, Darwin again refers to the Fernando peak, as follows: "At St. Helena there are similar great, conical, protuberant masses of phonolite, nearly 1,000 feet in height, which have been formed by the injection of fluid feldspathic lava into yielding strata. If this hill has had, as is probable, a similar origin, denudation has been here effected on an enormous scale."

The writer spent some months on the island of Fernando many years ago while a member of the Geological Survey of Brazil, and an article on its geology was published in this Journal in February, 1889. The following is quoted from that paper (vol. cxxxvii, page 152): "The Peak is the most striking landmark in the South Atlantic Ocean; it is 1000 feet high, with the upper portion perpendicular or overhanging in such a manner as to make the summit quite inaccessible. The few drawings of this peak that have been published are taken from the same point—the anchorage—and even the best of them, that in the Challenger reports, conveys but a poor idea of its grandeur. Seen from other points it presents a striking variety of outlines." Two cuts of the peak are given in that article, one of which was reproduced by Professor Dana in his Manual of Geology, 4th ed., p. 263. Owing to the points of view, neither of these cuts, however, gives a just idea of the shape of the peak. The one in Dana's Geology was made from a photograph taken with the camera pointing up at an angle of forty-five degrees.

1

The Peak of Fernando de Noronha seen from the land to the south. From a photograph made by J. C. Branner in July, 1876.

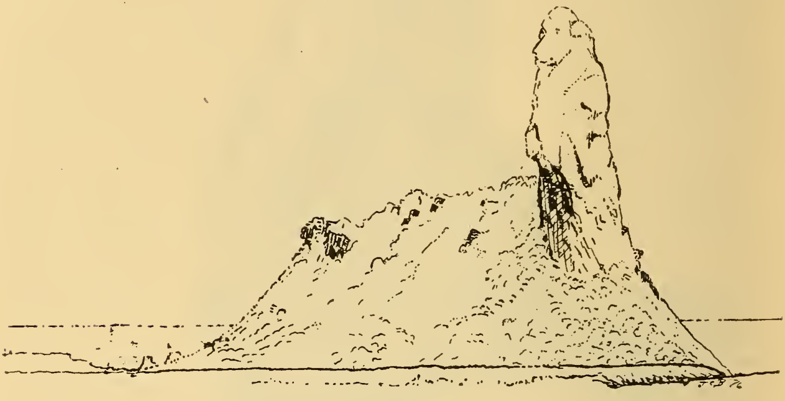
With this note is given a drawing (fig. 1) made from a photograph taken by the writer in 1876 from the plateau above which the peak rises; the observer looks northwest, and the peak is about a mile away. Attention is called to the upper slope on the right, and to its general resemblance to fig. 5, plate XII, of Dr. Hovey's description of the new cone of Mont Pelé published opposite page 276 of this Journal for October, 1903.

Fig. 2 is a sketch made by the writer from a point a little farther to the north and from a distance of about three-quarters of a mile. This view shows both the peak proper and the hill at its base on the west, which is of the same kind of rock as the peak itself, that is, phonolite. On the right the talus slope descends to the sea beach. The attention is called to the resemblance of this view to the profile given in fig. 3 of

Dr. Hovey's paper on Mont Pelé. The drawings are on different scales.

The vertical part of the rock is about 500 feet high. The edge of the plateau from which the sketch was made is shown in the foreground of fig. 2; it is about 275 feet above the ocean (aneroid) and this may be taken as nearly the general level of the island.

2



The Peak of Fernando de Noronha seen from the plateau above the village. A sketch made in July, 1876.

But little importance was attached to Mr. Darwin's suggestion in regard to the origin of the peak of Fernando until recent developments on Martinique brought it again to mind. It certainly is true that upon any other theory than that of the formation of the peak as a volcanic plug we have an amount of erosion to account for that does not seem to be in harmony with the general topography of the island.

But while the resemblance of the peak to the Mont Pelé plug is striking, it is realized that this resemblance may be quite accidental.

In Nature for October 15, 1903, p. 573, Sir Richard Strachey calls attention to a case in India of which the Mont Pelé peak reminds him.

Art. XLIV.—*Studies in the Cyperaceæ;* by Theo. Holm. XX. "*Greges Caricum.*"*

Of the two methods adopted for the classification of species, and especially of those pertaining to large genera, the artificial system, of course, has the advantage of being the most convenient, but seldom leads further than to their immediate determination. The natural classification is, on the other hand, much more difficult by being based upon supposed affinities between the species themselves, thus excluding such morphological characters as are common to a number of species, but of no importance from a biological point of view. Let us, for instance, consider Linnæus' classification of the species of *Carex*. When he treated the genus, "Vignea" had not yet been invented, and the "Indicæ" were not known. And with the object in view to render the determination of the species as easy as possible, Linnæus arranged these in accordance with the inflorescence, this being a single spike: staminate, pistillate or androgynous, or the spikes being several: androgynous or with the sexes separate, the pistillate spikes being either sessile or peduncled. Such classification is, of course, very artificial, considering the fact that the monostachyous species contain representatives of very different habit and of very different structure of the perigynium. But it is much less artificial than the system in which the species are simply classified as *Vigneæ:* all those with two stigmata, and *Carices genuinæ:* those with three. For in the former, the *Vigneæ*, if the number of stigmata be the most important character, the species must necessarily become badly mixed, since then *Carex vulgaris*, *lenticularis*, *angustata* and their numerous allies must be arranged side by side with *C. rosea*, *muricata*, *stellulata*, *vulpinoidea*, *stipata*, etc. The Linnæan method is still adopted in a number of manuals and systematic works, where it figures prominently in the artificial keys, and justifiably so. But it is rather surprising that the author, who treated the *Cyperaceæ* in the very modern and comprehensive work: "Die natürlichen Pflanzenfamilien," should not have felt called upon to give a more natural classification of the *Carices* than the one adopted, where

* Earlier numbers were published in this Journal as follows: No. 1 in vol. i, Fourth Series: 348, 1896—No. 2 in vol. ii: 214, 1896—No. 3 in vol. iii: 121, 1897—No. 4 in vol. iii: 429, 1897—No. 5 in vol. iv: 13, 1897—No. 6 in vol. iv: 298, 1897—No. 7 in vol. v: 47, 1898—No. 8 in vol. vii: 5, 1899—No. 9 in vol. vii: 171, 1899—No. 10 in vol. vii: 435, 1899—No. 11 in vol. viii: 105, 1899—No. 12 in vol. ix: 355, 1900—No. 13 in vol. x: 33, 1900—No. 14 in vol. x: 266, 1900—No. 15 in vol. xi: 205, 1901—No. 16 in vol. xiv: 57, 1902—No. 17 in vol. xiv: 417, 1902—No. 18 in vol. xv: 145, 1903—No. 19 in vol. xvi: 17, 1903.

the species appear in the old-fashioned sections: *Mono-*, *Homo-* and *Hetro-stachyæ* with the same distinction in regard to the distribution of the sexes as once proposed by Linnæus, and regardless of "natural affinities." We are told that *C. pauciflora* and *rupestris* together constitute one division "*Rupestres*," because they are monœcious and tristigmatic, while *C. cephalophora* and *Baldensis* represent the "*Bracteosæ*," because their inflorescence is capitate and subtended by leafy bracts, even if the former be distigmatic, the latter tristigmatic; moreover that *C. macrocephala* and *curvula* constitute the "*Curvulæ*" because both have three stigmata and a spicate-capitate inflorescence.

Almost a century after Linnæus had described the *Carices*, the genus became divided by Beauvais* in "*Vignea*" with two stigmata and a plano-convex achænium and "*Carex*" with three stigmata and a trigonous achænium. As a subgenus or at least as a section "*Vignea*" has been preserved, but not as a genus. A third section became proposed by Tuckerman,† the so-called "*Vigneastra*" including the *Indicæ*, and these were characterized as possessing androgynous, ramified spikes and two or three stigmata. This paper by Tuckerman actually contains the first attempt in combining the *Carices* in natural groups with names indicating the most characteristic type of each. Tuckerman did, however, begin his new system with the *Psyllophoræ*, the monostachyous, and passed from these over the *Vigneæ* and *Vigneastra* to the *Legitimæ*, somewhat similar to the old method. And he omitted to write the diagnoses of his groups, leaving the reader to interpret the affinities. But in the appended "Annotationes" Tuckerman expressed his views regarding the affinities of a few types, and he suggested, for instance, that the *Psyllophoræ* might perhaps be referable to the *Vigneæ* and *Legitimæ*, that the *Dioicæ* might belong to the *Stellulatæ*, the *Scirpinæ* to the *Montanæ*, and the *Rupestres* to the *Digitatæ;* in other words, Tuckerman had evidently grasped the correct idea of eliminating the *Monostachyæ* altogether as a section and to classify them as lesser developed types of the *Stellulatæ*, etc.

This same idea we find expressed, but much more carefully worked out in the posthumous work "Symbolæ Caricologicæ," published by Vahl under the auspices of the R. Danish Academy (1844). The author, Salomon Drejer, with remarkable skill undertook to treat the genus from a phyletic point of view, and he defined the transition from the lesser developed types to the more advanced in such a way as to overthrow the older, artificial classification. The number of stigmata, the

* In Lestiboudois' Essai sur la famille des Cypéracées, Paris, 1819, p. 22.
† Enumeratio methodica, 1843, p. 10.

distribution of the sexes and the form of the inflorescence had with him no weight unless they were in correlation with other characters which might be considered of biological importance, such as the structure of the perigynium (*utriculus*). In this way the species of the old section *Monostachyæ* became transferred to various pliostachyous groups as representing "formæ hebetatæ" of these, and even the *Indicæ* with their manifold decompound inflorescences, even these he did not feel inclined to preserve as distinct from the others. Only the *Vigneæ* and *Carices genuinæ* were recognized, though with the understanding that the former should not be restricted to distigmatic species alone, nor the latter to tristigmatic species.

Characteristic of the *Vigneæ* is, thus, not only the more or less dense-flowered, spicate or capitate inflorescence with commonly both sexes represented in each of the smaller spikes, or the normally two stigmata, but also the peculiar structure of the perigynium, being mostly plano-convex with the margins more or less prominent and the beak being usually slit deeper on the convex face, a structure that is, however, also met with in certain species of the *Carices genuinæ*, for instance among the *Stenocarpæ*. In the *Carices genuinæ* the perigynium exhibits three types, one in which the beak is very short, entire or subemarginate, a second in which there is a distinct beak with the orifice hyaline, two-lobed or irregularly bifid, while in the third type the beak is quite prominent with the apex bifid or even bidentate.

These three types of perigynium were suggested by Drejer as being sufficiently valid for dividing all the genuine *Carices* in three primary sections, as already indicated in his little book: Revisio critica Caricum borealium.—But this general classification does not, however, seem feasible when we remember the several modifications that are noticeable among the lesser and higher developed types within the minor "greges." On the other hand, we must fully admit the recognition of these characters as being very important, when applied to the central, specific types of each "grex," and when taken in connection with the other characters, which Drejer suggested as fundamental for the establishment of his "greges." He enumerates, for instance, the consistence of the perigynium, membranaceous or spongious, its surface being glabrous or pubescent, the bracts being leafy or scale-like, sheathing or merely auriculate at base, the spikes being erect or drooping, contiguous or remote, and finally the distribution of the sexes; this last character he considered, however, to be of minor importance, since it appears inconstant in a number of cases.—With these characters in mind Drejer classified a number of *Carices genuinæ* in eleven "greges" with diagnoses appended, but as already stated, his manuscript was left unfinished by his premature death, and none of the *Vigneæ* had been treated, nor did he leave any notes upon these. However, the general idea which he had formed relating to the classification of the latter is so clearly expressed in the introduction of his paper, that the "*greges*" of these, the *Vigneæ*, may be well constructed on the same basis as the others. But the method proposed by Drejer for the classification of these numerous species is so original and so distinct from any of the previous methods, for instance those suggested by Kunth, Fries and others, thus no comparison or combination of these seems possible.—If the *Vigneæ* be treated and if some new "greges" be suggested as supplemental to the *Carices genuinæ*, the treatment must be carried out in accordance with the same principles as once suggested by Drejer, whenever we intend to adopt and follow his method.

Nevertheless, an attempt has been made* to classify the *Vigneæ* and the *Carices genuinæ* in natural sections: the former in accordance with Fries, viz., *Acro-* and *Hyparrhenæ*, i. e. in accordance with the distribution of the sexes: with the staminate flowers borne at the top of the spikes or at the base of these, and the latter, the *Carices genuinæ*, in accordance with Drejer. It is readily perceived that these two methods are not to be combined, since the former, the one of Fries, is founded upon merely artificial characters, while the latter strives to be as natural as possible. Moreover, the interpretation of the "greges," proposed by Drejer, is far from correct, in spite of the fact that the diagnoses have been written in excellent Latin. Let us, for instance, examine the *Trachychlœnæ* Drej., as interpreted by Professor Bailey. With Drejer this "grex" contained such species as *C. glauca*, *hispida* and *trinervis*, while Professor Bailey has made it a complex of utterly different types and with the exclusion of *C. glauca*, which this author, strange to say, has referred to the *Acutæ* of Fries. This section, the *Acutæ*, did not, however, with Fries contain such species as *C. glauca*, but only *C. acuta* and *prolixa*, while Fries himself had *C. glauca* as a member of "*Pallescentes*." And the treatment of the *Vigneæ* by combining the various and very incongruous sections of Kunth, Fries, Nyman, Christ and Tuckerman has necessarily resulted in confusion.

A somewhat more successful attempt has been made by Rev. G. Kükenthal in his treatment of some South American *Carices*, in which the *Acro-* and *Hyparrhenæ* have become dissolved into groups that are more natural, and where the

* Bailey, L. H. Proceed. American Acad. Arts and Sci., vol. xxii, p. 59, 1886.

various sections or greges have been more correctly interpreted. However, the combination of *Microrhynchæ* and *Æorastachyæ* does not seem natural to us, and we can not either accept the *Bifurcatæ* Kükthl. as an alliance of two groups as distinct as the *Physocarpæ* and *Echinostachyæ*, nor can we accept the *Leptocephalæ* and *Physocephalæ* Bail. And the *Dactylostachyæ* Drej. were hardly intended for such divergent types as the *Oligocarpæ* or the *Laxifloræ*, nor does it seem natural to refer *Phyllostachys* as a whole or in part to the *Sphæridiophoræ* Drej. Whether the *Vigneastra* be distinct from the *Vigneæ* and *Carices genuinæ* remains to be seen; the characterization of the *Graciles*, the *Polystachyæ* and *Indicæ* at least does not seem to warrant any such segregation. If the author had treated a larger number of species and from other parts of the world, he would no doubt have altered some of his views and enlarged the number of "greges," especially of the *Vigneæ*.

Similar to the system adopted by Professor Bailey, Mr. Kükenthal has made a number of combinations of groups formerly proposed by Kunth, Fries, Tuckerman and others. And as we have stated above, such combinations are not always feasible, when we bear in mind that the principles upon which these classifications were based are quite distinct. We might illustrate this by an example taken from the *Canescentes* of Fries, as accepted by Mr. Kükenthal and Professor Bailey.

Fries himself defined the *Canescentes* as "Hyparrhenæ β *canescentes:* typice albidæ" including such species as *C. canescens*, *remota*, *stellulata*, *tenuiflora* and a few others. With Mr. Kükenthal the *Canescentes* are species with: "utriculi neque alati neque marginati neque spongiosi brevirostres vel erostrati," and excluding *C. remota*, which is transferred to another section: the *Remotæ* of Ascherson.

With Professor Bailey the *Canescentes* Fr. is supposed to be identical with the *Elongatæ* Kunth, the *Tenuifloræ* Kunth, the *Heleonasteæ* Kunth, the *Stellulatæ* Kunth, the *Deweyanæ* Tuckm., the *Loliaceæ* Nym., the *Monastes* Nym. and *Lagopinæ* Nym.

It would seem from the above statements that an independent treatment would be safer, since such contradictions as are liable to arise from combined systems would be averted. And with the object in view of establishing a classification of *Vigneæ* and *Carices genuinæ* in accordance with the principles suggested by Drejer, the writer has made an attempt to arrange a number of species from various parts of the world, but mostly from the northern hemisphere, and only such as have been directly accessible to study and represented by sufficient material. The result of our study is, as will be seen from the following pages, the maintenance of the *Vigneæ* and *Carices genuinæ*, while the *Vigneastra* appear to us as inseparable from these, especially from the latter. That we enumerate the *Vigneæ* before the *Carices genuinæ* must not be understood as if it were our idea that these are older than the others; we consider them both as two parallel groups that evidently developed from certain monostachyous types, branching out in several, more or less restricted "greges." In these, the "greges," we have begun with the simplest types, when such are represented in the shape of monostachyous species: "*formæ hebetatæ.*" The supposed central types are so indicated, but besides these there are usually certain species which cannot be placed in direct sequence with these, and which to some extent show transition to other "greges;" these are enumerated as "*Desciscentes.*"

As to the arrangement of the "greges" we have begun with those which we suppose are the least advanced in each group; among the "greges" themselves are several which to us appear as illustrating a parallel development, for instance *Athrochlænæ-Stenocarpæ* and *Podogynæ*, *Trichocarpæ-Echinochlænæ*, etc. When we compare the "greges" of the *Vigneæ* with those of the *Carices genuinæ* it is readily seen that there are several types among the latter which habitually remind us of the former, the *Vigneæ;* such analogies are not uncommon among the *Melananthæ*, the *Athrochlænæ* and the *Chionanthæ.*

However these analogies do not extend beyond the mere composition of the inflorescence and especially in regard to the distribution of the sexes: the spikes being often androgynous or gynæcandrous as in the *Vigneæ.* While apparently typical to several species, androgynous or gynæcandrous spikes occur so frequently among the *Carices genuinæ*, the formerly so-called "*Heterostachyæ*," that this character seems too fallacious to be depended upon to any large extent. But some exceptions exist, and we have not, so far, observed a single case where the terminal spike was not gynæcandrous in such species as *C. triceps*, *virescens* and *Shortiana*, to which such structure seems to be typical, besides a number of others, i. e. *C. squarrosa*, *atrata*, *alpina*, *Buxbaumii*, etc., even if exceptions be not infrequent.

It seems, also, to be a marked characteristic of the so-called "*Vigneastra*" that most of the spikes or sometimes all of them are androgynous, but as we have already stated, we have not felt induced to maintain this section, since none of the species, which we have had an opportunity of examining, proved distinct from the *Carices genuinæ.* While some of these *Vigneastra* possess a habit that is very distinct from other *Carices*, it is not difficult to see several and very important analogies in their morphological structure by which the distinction becomes very faint and hardly sufficient for the segregation of these as a special group. The following points may be taken into consideration: Tuckerman, who established the group, mentions the decompound spikes as being branched and androgynous, and the number of stigmata varying from two to three, and of the four sections enumerated by him, the writer has examined representatives of the *Indicæ*, the *Polystachyæ* and the *Graciles*, all of which have been accepted by Mr. Kükenthal (l. c.).

Of these the *Graciles* should include distigmatic species with mostly simple and single spikes; the *Polystachyæ*, on the other hand, should possess numerous spikes, from two to four together from each sheath, and with two or three stigmata, while in the *Indicæ* the spikes constitute a widely ramified inflorescence of which the secondary and tertiary axes are developed from perigynium-like organs, and the stigmata being constantly three. Among the *Graciles*, *C. brunnea* Thunbg. is a good type, and it is true that all the spikes are androgynous, and that the spikes are very often only one or two together on the same peduncle, and that the stigmata are but two. Nevertheless, this species can by no means be segregated from the *Carices genuinæ* on that account, but is barely referable to any of the *Vigneæ*, since the spikes are cylindrical, borne on long and slender peduncles, besides that the structure of the perigynium is very different from that of any member of the *Vigneæ*, being ellipsoid, much flattened, prominently striate, hairy on the nerves, and abruptly narrowed into a linear, bifid beak. It happens, however, that the perigynium is sometimes glabrous in Non-Indian examples, as stated by Mr. Clarke, but even such specimens would hardly be referable to the *Vigneæ* either.

Of the second section, the *Polystachyæ*, *C. Jamesonii* Boott shows us a plant with very long and slender, cylindrical, androgynous spikes, borne on long peduncles and more or less branched from the base. These branches are subtended by narrow bracts, somewhat longer than the scales but otherwise not different from these, and they all proceed from an ochrealike perigynium, but of which the flower is not developed; each secondary branch is thus merely the rhacheola extended, as is very frequently observed in a number of *Carices genuinæ*, even if it may be somewhat abnormal in these. Furthermore, in *C. Jamesonii* there are several peduncles developed from each leaf-sheath, making the inflorescence ample and rich-flowered, but otherwise the principal structure is well comparable with that of the inflorescence of the *Carices genuinæ;* we suggest the affinity of this species to be with the *Hymenochlænæ*.

Much more singular in structure and habit are the *Indicæ*, of which we might consider *C. cladostachya* Wahl. The culms are branched in almost their whole length and from the numerous leaf-sheaths long peduncled, androgynous spikes proceed, of which the secondary ramifications are sessile and developed from perigynia without flowers. These empty perigynia correspond, as we have described before,* with the basal ochreæ, but differ from these by their function and structure. Their function is to spread the lateral spikes into an horizontal position, and this takes place by means of a swelling of the base of these small organs. In other words, they represent prophylla with purely mechanical function, as we remember so well from the similar, but much higher developed, sheath-like prophylla in the umbels of *Cyperus*. The minor inflorescences of *C. cladostachya* may look more like those of a *Vignea*, but the presence of the empty perigynia with their special function makes the species better comparable with some of the *Carices genuinæ*, in which similar rudimentary and basal perigynia have been observed. The *Indicæ* contain, thus, the most singular types of the *Vigneastra*, but we have, nevertheless, failed to find a single point in their combined morphological structure by which their segregation from the others might be warranted. The almost constant presence of both sexes in each spike is of course noteworthy, but such androgynous inflorescences are, as we know, not uncommon among the other *Carices*. And we think that such cases where a species with normally gynæcandrous spikes appears as inseparable from others which are truly heterostachyous, that such cases may be considered more anomalous than when we place the *Vigneastra* as members of the various "greges" of *Carices genuinæ.*

We refer to *C. Magellanica*, of which the lateral spikes are normally gynæcandrous; still no one would doubt its affinity to be with *C. limosa* and *rariflora*. And we might, also, recall the singular *C. stenolepis* in which the lateral spikes are constantly gynæcandrous besides, not infrequently, the terminal, and the affinity of this species seems, notwithstanding, to be with the *Spirostachyæ*, as suggested by Drejer (l. c.).

Some few "*Carices genuinæ*," for no author has as yet segregated them from these, deserve just as much the distinction of being enumerated as *Vigneastra* as those mentioned by Tuckerman, Bailey and Kükenthal, and these are: the pliostachyous *C. Willdenovii*, *Steudelii*, *Backii*, *illegitima*, *Linkii* and *pedunculata* with all the spikes androgynous and in no wise to be distinguished from the *Vigneastra*;† the only difference which we see lies in their smaller size. There is, on the other hand, a species which we have enumerated as a member of the *Carices genuinæ*, and which, according to our opin-

* This Journal, vol. ii, 1896, 214, and vol. x, 1900, p. 33.

† This Journal, vol. x, 1900, p. 33.

ion, represents the most peculiar type among these; this is *C. Fraseri.* By the structure of its leaf, being destitute of sheath, ligule and midrib in connection with the characteristic inflorescence and rhizome,* this species would be better separable from the other *Carices* than any of the most highly developed *Vigneastra.*

Synopsis of the "greges."

I. VIGNEÆ.

Brachystachyæ nob.

Spikes several, short, few-flowered, sessile, remote or the upper ones contiguous, gynæcandrous or, but seldom, androgynous; the bracts often conspicuous, but very narrow; scales mostly hyaline; perigynia somewhat spreading, green or light brown, ovate, mostly sessile, plano-convex, nervose, glabrous or a little scabrous along the upper margins, sometimes spongious at the base, the beak short, obliquely cut or almost entire; stigmata two.

Centrales: C. trisperma Dew., *tenuiflora* Wahl., *loliacea* Schk., *macilenta* Fr., *canescens* L., *vitilis* Fr., *helvola* Bl., *Bonanzaensis* Britt.
Desciscentes: C. microstachya Ehrh., *tenella* Schk.

Neurochlœnæ nob.

Spikes several, short but many-flowered, sessile, mostly contiguous, gynæcandrous or the lateral wholly pistillate; bracts inconspicuous; scales brownish; perigynia erect, brownish or dark green, often shortly stipitate, elliptical to oval or roundish, plano-convex, nervose, glabrous or scabrous above, the beak very prominent, at least in the central types, slit on the convex face, the orifice hyaline; stigmata two.

Hebetatæ: C. nardina Fr., *oreophila* Mey., *ursina* Dew.
Centrales: C. glareosa Wahl., *lagopina* Wahl., *Pribylovensis* Macoun, *cryptantha* Holm, *neurochlœna* sp. n.,† *heleonastes* Ehrh., *norvegica* Willd.

Argyranthæ nob.

Spikes several, mostly short and loose-flowered, sessile. contiguous or the lower ones remote, gynæcandrous or the lateral wholly pistillate; bracts short and narrow; scales hyaline or light brown; perigynia erect, membranaceous, light green, stipitate, lanceolate, plano-convex, nervose, serrulate along the narrow margins, the beak long, bidentate; stigmata two.

Centrales: C. Deweyana Schw., *bromoides* Schk.

* This Journal, vol. iii, 1897, p. 121.
† The diagnoses of the new species will be published in a subsequent paper in this Journal.

Astrostachyæ nob.

Spikes several, short and few-flowered, sessile, remote, gynæcandrous or the lower ones purely pistillate; bracts short and narrow; scales brownish; perigynia spreading, brownish, sessile, cordate or ovate, plano-convex, nervose, spongious at the base, winged, tapering into a serrulate, bidentate beak; stigmata two.

Hebetatæ: C. dioica L., *paralela* Læst., *gynocrates* Wormskj., *Davalliana* Sm., *exilis* Dew.

Centrales: C. stellulata Good., *scirpoides* Schk., *sterilis* Willd., *interior* Bail., *albata* Boott, *nubigena* Don, *elongata* L., *læviculmis* Meinsh.

Desciscens: C. remota L.

Acanthophoræ nob.

Spikes several, mostly short, but often dense-flowered, sessile, contiguous or remote, androgynous; bracts often long, but narrow; scales brownish; perigynia somewhat spreading, brownish, mostly sessile, ovate and acuminate to suborbicular and abruptly beaked, plano-convex, faintly nerved or nerveless, spongious at the base, narrowly winged, the beak serrulate, bidentate; stigmata two.

Centrales: C. rosea Schk., *divulsa* Good., *sparganioides* Muehl., *Muehlenbergii* Schk., *glomerata* Thunbg., *cephaloidea* Dew., *muricata* L., *lejorhyncha* Mey., *Hookeriana* Dew., *occidentalis* Bail., *vagans* sp. n., *trachycarpa* Cheesem., *Hoodii* Boott, *gravida* Bail., *alopecoidea* Tuckm., *conjuncta* Boott., *vulpina* L., *phaeolepis* sp. n., *chrysoleuca* sp. n., *vitrea* sp. n.

Desciscentes: C. cephalophora Muehl., *vulpinoidea* Michx., *vicaria* Bail., *Maackii* Maxim., *gibba* Wahl.

Stenorhynchæ nob.

Spikes several in a dense-flowered, decompound panicle or head, sessile, contiguous, androgynous; bracts conspicuous, but usually narrow; scales green or light brown; perigynia spreading, light brown or greenish, stipitate, ovate, tapering into a very long, bidentate beak, plano-convex, nervose, the narrow margins serrulate; stigmata two.

Centrales: C. crus corvi Shuttlew., *stipata* Muehl.

Sychnocephalæ nob.

Spikes numerous in a dense-flowered head, sessile, gynæcandrous; bracts very long, leaf-like; scales green or light brown; perigynia erect, linear-lanceolate, acuminate, light green, stipitate, compressed, few-nerved, wingless, the beak very long, serrulate, bidentate; stigmata two.

Centrales: C. cyperoides L., *sychnocephala* Carey.

Xerochlœnæ nob.

Spikes many, rather large, in a dense-flowered, spicate inflorescence, sessile, mostly contiguous, androgynous; bracts often conspicuous, setiform; scales brownish; perigynia mostly erect, seldom spreading, brown, stipitate or sessile, broadly ovate to orbicular, plano-convex, nervose, more or less winged, serrulate, tapering into a distinct, bidentate beak; stigmata two, seldom three. Some species show tendency of becoming diœcious.

Centrales: C. divisa Huds., *marcida* Boott, *Sartwelli* Dew., *disticha* Huds., *repens* Bell., *arenaria* L., *arenicola* Fr. et Sav., *Kirkii* Petrie, *potosina* Hemsl, *Schreberi* Schr., *brizoides* L.
Desciscentes: C. inversa R. Br., *resectans* Cheesem., *Douglasii* Boott, *macrocephala* Willd.

Psyllophoræ Lois. ex p.

Spike single, brownish to light green, androgynous, lax and few-flowered, the pistillate portion squarrose at maturity; scales oblong, acuminate, those of the pistillate flowers deciduous; perigynium shining brown to greenish, erect, but reflexed at maturity, membranaceous, elliptical, shortly stipitate, obsoletely two-nerved, glabrous, tapering into a beak with hyaline, obliquely cut orifice; stigmata two.

Hebetatæ: C. pulicaris L., *macrostylon* Lapeyr., *sagittifera* Lowe.

Phænocarpæ nob.

Spikes numerous, small, in a dense-flowered panicle or spicate inflorescence, sessile, contiguous, androgynous; bracts short, filiform; scales brownish; perigynia erect or somewhat spreading, ovate to orbicular, shining brown, spongious at base, plano-convex, nervose, with thin margins and a serrulate, bidentate beak; stigmata two.

Centrales: C. paradoxa Willd., *teretiuscula* Good., *paniculata* L., *appressa* R. Br., *virgata* Soland., *decomposita* Muehl.

Athrostachyæ nob.

Spikes several in a dense-flowered head, or the lower ones somewhat remote, sessile, gynæcandrous; bracts seldom conspicuous; scales brownish; perigynia erect, lanceolate to ovate or suborbicular, brown, plano-convex, nervose, more or less broadly winged with a long, serrulate, obliquely cut or bidentate beak; stigmata two.

Centrales: C. tribuloides Wahl., *Crawfordii* Fern., *scoparia* Schk., *Muskingumensis* Schw., *leporina* L., *athrostachya* Olney, *festiva* Dew., *petasata* Dew., *pinetorum* Liebm., *siccata* Dew., *pratensis* Drej., *adusta* Boott, *kaloides* Petrie, *viridis* Petrie, *ænea* Fern., *Liddonii* Boott.
Desciscentes: C. Bonplandii Ktb.*

* = *illota* Bailey.

Pterocarpæ nob.

Spikes several, large, heavy and dense-flowered, contiguous or the lower ones remote, sessile, gynæcandrous; bracts inconspicuous; scales light brown or green; perigynia erect or slightly spreading, ovate to orbicular, light brown or greenish, compressed, nervose, broadly winged with a prominent, serrulate, bidentate beak; stigmata two.

Centrales: C. cristata Schw., *albolutescens* Schw., *mirabilis* Dew., *alata* Torr., *straminea* Willd., *stramini formis* Bail., *tenera* Dew., *Bicknellii* Britt., *silicea* Olney, *festucacea* Schk.
Desciscentes: C. Bebbii Olney, *foenea* Schk., *planata* Fr. et Sav., *neurocarpa* Maxim.

Microcephalæ nob.

Spike single, shining brown, very small, roundish to oval, dense-flowered, androgynous; scales broadly ovate, brown with hyaline margins; perigynia greenish, spreading at maturity, membranaceous, broadly ovate, sessile, nerveless, glabrous, tapering into a straight beak with hyaline orifice, slit on the convex face; stigmata two.

Hebetata: C. capitata L.

Cephalostachyæ nob.

Spikes several, reddish brown, androgynous, dense-flowered, sessile in a roundish or oblong head; bracts mostly inconspicuous, scales ovate to lanceolate, acute; perigynia shining brown, plano-convex, elliptical to ovate, sometimes turgid, stipitate to sessile, prominently many-nerved, scabrous along the beak, the orifice of which is bidentate or merely slit on the convex face; stigmata two.

Centrales: C. foetida All., *Colensoi* Boott, *stenophylla* Wahl., *chordorrhiza* Ehrh.

Sphærostachyæ nob.

Spikes several, androgynous, dense-flowered, sessile in a roundish head; bracts inconspicuous; scales broadly ovate, acute, shining brown with hyaline margins; perigynia yellowish, becoming fuscous at maturity, membranaceous, ovate, turgid, distinctly stipitate and diverging, nerveless or nearly so, glabrous or minutely scabrous along the prominent beak with obliquely cut orifice; stigmata two.

Centrales: C. incurva Lightf., *duriuscula* Mey.

II. Carices genuinæ.

Melananthæ Drej.

Spikes several, dense-flowered, peduncled, but mostly contiguous, gynæcandrous, or the terminal staminate and the lateral pistillate; bracts conspicuous, sheathless; scales mostly dark; perigynia erect, often purplish spotted or black, elliptical, sessile, somewhat compressed, few-nerved, minutely granular and, sometimes, scabrous along the upper margins, the beak short, entire or emarginate; stigmata three.

Hebetatæ: *C. alpina* Sw., *melanantha* Mey., *melanocephala* Turcz.
Centrales: *C. atrata* L., *ovata* Rudge, *aterrima* Hppe., *bella* Bail., *nigra* All., *chalciolepis* Holm, *nivalis* Boott, *obscura* Nees, *Mertensii* Presc., *Parryana* Dew., *stylosa* Mey., *accedens* nob.,* *Raynoldsii* Dew., *holostoma* Drej., *Buxbaumii* Wahl., *bifida* Boott, *quadrifida* Bail., *Gmelini* Hook.
Desciscentes: *C. ustulata* Wahl., *venustula* sp. n., *Montanensis* Bail., *microchæta* sp. n., *Tolmiei* Boott, *nigella* Boott, *spectabilis* Dew.†

Microrhynchæ Drej.

Spikes several, often dense-flowered, sessile or short-peduncled, contiguous or, sometimes, remote, the terminal staminate, the lateral pistillate or the uppermost staminate or androgynous; bracts foliaceous, sheathless; scales mostly dark and obtuse; perigynia erect, mostly light green, roundish to elliptical, often stipitate, compressed, more or less prominently nerved, granular and often scabrous along the upper margins, the beak short, entire to emarginate; stigmata two.

Hebetatæ: *C. rufina* Drej.
Centrales: *C. stricta* Good., *angustata* Boott, *rhomboidea* Holm, *prionophylla* Holm, *cæspitosa* L., *lugens* Holm, *Yukonensis* Britt., *Hindsii* Clarke, *decidua* Boott, *vulgaris* Fr., *Thunbergii* Steud., *gymnoclada* Holm, *tricostata* Fr., *turfosa* Fr., *limula* Fr., *anguillata* Drej., *Groenlandica* Lge., *rigida* Good., *Fyllæ* Holm, *hyperborea* Drej., *Warmingii* Holm. *chimaphila* Holm, *stans* Drej., *aquatilis* Wahl., *sphacelata* sp. n., *chionophila* sp. n., *nudata* Boott, *consimilis* sp. n., *cyclocarpa* sp. n., *interrupta* Bcklr., *acutina* Bail., *limnocharis* sp. n., *variabilis* Bail., *lenticularis* Michx., *torta* Boott, *acuta* L., *prolixa* Fr., *Bueckii* Wimm., *Sitchensis* Presc.,‡ *Nebrascensis* Dew., *pulchella* nob.,§ *notha* Kth., *laciniata* Boott.
Desciscentes: *C. scopulorum* Holm, *orbicularis* Boott.

Æorastachyæ Drej.

Spikes several, long and dense-flowered, long-peduncled, more or less drooping, remote, the terminal and uppermost lateral staminate, the others pistillate; bracts foliaceous and often very long, sheathless; scales mostly dark, acuminate to

* = *spreta* Bailey non Steudel.
† = *invisa* Bailey.
‡ = *Howellii* Bailey.
§ = *Hallii* Bailey non Boott.

aristate and longer than the perigynia; perigynia erect, mostly light green, oval to roundish, sessile, more or less turgid, faintly nerved, often granular, sometimes minutely scabrous along the upper margins, the beak short, entire to emarginate; stigmata mostly three.

Centrales: *C. subspathacea* Wormskj., *salina* Wahl., *hæmatolepis* Drej., *halophila* Nyl., *Drejeriana* Lge., *cryptocarpa* Mey., *capillipes* Drej., *Lyngbyei* Hornem., *macrochæta* Mey., *nesophila* sp. n., *scita* Maxim., *ternaria* Forst., *phacota* Sprgl., *prælonga* C. B. Clarke, *aperta* Boott,* *crinita* Lam., *gynandra* Schw., *maritima* L., *glaucescens* Ell., *pruinosa* Boott, *picta* Boott, *Kiotoensis* Fr. et Sav., *incisa* Boott, *Schottii* Dew.,† *magnifica* Dew., *lacunarum* sp. n., *Magellanica* Lam., *limosa* L., *laxa* Wahl., *rariflora* Sm., *stygia* Fr., *littoralis* Schw.

Cenchrocarpæ nob.

Spikes several, loose-flowered, peduncled, but erect, mostly remote, the terminal staminate, the lateral pistillate; bracts foliaceous, sheathing; scales dark or greenish, obtuse; perigynia erect, glaucous, oval to elliptical, nearly sessile, trigonous, turgid, more or less distinctly nerved, glabrous, the beak mostly short with entire or obliquely cut orifice; stigmata three.

Hebetatæ: *C. bicolor* All., *aurea* Nutt.

Centrales: *C. intermedia* Miq., *panicea* L., *livida* Willd., *Californica* Bail., *sparsiflora* Wahl., *tetanica* Schk., *Meadii* Dew., *Crawii* Dew., *vaginata* Tausch.,‡ *polymorpha* Muehl.

Desciscentes: *C. granularis* Muehl., *pallescens* L., *Torreyi* Tuckm., *rigens* Boott.

Lejochlænæ nob.

Spikes several, lax and few-flowered, peduncled, erect or somewhat drooping, remote, the terminal staminate, the lateral pistillate; bracts foliaceous, sheathing; scales hyaline, mucronate; perigynia erect, pale green, often glaucous, elliptical, stipitate, trigonous and turgid, many-nerved, glabrous, the beak distinct and often curved, the orifice oblique; stigmata three.

Hebetatæ: *C. polytrichoides* Muehl., *Geyeri* Boott, *multicaulis* Bail., *ambigua* Link.

Centrales: *C. digitalis* Willd., *plantaginea* Lam., *Careyana* Torr., *laxiflora* Lam., *Hendersonii* Bail., *platyphylla* Carey, *Hitchcockiana* Dew., *olbiensis* Jord., *laxiculmis* Schw., *ptychocarpa* Steud., *siderosticta* Hance.

Desciscentes: *C. grisea* Wahl., *oligocarpa* Schk., *conoidea* Schk., *glaucodea* Tuckm.

* = *turgidula* Bailey. † = *obnupta* Bailey. ‡ = *Saltuensis* Bailey.

Dactylostachyæ Drej.

Spikes several, lax and few-flowered, peduncled, erect or somewhat drooping, contiguous, seldom remote, the terminal staminate, the lateral pistillate; bracts sheathing, but often bladeless; scales reddish brown, obtuse; perigynia erect, dark green, elliptical, trigonous, stipitate, nervose, pubescent, the beak short, straight with oblique orifice; stigmata three.

Hebetatæ: C. grallatoria Maxim., *heteroclita* Fr. et Sav., *humilis* Leyss.

Centrales: C. digitata L., *ornithopoda* Willd., *ornithopodioides* Hsm., *concinna* R. Br., *amphora* Fr. et Sav., *Brenneri* Christ., *pediformis* Mey., *lanceolata* Boott, *Richardsonii* R. Br., *conica* Boott, *pedunculata* Muehl., *Halleriana* Asso, *Boottiana* Benth., *Baltzellii* Chapm., *Linkii* Schk., *illegitima* Cesati, *cryptostachys* Brongt.

Desciscens: C. triquetra Boott.

Trachychlœnæ Drej.

Spikes several, cylindrical, dense-flowered, peduncled and nodding, remote or the upper ones contiguous, the terminal staminate, the lateral androgynous or wholly pistillate; bracts foliaceous with very short sheaths; scales dark, acute; perigynia somewhat spreading at maturity, purplish spotted, ovate to subglobose, sessile, faintly nerved, minutely hairy or scabrous, the beak short, emarginate to subbidentate; stigmata mostly three.

Centrales: C. glauca Scop, *virescens* Muehl., *triceps* Michx., *trinervis* Degl., *hispida* Schk., *setigera* Don.

Desciscens: C. spissa Bail.

Microcarpæ Kuekthl.

Spikes several, cylindrical and often very long, more or less dense-flowered, peduncled, nodding, remote or the upper ones contiguous, the terminal staminate, the lateral pistillate or, sometimes, the upper ones androgynous; bracts foliaceous with long sheaths; scales hyaline to light green or brown, acute; perigynia often small to the size of the plants, somewhat spreading at maturity, light green, elliptical, trigonous and sometimes turgid, sessile, nervose, glabrous, the beak short with the orifice entire, oblique; stigmata three.

Centrales: C. microcarpa Bertol., *Mendocinensis* Olney, *strigosa* Huds., *gracillima* Schw., *maxima* Scop.

Desciscentes: C. oxylepis Torr. et Hook., *Davisii* Schw. et Torr., *formosa* Dew.

Athrochlœnæ nob.

Spike single, androgynous, dense-flowered, the pistillate portion squarrose at maturity: scales lanceolate or oblong, obtuse, deciduous; perigynia shining brown, erect, but reflexed at maturity, membranaceous, fusiform or ovate, prominently stipitate, nerveless, glabrous, tapering into a long beak with the orifice hyaline and obliquely cut; stigmata mostly three.

Hebetatæ: C. pyrenaica Wahl., *nigricans* Mey.

Stenocarpæ nob.

Spikes several, slender and not very dense-flowered, borne on long peduncles, often drooping, remote or the upper ones contiguous, the terminal and, sometimes, the uppermost lateral staminate, the others pistillate; bracts mostly filiform and short, sheathing; scales purplish or brown, acuminate; perigynia purplish, slightly spreading, membranaceous, attenuated at both ends, triquetrous, faintly few-nerved, glabrous or a little scabrous above, the beak prominent, bidentate with erect teeth or obliquely cut, often hyaline; stigmata three.

Hebetatæ: C. lejocarpa Mey., *circinata* Mey., *hakkodensis* Franch., *mucronata* All., *curvula* All.

Centrales: C. sempervirens Vill., *frigida* All., *ferruginea* Scop., *tristis* M. Bieb., *luzulæfolia* W. Boott, *luzulina* Olney, *ablata* Bail., *firma* Host., *hirtella* Drej., *hispidula* Gaud., *gynodynama* Olney, *tenax* Reut., *setosa* Boott, *juncea* Willd., *psychrophila* Nees, *petricosa* Dew., *stenantha* Fr. et Sav.

Desciscentes: C. tenuis Host, *misandra* R. Br., *cruenta* Nees, *longicruris* Nees.

Podogynæ nob.

Spikes several, the terminal and, sometimes, the uppermost lateral (1 or 2) staminate, clavate, long-peduncled, the others pistillate, very robust, dense-flowered, globose to ovoid or cylindrical, long-peduncled, drooping, contiguous or somewhat remote; bracts foliaceous, narrow, sheathless; scales purplish black, lanceolate, acuminate to emarginate, often aristate; perigynia light green, purplish above, spreading on very long, ciliate stipes, membranaceous, lanceolate, compressed, two-nerved, ciliate, the beak prominent, bidentate; stigmata two.

Centralis: C. podogyna Fr. et Sav.

Lamprochlænæ Drej.

Spikes several, short and few-flowered, sessile or peduncled, erect, contiguous, the terminal staminate, the lateral pistillate; bracts narrow, sheathing; scales brownish, broad, mucronate, the margins hyaline; perigynia shining brown, erect, ovate or elliptical to almost orbicular, somewhat turgid, trigonous, sessile, faintly nerved, glabrous to minutely scabrous, the beak short with hyaline, oblique orifice; stigmata three.

Hebetatæ: C. rupestris All., *obtusata* Liljebl.

Centrales: C. obesa All., *nitida* Host, *pedata* Wahl., *eburnea* Boott, *alba* Scop., *villosa* Boott, *pilosa* Scop., *depauperata* Good.

Chionanthæ nob.

Spikes several, snow-white, androgynous, the staminate portion dense-flowered, the pistillate few-flowered, almost sessile in a roundish or oval head; bracts foliaceous with long and green blades; scales white, ovate, acute or obtuse; perigynia white with a few minute, purplish streaks and spots above, oblong, trigonous, sessile, two-nerved, glabrous, somewhat inflated, the beak very short, entire, but erosely denticulate around the orifice; stigmata three; rhacheola not developed.

Centralis: C. Baldensis L.

Leucocephalæ nob.

Spike single, snow-white, androgynous, dense-flowered; scales of staminate flowers elliptical, those of the pistillate broad and obtuse to emarginate, all white; perigynia somewhat spreading, membranaceous, whitish, elliptical, sessile, faintly nerved, glabrous, the beak very short, obliquely cut; stigmata three; rhacheola well-developed; leaves destitute of sheath, ligule and midrib.

Centralis: C. Fraseri Andrews.

Elynanthæ nob.

Spike single, androgynous, the pistillate portion few-flowered; scales brown, very broad, amplectent; perigynia membranaceous, whitish to brown, erect, oval to obovoid, obtusely triangular in cross-section, sessile, faintly two-nerved, pubescent above, the beak short, but distinct, with hyaline entire or obliquely cut orifice; stigmata three.

Hebetatæ: C. filifolia Nutt., *elynoides* Holm.

Sphæridiophoræ Drej.

Spikes several, the terminal staminate, clavate, the lateral pistillate and roundish, few-flowered, sessile or the lowest one peduncled, erect, contiguous to remote; bracts foliaceous, narrow, sheathless; scales brownish or purplish, acuminate, often mucronate; perigynia dark green, slightly spreading, elliptical to obovate or globose, trigonous, sessile or shortly stipitate, obscurely nerved, more or less pubescent, the beak short, emarginate to bidentate with the teeth erect; stigmata three.

Hebetatæ: C. scirpoidea Michx.

Centrales: C. ericetorum Poll., *membranacea* Poll., *polyrrhiza* Wallr., *præcox* Jacq., *montana* L., *Moorcroftii* Boott, *varia* Muehl., *communis* Bail., *pilulifera* L., *breviculmis* R. Br., *deflexa* Hornem., *Rossii* Boott, *pennsylvanica* Lam., *verecunda* nob.,* *turbinata* Liebm., *Floridana* Schw., *leucodonta* nob.†

* = *inops* Bail. non Kunze.

† = *rigens* Bailey non Boott.

Desciscentes: *C. tomentosa* L., *globularis* L., *Chapmanii* Sartw., *dasycarpa* Muehl., *Whitneyi* Olney, *pubescens* Michx., *Coulteri* Boott, *pisiformis* Boott.

Trichocarpæ nob.

Spikes several, cylindrical and more or less robust, dense-flowered, sessile or the lowest ones peduncled, but erect, remote, the terminal and uppermost lateral staminate, the others pistillate; bracts foliaceous, often very long, sheathing; scales purplish or brown, mucronate to aristate; perigynia brownish or dark green, erect, ovate to ovate-lanceolate or elliptical, more or less turgid, sessile, nervose, more or less pubescent, prominently beaked, the beak bidentate with spreading teeth; stigmata three.

Centrales: *C. vestita* Willd., *Yosemitana* Bail., *hirtissima* W. Boott, *Oregonensis* Olney, *hirta* L., *filiformis* L., *lanuginosa* Michx., *evoluta* Hartm., *Houghtonii* Torr., *trichocarpa* Muehl., *aristata* R. Br., *striata* Michx., *Pierotii* Miq., *pumila* Thunbg., *Wahuensis* Mey., *psilocarpa* Steud.

Desciscentes: *C. nutans* Host, *paludosa* Good., *riparia* Curt., *subdola* Boott, *trifida* Cavan., *Songorica* Karel. et Kir., *baccans* Nees, *Myosurus* Nees, *composita* Boott, *brunnea* Thunbg.

Echinochlænæ nob.

Spikes several, cylindrical, dense-flowered, sessile and erect, remote, the terminal staminate or sometimes andro- to gynæcandrous, the lateral pistillate, often with a few staminate flowers at the base or apex; bracts foliaceous and often very long, sheathing; scales light purplish to brown, mucronate to aristate; perigynia shining reddish brown, seldom grayish, erect, elliptical to oval, plano-convex or trigonous, sessile, nerved, the beak short, bidentate and prominently spinulose; stigmata two or three.

Centrales: *C. lucida* Boott, *Lambertiana* Boott, *Buchanani* Berggr., *Wakatipu* Petrie, *dipsacea* Berggr., *dissita* Sol., *uncifolia* Cheesem., *Petriei* Cheesem., *testacea* Sol., *Neesiana* Endl.

Desciscentes: *C. decurtata* Cheesem., *Raoulii* Boott., *comans* Berggr., *cirrhosa* Berggr.

Hymenochlænæ Drej.

Spikes several, cylindrical, slender and not very dense-flowered, peduncled and drooping, remote, the terminal staminate, the lateral pistillate; bracts foliaceous, the lowest sheathing; scales hyaline with green, excurrent midrib; perigynia light green, erect to slightly spreading, membranaceous, oval to elliptical, turgid and trigonous, stipitate, faintly nerved or nerveless, scabrous along the prominent, bifid or bidentate beak with hyaline orifice; stigmata three.

Hebetatæ: C. *rhizopoda* Maxim., *Steudelii* Kth., *Willdenowii* Schk., *Backii* Boott, *macroglossa* Fr. et Sav., *filipes* Fr. et Sav. *parciflora* Boott, *longerostrata* Mey.

Centrales: C. *arctata* Boott, *vacillans* Sol., *debilis* Michx., *silvatica* Huds., *elata* Lowe, *Cherokeensis* Schw., *Arnellii* Christ, *transversa* Boott, *curvicollis* Fr. et Sav., *anisostachys* Liebm., *longirostris* Torr., *Turczaninoviana* Meinsh., *flexilis* Rudge, *capillaris* L., *Krausei* Bcklr., *Williamsii* Britt.

Desciscentes: C. *Assiniboinensis* W. Boott, *prasina* Wahl., *Chinensis* Retz., *scabrata* Schw., *confertiflora* Boott, *dispalatha* Boott, *olivacea* Boott, *amplifolia* Boott, *speciosa* Kth., *Jamesonii* Boott.

Spirostachyæ Drej.

Spikes several, cylindrical, but rather short, dense-flowered, peduncled, but mostly erect, remote, the terminal staminate, the lateral pistillate; bracts foliaceous, sheathing; scales brownish, acuminate; perigynia mostly greenish, more or less spreading at maturity, oval to elliptical, somewhat turgid, sessile, nervose, glabrous or scabrous along the beak, which is quite long and bifid; stigmata three.

Centrales: C. *Hornschuchiana* Hppe., *diluta* M. Bieb., *punctata* Gaud., *distans* L., *binervis* Sm., *lævigata* Sm., *Camposii* Boiss. et Reut., *Lemmonii* W. Boott, *extensa* Good., *Mairii* Coss. et Germ., *aphanolepis* Fr. et Sav., *trichostyles* Fr. et Sav., *Ringgoldiana* Boott, *Michelii* Host, *brevicollis* D. C., *flava* L., *Oederi* Retz., *viridula* Michx., *Morrowii* Boott.

Desciscentes: C. *squarrosa* L., *typhina* Michx., *stenolepis* Torr.

Echinostachyæ Drej.

Spikes several, cylindrical, robust and dense-flowered, the terminal staminate often gynæcandrous, the lateral pistillate, peduncled and drooping, contiguous, squarrose at maturity; bracts foliaceous and very long, the lowest one sheathing; scales lanceolate, light brown or greenish, mucronate to aristate; perigynia greenish, reflexed at maturity, membranaceous, ovate to elliptical-ovate, somewhat inflated, trigonous, stipitate, prominently nerved, glabrous, the beak distinct, bidentate; stigmata three.

Hebetatæ: C. *microglochin* Wahl., *pauciflora* Lightf.

Centrales: C. *subulata* Michx., *Pseudocyperus* L., *Forsteri* Wahl., *alopecuroides* Don, *Doniana* Sprgl., *fascicularis* Sol., *Schweinitzii* Dew., *hystricina* Muehl., *retrorsa Schw.*

Physocarpæ Drej.

Spikes several, cylindrical, sessile or the lowermost peduncled, erect, remote, the terminal and, sometimes, the uppermost lateral staminate, the others pistillate; bracts foliaceous, but mostly narrow, sheathless; scales lanceolate, acuminate, brownish or purple; perigynia shining, light green to dark purplish, almost black, spreading, but not reflexed, membranaceous, globular to oblong-elliptical, membranaceous, inflated, sessile, nervose, glabrous, the beak short, bidentate to merely emarginate; stigmata three, seldom two.

Hebetatæ: *C. Engelmannii* Bail.
Centrales: *C. ambusta* Boott, *oligosperma* Michx., *miliaris* Michx., *ampullacea* Good., *lævirostris* Fr., *rotundata* Wahl., *utriculata* Boott, *physocarpa* Presl., *physochlæna* sp. n., *vesicaria* L., *pulla* Good., *Olneyi* Boott, *mirata* Dew.,* *compacta* R. Br.

Physocephalæ Bail. ex p.

Spike single, oval to globose, androgynous; scales lanceolate, reddish brown with broad hyaline margins; perigynia reddish brown, spreading, membranaceous, much inflated, sessile, faintly nerved, glabrous, the beak short with hyaline, obliquely cut orifice; stigmata three.

Hebetata: *C. Breweri* Boott.

Rhynchophoræ nob.

Spikes several, cylindrical, very robust and dense-flowered, sessile or short peduncled, mostly erect, contiguous, the terminal staminate, the others pistillate or, sometimes, the uppermost lateral staminate; bracts foliaceous and very long, the lowermost with a short sheath; scales pale, lanceolate, aristate or mucronate; perigynia greenish, erect or ascending, membranaceous, ovate, much inflated, stipitate, strongly nerved, glabrous or scabrous along the very prominent beak, which is sharply bidentate; stigmata three.

Hebetatæ: *C. uda* Maxim., *Michauxiana* Bcklr., *folliculata* L.
Centrales: *C. intumescens* Rudge, *Grayii* Carey, *Idzuræi* Fr. et Sav., *monile* Tuckm., *Halei* Carey, *bullata* Schk., *Tuckermannii* Boott, *lupulina* Muehl., *gigantea* Rudge, *lurida* Wahl., *Dickinsii* Fr. et Sav.
Desciscens: *C. rhynchophysa* Mey.

Brookland, D. C., Aug., 1903.

* = *exsiccata* Bailey.

Art. XLV.—*Action of Ultra-Violet Light upon Rare Earth Oxides*; by Charles Baskerville.

During the extended investigations of the action of ultra-violet light, cathode rays, Röntgen rays, and the emanations of radium upon gems and minerals in the Morgan-Tiffany gem and Morgan-Bement mineral collections in the American Museum of Natural History, a number of rare earth oxides were subjected to the action of ultra-violet light.* The following oxides were exposed to ultra-violet light produced by a Piffard lamp:

Gadolinium oxide (prepared by Waldron Shapleigh).†

Lanthanum oxide (prepared by H. S. Miner).

Neodidymium oxide (prepared by a method of Baskerville and Stevenson).

Praseodidymium oxide (prepared by the method of Baskerville and Turrentine).

Cerium oxide (prepared by H. S. Miner).

Samarium oxide (prepared by Waldron Shapleigh).

Thorium dioxide (chemically pure according to general acceptation previous to 1900, prepared by Baskerville and Davis).

Yttrium oxide (prepared by Waldron Shapleigh).

Yttrium, erbium, and ytterbium oxides mixed (prepared by H. S. Miner).

Erbium oxide (bought from Kahlbaum).

Erbium group oxides (prepared by Benton Dales).

Uranium oxide (prepared by S. Auchmuty Tucker).

Uranium oxide (prepared by S. Auchmuty Tucker).

Yttrium oxide (prepared by Dennis and Dales).

Ytterbium oxide (prepared by Benton Dales).

Titanium dioxide (bought from Eimer and Amend).

Zirconium dioxide (prepared by Venable and Baskerville).

Only two of the above oxides responded at all to the action of ultra-violet light, namely, zirconium and thorium dioxides, which phosphoresced strongly. The thorium dioxide remained luminous in the dark for a greater length of time. The zirconium dioxide showed no radio-activity when tested by the electrical and photographic methods. It is strange that the two rare earths forming normally the dioxide are the only ones to exhibit this property. This will be investigated further.

* Reported to New York Academy of Sciences, Oct. 6, 1903.

† My thanks are due to Doctors Miner, Tucker and Dales for the generous loan of preparations.

In view of the fact that these two earths give this characteristic response to ultra-violet light, it became immediately of interest to learn the effect of the light upon minerals carrying those substances in different proportions. The following minerals were subjected to the action of ultra-violet light without a single one of them giving either fluorescence or phosphorescence:

SAMARSKITE, Berthier Co., Que.
THORITE (Orangite), Arendal, Norway.
  " Barkevik, Norway.
  " (Auerlite), Green River, N. C.
SIPYLITE, Amherst Co., Va.
COLUMBITE, Portland, Conn.
MONAZITE, Arendal, Norway.
  " Zlatoust, Ural.
  " 171st St. and Washn. Ave., New York.
  " Amelia C. H., Va.
  " Alexander Co., N. C.
Monazite sand, Rio, Brazil.
MONAZITE, Tyedestrand, Norway.
XENOTIME, Cheyenne Canyon, Colo.
  " Alexander Co., N. C.
  " Hitteröe, Norway.
EUXENITE (in Samarskite), Mitchell Co., N. C.
AESCHYNITE, Hitteröe, Norway.
POLYCRASE, nr. Marietta, S. C.
FERGUSONITE, Llano Co., Texas.
  " Ytterby, Sweden.

The extended investigation of the action of ultra-violet light upon minerals carried out by Dr. Geo. F. Kunz and the writer will shortly be published in full.

University of North Carolina, Sept. 15th, 1903.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *A New Method for the Determination of the Faintest Traces of Arsenic.*—Armand Gautier, who has devoted much attention to the determination of small amounts of arsenic, and to the distribution of this element, has now described a very simple and accurate method for determining the most minute quantities of it. The method, which is particularly well adapted to the examination of chlorides, while the older methods present difficulties in such cases, consists in adding, under proper conditions, specially purified ferric sulphate solution to the liquid to be tested, boiling, and thus precipitating all the arsenic with the basic ferric salt; then dissolving the filtered precipitate in sulphuric acid and using the resulting solution directly in the Marsh apparatus.

The method is so delicate that $0 \cdot 001^{mg}$ of arsenic in a liter of water is entirely recovered by means of it. A sample of sea-water taken at 30^{km} from the coast of Brittany, at a depth of 5^{m} gave $0 \cdot 010^{mg}$ of arsenic per liter; water from near the Azores, at 10, 1335 and 5943^{m} depth gave 0·025, 0·010 and $0 \cdot 080^{mg}$ per liter; water from a salt spring at Missery gave $0 \cdot 010^{mg}$ per liter; various samples of common salt gave from 0·001 to $0 \cdot 045^{mg}$ in 100^{g}, while a sample of the same substance from a volcanic fissure at Vesuvius gave $0 \cdot 175^{mg}$ in 100^{g}. Various reagents supposed to be pure were found to contain arsenic; thus water distilled from copper and glass after the addition of sodium carbonate gave 0·0007 and $0 \cdot 0011^{mg}$ per liter, while so-called pure ammonia-bicarbonate of soda, potassium nitrate and sulphate, etc., gave appreciable quantities of the element.—*Bulletin*, xxix, 859. H. L. W.

2. *The Influence of Small Quantities of Water in bringing about Chemical Reactions between Salts.*—Many experimenters have investigated the influence of traces of moisture in reactions between gases, but apparently no one has hitherto made similar experiments with solids. Perman has therefore made a number of experiments in this direction, and has chosen for this purpose the salts of lead and mercury mixed with salts of potassium, usually the iodide, where the progress of a reaction would be indicated by a change of color. Equivalent quantities of lead chloride and potassium iodide were dried over strong sulphuric acid and then mixed. It was found that after drying forty-eight hours no visible change took place on mixing the salts, but on keeping the mixture a week in a sealed flask a faint yellow color appeared, which, after some months, became bright yellow. Attempts were made to find how much water was necessary in order to make the reaction immediately visible; the results were not very concordant, but indicated that about $0 \cdot 5^{mg}$ was necessary when 2^{g} of potassium iodide and an equivalent quantity of

lead chloride were mixed in a glass flask of 200^{cc} capacity. It was found that lead formate and lead nitrate act in a similar way to the chloride, when mixed with potassium iodide, while lead sulphate reacts much more slowly, although exposed to the air, and the carbonate and oxide react very slowly indeed.

When mercuric chloride and potassium iodide were treated in exactly the same way as has been described, a strong coloration was produced on mixing, but by drying with specially prepared phosphorus pentoxide, the mixture obtained has been kept for some months without change. Mercuric cyanide showed no reaction with potassium iodide, while mercuric chloride and potassium chromate reacted very slowly, although exposed to the air.

The author believes that there is no reason for thinking that the reactions take place in any way essentially different from similar reactions in solution, except in their slowness. He observes that mercuric chloride, which is ionized but slightly in solution, appears to react more rapidly than the readily ionized lead chloride; hence it appears that ionization cannot be the cause of the difference, and the conclusion is reached that the specific reaction velocity seems to be the real determining factor.—*Chem. News*, lxxxviii, 197. H. L. W.

3. *The Determination of Argon in the Atmosphere.*—MOISSAN has determined the amount of argon in more than twenty samples of air from many different localities. The oxygen and nitrogen of the air were absorbed by hot mixtures of lime and metallic magnesium, and the last traces of these gases, as well as of hydrogen, were removed by the action of hot metallic calcium which this investigator has succeeded in preparing in a state of great purity. The description of the method of analysis indicates that the results are very exact. With the exception of a single analysis, where 0·9492 per cent of argon was found in a sample of air from the Atlantic Ocean, the results are very concordant, and show that the amount of argon in the air is very constant, whether taken on land or sea, or at high or low altitudes. For instance, the percentage of argon found in another Atlantic Ocean sample was 0·9318; two from Paris, 0·9337 and 0·9319; from London, 0·9325; from Berlin, 0·9323; two from the summit of Mt. Blanc, 0·9352 and 0·9327; from St. Petersburg, 0·9329; from Moscow, 0·9323; from the summit of Mt. Pelée, 0·9366; from the Gulf of Naples, 0·9326; and from Venice, 0·9357. The author sums up by saying that samples of air collected in the interior of continents at altitudes from 0 to 5800^{m} show in 100^{cc} an amount of argon which varies from 0·932 to 0·935^{cc}, while samples of air from the surface of different seas show in general a slightly larger amount of argon but are also very constant except in the case of a single sample. The author states also that these researches have confirmed the important views of Dumas and Boussingault concerning the constancy in composition of the terrestrial atmosphere.— *Comptes Rendus*, cxxxvii, 600. H. L. W.

4. *A New Method for Detecting Chlorides, Bromides and Iodides.* — BENEDICT and SNELL have devised the following method for the purpose under consideration: The reagents used are potassium iodate of one-tenth, potassium iodide of one-fifth and nitric acid of five times "molar" concentration (sp. gr. of HNO_3 1·18). The operations are carried out in a rather wide test-tube. To the neutral solution acetic acid and KIO_3 are added. If iodine is thus found the liquid is boiled with addition of small quantities of KIO_3 until no further coloration is produced. To the liquid is then added nearly one-half its volume of dilute nitric acid. Coloration shows bromine, which may be confirmed by shaking a portion with chloroform or carbon disulphide. The main solution is boiled until colorless, 1 or 2^{cc} of KI are added, and the liquid is boiled again until colorless. An equal volume of concentrated nitric acid is then added together with a few drops of silver nitrate solution. A white precipitate, insoluble on warming, shows silver chloride. The concentrated nitric acid is added to prevent the precipitation of silver iodate in case there should be iodate still left in the solution after the treatment with potassium iodide. When a thiocyanate is present, the test for iodine is made in a portion after the addition of sodium acetate. If salts of other acids are present, the silver halides are first precipitated, filtered and washed, then decomposed with zinc and dilute sulphuric acid, neutralized, filtered, and treated as above. The method is said to give very satisfactory results, but it is evident that considerable care would be necessary in making the test for iodine, since other reducing agents would give the same reaction as an iodide.—*Jour. Amer. Chem. Soc.*, xxv, 809. H. L. W.

5. *Quartz Glass.* — A very full account of the behavior of this material has been given by H. HERAEUS before the International Congress of Practical Chemistry held lately in Berlin. The history of the working of quartz was related. Experiments were made as early as 1839; and the prominent experimenters in the subject have been Gaudin, Gautier, Boys, Dufour, Hutton, Shenstone, and, also, Heraeus.

The chemical relations of quartz are especially interesting. Quartz vessels are unaffected by water, acids and salt solutions ; but are affected by alkaline fluids. At high temperatures all oxides are dangerous for the vessels. One therefore should carefully clean such vessels; and abstain from touching them with the fingers. If one encloses a quartz tube in an electric furnace and heats it for several hours to about 1300°, its surface remains clear and limpid when it is taken out of the furnace. With a microscope, however, one perceives a slight change of the surface; when it cools sufficiently to be taken by the hand the whole surface becomes quickly clouded and non-transparent. Heraeus attributes this to a vitrification of the amorphous silicate and is a surface action. When this experiment is repeated in a closed platinum cylinder no such silicate is formed. At high temperatures the quartz is attacked by phosphoric acid; according to Prof. Mylius, crystallized silicic-phosphoric acid is formed—this also happens with the melting of phosphoric-ammonia-magnesia in phosphoric acid determinations.

Quartz at highest temperatures is not attacked by metals free from oxides. It allows a slow passage of hydrogen. This is much less than in the case of platinum and enters at a higher temperature than in the case of the latter. Shenstone states that a mixture of nitrogen and oxygen in quartz vessels, heated to the melting point of platinum, is converted into hyponitrous acid. The temperature of melting of quartz is about 2000°. The coefficient of expansion is extraordinarily low—far lower than with any known material—and makes the quartz very suitable for thermometers which are now constructed by Dr. Siebert and Kuhn.

If one passes an electric discharge through a rarified quartz tube a strong odor of ozone is noticed. This is a very noticeable phenomenon with Arons mercury lamp enclosed in a quartz vessel. It is impossible to remain long near such lamp. This behavior of quartz was first noticed by Lenard, Ann. d. Physik, 503, 1900.—*Deutsche Mechaniker Zeitung*, Oct. 1, 1903. J. T.

6. *Absorption of Ultra-Violet Rays by Ozone.*—It is well known that the earth's atmosphere absorbs the ultra-violet rays below $\lambda = 3000$. W. N. Hartley found an absorption band of ozone at a mean wave-length of $\lambda = 2560$. EDGAR MEYER has taken up this subject and has obtained quantitative results by a new method. The new feature of the method consists in the employment of the photoelectric photometer of Kreusler to determine the regions of absorption. This photometer is described in the Ann. der Phys., vi, p. 398, 1901. It was found that the extinction coefficient of ozone increased with the amount of ozone, and Hartley's absorption band was rediscovered; but at a mean wave length of $\lambda = 2580$.

Since the earth's atmosphere strongly absorbs the ultra-violet rays, Meyer discusses the question whether this absorption is largely due to ozone. A. Levy concludes from his ozonometric measurements, extended over twenty years, that 100^{cb} of air contains $1{\cdot}65^{mg}$ of ozone. Meyer takes this result, makes the assumption that it is the ozone which absorbs the short waves, and computes the energy distribution in the solar spectrum by the aid of Planck's formula. The graphical representation of the results show that in the region 2200 there is more than twice the energy that appears at wave-length 2500. The quantitative determination of the absorption bands of ozone are more conclusive than the determination of the question whether the ozone is chiefly instrumental in the absorption of the short waves of light.—*Ann. der Physik*, No. 12, 1903, pp. 849–859. J. T.

7. *Induced Thorium Activity.*—Thorium possesses, in common with radium, two kinds of radiation; the straight line radiations and the so-called emanation. Rutherford attributes the induced activity to this emanation. If one brings the source of

the radio-active emanation into an electric field the greater portion condenses on the negative electrode which then becomes temporarily active. According to J. J. Thomson and Rutherford the radio-active emanation throws off a negative electron that ionizes the air, resulting in a positive charge which wanders to the cathode. Curie sees in the emanation only a peculiar kind of streaming out of energy, a condition of matter in which possibly a gas is the bearer of the energy. Rutherford attributes the phenomenon to a radio-active gas of the argon group. The radio-activity is the indication of a series of atomic reactions. Out of thorium, for instance, comes ThX, from the latter arises the emanation and this again suffers a sub-atomic chemical change with formation of induced activity. F. von Lerch studies induced activity without regard to any especial hypothesis and sums up his results at the end of his article. One of his conclusions is that palladium appears to absorb the emanations. He also concludes that his experiments show the material nature of induced activity.—*Ann. der Physik*, No. 12, 1903, pp. 745–766.

J. T.

8. *Effect of Pressure on Arc Spectra.* — J. E. Petavel and R. S. Hutton find that at about 44 atmospheres a number of iron lines in the ultra-violet above 3800 are very strongly reversed. The absorption due to the presence of iron vapor results in a diminution of intensity toward the violet end of the spectrum, It was found that certain of the lines appear in the vacuum glow spectrum with their characteristic intensity, neighboring lines of almost equal importance in the ordinary arc and self-induction spark have so greatly diminished as to be quite invisible, the effect, therefore, is in no way connected with the actual exposure of the photograph or the intensity of the light.—*Phil. Mag.*, November, 1903, pp. 569–577. J. T.

II. Geology and Mineralogy.

1. *United States Geological Survey*, C. D. Walcott, Director.—Among recent publications of the Geological Survey are the following:

Water Supply ard Irrigation Papers, No. 80. The Relation of Rainfall to Run-off; by George W. Rafter. 102 pp., 23 figs. The relation of rainfall to run-off is influenced by many complex factors and no general expression is possible. Rainfall records covering less than 35 years are not reliable, and no satisfactory run-off records are at hand. Mr. Rafter undertakes to establish a more rational theory than has heretofore been proposed.

No. 81. California Hydrography; by Joseph Barlow Lippincott. 478 pp., 4 figs. The data covering the water supply of California has been collected from various sources.

Nos. 82, 83, 84. Progress of Steam Measurements for the Calendar year 1902; by F. H. Newell. No. 82 (195 pp.) covers the Northern Atlantic coast and St. Lawrence Drainage; No. 83 (300 pp.) the Southern Atlantic, Eastern Gulf, Eastern Mississippi and Great Lakes Drainage; No. 84 (196 pp.) the Western Mississippi and Western Gulf Drainage.

BULLETINS No. 212. Oil fields of the Texas-Louisiana Gulf Coastal Plain; by C. W. HAYES and WILLIAM KENNEDY. 170 pp., 11 pls., 12 figs. The geology of the Gulf coastal plain is described and also the detailed geology of the oil pools of the different districts. The elliptical domes which have furnished the conditions for oil accumulation are of a different class from the anticlines of the Appalachian region and "could scarcely have been produced by horizontal compression." The oil of this district is "derived, in part at least, from the action of decomposing organic matter, both animal and vegetable, but chiefly the latter, upon gypsum." The "oil ponds" in the Gulf water are shown not to be produced by diatoms but 'derived from oil that is either indigenous in the mud or derived from underlying rocks.'

No. 214. Geographic Tables and Formulas; by SAMUEL S. GANNETT. 284 pp. The tables and formulas used by topographers in the field and the office have been brought together in convenient form.

No. 215. Catalogue and Index of the Publications of the U. S. Geological Survey 1901 to 1903; by PHILIP C. WARMAN. 234 pp.

No. 216. Primary Triangulation and Primary Traverse, Fiscal year 1902–03; by S. S. GANNETT. 211 pp., 1 map.

PROFESSIONAL PAPER, No. 15.—The Mineral Resources of the Mount Wrangell District, Alaska; by W. C. MENDENHALL and F. C. SCHRADER. 68 pp., 10 pls., 5 figs. The Mount Wrangell district has important deposits of copper and of gold. The copper, chiefly bornite, occurs along the contact between the Nikolai greenstone (Carboniferous, 4000 ft. thick) and the Chitistone limestone (Permian) and has been concentrated from the greenstones. Gold to the value of $225,000 was mined in the Chestochina field in 1902. "The region is extensively glaciated but the present glaciers are but insignificant remnants of their predecessors," and the surface forms of the ores have been removed.

PROFESSIONAL PAPER, No. 13.—Drainage Modifications in Southeastern Ohio and Adjacent Parts of West Virginia and Kentucky; by W. G. TIGHT. 108 pp., 17 pls., 1 fig. Taken in connection with Leverett's monograph on the Erie and Ohio Basins (U. S. G. S. Mon. XLI), Professor Tight's paper gives a detailed account of the interesting drainage modifications of the upper Ohio and its tributaries. A very extensive rearrangement of divides and basins has taken place, the general history of which is outlined as follows: the high level valleys are pre-Glacial; the deflection of the streams producing the present drainage system was accomplished by the first advance of the ice sheet (pre-Kansan?); the extensive erosion of the valleys to depths below present drainage lines was accomplished during a long interglacial interval; these interglacial valleys were partially filled by deposits from flooded streams and afterwards partially recut during the last Glacial epoch ; post-Glacial erosion is represented by the channels cut in the floor of these deposits since the waters have acquired their present volume. "The Ohio River Valley from New Martinsville to Manchester is of interglacial origin."

2. *Nebraska Geological Survey.*—E. H. BARBOUR, State Geologist. Volume I, 1903. 242 pp., 166 figs., 13 pls.—For a number of years geological exploration has been carried on in Nebraska by Professor Barbour, both at private expense and as director of the Morrill Geological Expedition. The State has now made an appropriation for the publication of reports. The present report contains chapters on Hydrography, on Geology including mineral resources, on Soils, and on the Geology of Jefferson County. Considerable study has been made of the drainage conditions and attention is called to the down-stream shifting of the Loup tributaries of the Platte, and to the local artesian and salt water basins. The geological formations represented are : Carboniferous 1200 ft. (8 to 10 inches of coal); Permo-Carboniferous, 200 ft.; Dakota, water-bearing beds, 250 ft.; Benton, 200 ft.; Niobrara; Pierre, 100 to 3000 ft.; Oligocene, Bad Lands, 600 to 800 ft.; Miocene, Butte Sands, 500 to 600 ft.; Pliocene, 200 ft.; Pleistocene, drift and loess. Volcanic dust is found widely distributed over the State.

3. *The Geological Structure of Monzoni and Fassa;* by MARIA M. OGILVIE GORDON. Trans. Edinb. Geol. Soc., vol. viii, special pt., pp. 179, with maps, figs. and pls. 1902–3.—The Monzoni region has long been known as a classic field of research in varied branches of geology, and since the publication of Brögger's remarkable memoir (Die Eruptionsfolge der Triadischen Eruptivgesteine bei Predazzo in Süd-Tyrol) numerous papers dealing with features of the area and especially with the problems of the igneous rocks have appeared. In some instances these have led to discussions which have become rather acrimonious in character, the varied opinions apparently having arisen from insufficient study of the field relationships.

All this makes the present work by Mrs. Ogilvie Gordon the more timely as it consists mainly of the results of detailed and patient study and mapping of the field relations, and her conclusions, which are not based upon generalities, but upon observed facts, throw a flood of light upon the structure of the area and will prove of service in helping to solve similar problems elsewhere. The important features of her paper are the location and description of the various folds, and systems of faults, and the relation which the igneous intrusions bear to these fold and fault systems. The intrusions she believes to be of Tertiary age.

L. V. P.

4. *North American Plesiosaurs;* by S. W. WILLISTON. Publications of Field Columbian Museum. Geological series, vol. ii, No. 1, 77 pp., 29 pls.

This paper has been presented by the author as part of one of a series of monographic studies on the North American representatives of this order. Of all the larger groups of the reptiles from the American Mesozoic, the Plesiosaurs have probably been least satisfactorily known. This is the more remarkable as the group has shown a high degree of differentiation and skeletal remains can not be considered as rarities. Thirty-four species and nineteen genera of Plesiosaurs are listed by the author. The majority of these have been known only from small portions of the skeleton and, excepting the specimens described by the author, the general osteology of no single species had been satisfactorily worked out. The full description and the excellent illustrations of *Dolichorhynchops osborni* Williston incorporated in this paper furnish for the first time the materials upon which a satisfactory comparative study of the American forms of this group can be based. Important contributions to our knowledge of the general structure of the Plesiosaurs are made by the author in his interpretation of the structure of the frontal, occipital and palatine regions. In *Dolichorhynchops*, the elements which represent what have been considered as the frontals appear to be parietals reaching forward to the premaxillaries and separating the true frontals. The supraoccipital region in this form consists of two distinct and considerably separated elements. In *Brachauchenius* the palatines and pterygoids are broadly contiguous along the median line and the openings far back between the pterygoids are thought to represent the internal nares. An important addition to the types of Plesiosaurs already known is made in the description of *Brachauchenius lucasi* Williston, based upon a large-headed, short-necked species from the Benton Cretaceous of Ottawa County, Kansas. This genus shows single-headed cervical ribs and has the peculiar characters of the palate mentioned above. The addition of this very distinct type to the numerous genera already known serves to emphasize the statement that the Plesiosaurs have shown a remarkable degree of differentiation in this country.

Professor Williston has already given us a most valuable monographic study on one of the groups of American marine reptiles, viz., the Mosasaurs, and we shall look forward with much interest to the appearance of his completed work on the order which is now engaging his attention. J. C. M.

5. *Spodumene from Pala, California.* — The beautiful amethystine spodumene from Pala, San Diego, Cal., which was described by G. F. Kunz in the September number (p. 264) and named *Kunzite* by Baskerville (see Science, Aug. 12, and this Journal, p. 335), is also the subject of a descriptive article by W. T. Schaller (Univ. California, Bull. Geol., iii, 265, Sept., 1903). The crystals are simple and show the forms in the prismatic zone, *a* (100), *b* (010), *l* (320), *m* (110), *n* (130), *A* (350). The peculiar etching figures are discussed and figured in detail and approximate symbols assigned to them. The following results are given as the average of several analyses:

SiO_2	Al_2O_3	Mn_2O_3	Li_2O	Na_2O	K_2O	Ign.
64·42	27·32	0·15	7·20	0·39	0·03	0 = 99·51

A view is given of the mine from which the mineral is obtained and it is remarked that the green variety of the species, hiddenite, is also found there.

III. Miscellaneous Scientific Intelligence.

1. *National Academy of Sciences.*—The autumn meeting of the National Academy of Sciences was held at Chicago from Nov. 17 to 29. The list of titles of papers presented will be given in the following number.

2. *American Association.*—The annual meeting of the American Association for the Advancement of Science will be held in St. Louis in Convocation Week, beginning on December 28. Most of the societies usually affiliated with the Association will hold their meetings at the same place and time, and joint sessions in many cases are promised. The success of the first Convocation held at Washington a year ago gives reason to anticipate an equally interesting occasion at St. Louis.

3. *Annual Report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures and conditions of the Institution for the year ending June 30, 1902.* Pp. lxvi, 687, with many plates. Washington, 1903.—The report of the Secretary, S. P. Langley, in the volume now issued, was noticed on p. 242 of the preceding volume. In addition to this and other administrative matters the volume contains a General Appendix (pp. 117–659) which presents the usual selection of interesting scientific memoirs relating chiefly to the year 1902.

4. *The Physico-Chemical Review.*—It is announced that an international review of the sciences of physical chemistry and the allied branches of chemistry and physics will be begun in 1904 with Dr. Max Rudolphi, of Darmstadt, as editor-in-chief, and with the cooperation of numerous scientists in Germany and abroad. It will contain abstracts of papers published elsewhere; these will be in French and English as well as German and will be prepared by the authors so far as possible. The Review will be issued twice a month, making an annual volume of about 860 pages. Specimen numbers will be sent post-free by the publishers, Gebrüder Borntraeger, Dessauer Strasse 29, Berlin SW.

Obituary.

Robert Henry Thurston, Director of Sibley College and Professor of Mechanical Engineering at Cornell University, died in Ithaca on October 25th, his sixty-fourth birthday.

Professor Henry Carrington Bolton, the well known chemist and author, died in Washington on November 19 at the age of sixty years.

INDEX TO VOLUME XVI.*

A

Academy of Sciences, National, Chicago meeting, 475.
Alden, W. C., Elkland-Tioga folio, Penna., 394.
Arc spectra, effect of pressure on, Petavel and Hutton, 471.
Ascutney Mt., Vermont, geology, Daly, 267.
Association, American, meeting at St. Louis, 475.

B

Barker, G. F., radioactivity of thorium minerals, 161.
Barus, C., constants of coronas, 325.
Baskerville, C., spodumene from California, 335; action of ultra-violet light upon rare earth oxides, 465.
Beecher, C. E., the genus Romingeria, 1.
Blake, J. C., some isomorphous triple thiocyanates, 12; colors of allotropic silver, 282; colloidal gold, 381; Bredig's silver hydrosols, 431; red colloidal gold solutions, 433.
Boltwood, B. B., chemical analysis by electrolysis, 100.

BOTANY.

Cyperaceæ, studies in, XIX, Holm, 17; XX, 445.
Garden in Cuba, experimental, Atkins, 105.
Triadenum virginicum (L.) Rafin. Holm, 369.

Branner, J. C., geology of the Hawaiian Islands, 301; peak of Fernando de Noronha, 442.
Bredig's silver hydrosols, Blake, 431.
British Museum, Catalogue of bird's eggs, Oates and Reid, 400.
Bumstead, H. A., obituary notice of J. W. Gibbs, 187; radio-active gas in surface water, 328.
Bush, L. P., dates of publication of certain genera of fossil vertebrates, 96.

C

California, river terraces of Klamath region, Hershey, 240.
Canada geological survey, 395.
Cathode light, spectra, Deslandres, 391.
— radiations, investigated by phosphorescence, Lenard, 391.
— space, dark, Schmidt, 391.
Chemical Analysis by Electrolysis, Classen and Boltwood, 100.
Chemisches Praktikum, Wolfrum, 101.
Chemistry, Analytical, Classen, 390.
— Physical, Van't Hoff, 390.

CHEMISTRY.

Argon in the atmosphere, Moissan, 468.
Arsenic, new method for determination, Gautier, 467.
Cæsium, iodides, Foote, 100.
Calcium cyanamide, use of, Erlwein, 388.
Chlorides, bromides, etc., new method for detecting, Benedict and Snell, 469.
Chlorine smelting with electrolysis, Swinburne, 330.
Gases, Mazza separator for, 330.
— separation by centrifugal force, Claude and Demoussy, 389.
Gold, iodometric determination, Maxson, 155.
— colloidal, Blake, 381.
— — solutions, Blake, 433.
Hydrogen, heat of combustion of, Mixter, 214.

* This Index contains the general heads, Botany, Chemistry (incl. chem. physics), Geology, Minerals, Obituary, Rocks, Zoology, and under each the titles of Articles referring thereto are mentioned.

Hydrosols, Bredig's silver, Blake, 431.
Lead, radio-active, Hofmann and Wölfl, 99.
Nitrogen, utilization of atmospheric, Frank, 388.
Potassium and barium nitrates, double salt of, Wallbridge, 331.
Radium, action of salts of, upon globulins, Hardy, 329.
— and helium, Ramsay, 329.
Salts, effect of water on chemical reactions, Perman, 467.
— double, investigations by physical means, Foote, 389.
Silver, allotropic, colors of, Blake, 282.
— colloidal, Hanriot, 100.
Sodium sulphate solutions, Marie and Marquis, 99.
Thiocyanates, on isomorphous triple, Blake, 12.
Ultra-violet light, action on rare earth oxides, Baskerville, 465.
Uranium, determination by zinc reductor, Pulman, 229.

Classen, A., Chemical analysis by electrolysis, 100: Ausgewählte Methoden der analytischen Chemie, 390.
Climate, polar, relation to evolution, Wieland, 401.
Coast Survey, United States, 1902 report, Tittman, 106.
Cohen, E., Meteoritenkunde, 336.
Cold Spring, L. I., monographs, 400.
Coral reefs, origin of, as shown by the Maldives, Gardiner, 203.
Coronas, constants of, Barus, 325.
Crapper, E. H., Electric and Magnetic Circuits, 393.
Crookes, W., Spinthariscope, 99.
Cuba, experimental garden in, Atkins, 105.

D

Daly, R. A., mechanics of igneous intrusion, 107.
Dielectric constants, heat of a change in connection with changes in, Speyers, 61.

E

Eakle, A. S., identity of palacheite and botryogen, 379.
Earthquake investigation committee publications, 335.
Eaton, G. F., characters of Pteranodon, 82.
Electric and Magnetic Circuits, Crapper, 393.
Electricity, discharge from hot platinum, Wilson, 392.
Emmons, S. F., contributions to Economic Geology, 101; Little Cottonwood granite of the Wasatch Mts., 139.

F

Fairchild, H. L., Elements of Geology, 396.
Fernando de Noronha, peak of, Branner, 442.
Fitzgerald, G. F., scientific writings of, Larmor, 106.
Fuller, M. L., Elkland-Tioga folio, Penna., 394.

G

Gardiner, J. S., origin of coral reefs as shown by the Maldives, 203; Maldive and Laccadive Archipelagoes, 400.
Geological map of New York State, Merrill, 102.

GEOLOGICAL REPORTS.

Canada, 395.
Maryland, Vol. IV, Clark, 104.
Nebraska, Vol. I, Barbour, 473.
New Jersey, 103.
South Africa, 474.
United States, 23 Annual Report, 332.
— Bulletins, Nos. 205–210, 185; No. 213, 101; Nos. 212, 214–216, 472.
— Folios, Nos. 87–91, 332; Nos. 92, 93, 394.
— Monographs, XLII–XLIV, 185.
— Professional papers, Nos. 1–10, 332; Nos. 13, 15, 472.
— Water supply and irrigation papers, Nos. 73, 75, 76, 101; Nos. 78, 79, 332; Nos. 81–84, 471.
Wisconsin, bulletins 9, 10, 267.

Geology, Elements of, LeConte and Fairchild, 396.
— Economic, contributions to, 1902, Emmons and Hayes, 101.

GEOLOGY.

Ascutney Mt., Vermont, geology, Daly, 267.
Baptanodon, Knight, 76.
Batrachian, from the Coal Measures of Joggins, N. S., Matthew, 185.

Climate, polar, relation to evolution, Wieland, 401.
Codonotheca, Sellards, 87.
Cretaceous, pseudoceratites of, Hyatt, 335.
Crinoids, biserial arm in certain, Grabau, 289.
Elkland-Tioga, and Gaines folios, New York and Penna., 394.
Eocene mammalia in the Marsh collection, studies, Wortman, 345.
Fauna of Stafford limestone, New York, Talbot, 148.
Faunas, correlation of geological, Williams, 334.
Fossil vertebrates, dates of publication of certain genera of, Bush, 96.
Hawaiian Islands, geology, Branner, 301.
Igneous intrusion, mechanics of, Daly, 107.
Lakes, ephemeral, in arid regions, Keyes, 377.
Monzoni and Fassa, geological structure, Gordon, 473.
Paleozoic faunas of New Jersey, Weller, 103.
Permian of Kansas, fossil insects in, Sellards, 323.
Plesiosaurs, North American, S. W. Williston, 473.
Pteranodon, Eaton, 82.
River terraces of Klamath region, California, Hershey, 240.
Romingeria, on the genus, Beecher, 1.
Silicic acid in mountain streams, Headden, 169.
Stafford limestone of New York, fauna of, Talbot, 148.
Gibbs, Josiah Willard, obituary notice, Bumstead, 187.
Glass, quartz, Heraeus, 469.
Grabau, A. W., biserial arm in certain crinoids, 289.
Green's mathematical papers, 392.

H

Hall, C. W., Geography of Minnesota, 104.
Harrington, B. J., formula of bornite, 151.
Hawaiian Islands, geology of, Branner, 301.
Hayes, C. W., Contributions to economic geology, 101.
Headden, W. P., silicic acid in mountain streams, 169.
Heat of combustion of hydrogen, Mixter, 214.
Hershey, O. H., river terraces of California, 240.
Hill, B. F., Texas mercury minerals, 251.
Holm, T., studies in the Cyperaceæ, XIX, 17; XX, 445; Triadenum virginicum (L.) Rafin., 369.
Hovey, E. O., new cone of Mt. Pelé, Martinique, 269.
Howe, E., tuffs of the Soufrière, St. Vincent, 317.
Hyatt, A., pseudoceratites of the Cretaceous, 335.

I

Igneous intrusions, mechanics of, Daly, 107.

K

Kansas, fossil insects in the Permian of, Sellards, 323.
Keyes, C. R., ephemeral lakes in arid regions, 377.
Knight, W. C., notes on the genus Baptanodon, 76.
Kunz, G. F., new lilac-colored spodumene, 264; Californite, 397; native bismuth and bismite, California, 398; production of precious stones in 1902, 399.

L

Lakes, ephemeral in arid regions, Keyes, 377.
Le Conte, J., Elements of Geology, 396.
Light Waves and their uses, Michelson, 331.

M

Maldive and Laccadive Archipelagoes, Gardiner, 400.
Maldives, origin of coral reefs as shown by, Gardiner, 203.
Marsh collection, studies of Eocene Mammalia in, Wortman, 345.
Martinique, new cone of Mt. Pelé, Hovey, 269; Branner, 442.
Maryland geological survey, vol. iv, Clark, 104.
Mathematical papers of George Green, 392.
Maxson, R. N., iodometric determination of gold, 155.
Merrill, F. J. H., New York State geologic map, 1901, 102.
Meteoritenkunde, Cohen, 336.

Meteorites, New South Wales, Liversidge, 336.
— Siemaschko collection bought by H. A. Ward, 335.
Michelson, A. A., light waves and their uses, 331.
Mineral Tables, Weisbach, 335.

MINERALS.

Anthophyllite, Mass., 339. Arsenic, native, Arizona, 336. Artinite, 185.
Bismite, California, 398. Bismuth, California, 398. Boothite, California, 186. Bornite, formula, 151. Botryogen, 379.
Californite, 397. Calomel, Texas, 253. Cerussite, Colorado, 343. Chrysocolla, Palmer, 45.
Eglestonite, Texas, 253.
Fayalite, Mass., 339.
Kunzite, 335, 474.
Montroydite, Texas, 259.
Palacheite, Californite, 186, 379. Phosgenite, Colorado, 343. Platinum in ore of Rambler mine, Wyo., 268.
Spodumene, new lilac-colored, California, 264, 335, 474.
Terlinguaite, Texas, 255. Thorium minerals, radioactivity, Barker, 161.
Vesuvianite, 397.

Minnesota, Geography, Hall, 104.
Mixter, W. G., heat of combustion of hydrogen, 214.
Monzoni and Fassa, geological structure, Gordon, 473.
Moses, A. J., new mercury minerals of Texas, 253.
Mt. Pelé, Martinique, new cone, Hovey, 269; Branner, 442.

N

National Bureau of Standards, Stratton, 106.
— Museum, U. S., 399.
Nebraska geol. survey, vol. 1, Barbour, 473.
Nebulosity around Nova Persei, cause of, Very, 49.
New Jersey geological survey, 103.
New York State geological map, 1901, Merrill, 102.
— Museum, 102.
Nova Persei, cause of nebulosity around, Very, 49.

O

OBITUARY.

Bolton, H. C., 475.
Gibbs, J. W., 187.
Knight, W. C., 268.
Lesley, J. P., 106.
Renard, M., 268.
Smith, H. L., 268.
Thurston, R. H., 475.

Ostwald's Klassiker der Exakten Wissenschaften, 336.

P

Palmer, C. M., hydration of chrysocolla, 45.
Physico-Chemical Review, 475.
Precious stones, production of in 1902, Kunz, 399.
Pulman, O. S., determination of uranium by zinc reductor, 229.

R

Radiation from the earth's surface, penetrating, Cooke, 392.
Radio-active gas in surface water, Bumstead and Wheeler, 328.
— lead, Hofmann and Wölfl, 99.
Radio-activity of thorium minerals, Barker, 161.
Radium, see CHEMISTRY.
Read, T. T., rare metals from Rambler mine, Wyoming, 268.
Reynolds, O., Sub-Mechanics of the Universe, 331.

ROCKS.

Granite, Little Cottonwood of the Wasatch Mts., Emmons, 139.
Igneous rocks, chemical analyses, Washington, 396.
— — mechanics of intrusion, Daly, 107.
Plumasite, California, 105.
Tuffs of the Soufrière, St. Vincent, Howe, 317.

S

Sellards, E. H., Codonotheca, 87; fossil insects in the Permian of Kansas, 323.
Sharpe, R. B., Hand-list of Birds, 400.
Smithsonian Institution, Report for 1902, 475.
Solar radiations, penetrative, Blondlot, 390,
Soufrière, St. Vincent, tuffs of, Howe, 317.

Speyers, C. L., heat of a change and changes in dielectric constants, 61.
Spinthariscope, Crookes, 99.
St. Vincent, tuffs of Soufrière, Howe, 317.
Stellar revolutions within the Galaxy, Very, 127.

T

Talbot, M., fauna of Stafford limestone of New York, 148.
Texas, mercury minerals of, Hill, 251; Moses, 253.
Thorium activity, induced, 470.

U

Ultra-Violet light, action upon rare earth oxides, Baskerville, 465.
— rays, absorption by ozone, Meyer, 470.
United States—See Geological Reports; also Coast Survey and National Museum.
Universe, Sub-mechanics of, Reynolds, 331.

V

Van't Hoff, J. H., Physical Chemistry, 390.
Very, F. W., cause of nebulosity around Nova Persei, 49; stellar revolutions within the galaxy, 127.

W

Warren, C. H., mineralogical notes, 337.
Washington, H. S., Chemical analyses of igneous rocks, 396.
Wasatch Mts, Little Cottonwood granite, Emmons, 139.
Weisbach, Tabellen, 335.
Weller, S., Paleozoic faunas of New Jersey, 103.
Wheeler, L. P., radio-active gas in surface water, 328.
Wieland, G. R., polar climate in time in relation to evolution, 401.
Williams, H. S., correlation of geological faunas, 334; shifting of faunas, 334.
Williston, S. W., North American Plesiosaurs, 473.
Wisconsin geological survey, 267.
Wolfrum, A., Chemisches Praktikum, 101.
Wortman, J. L., studies of Eocene mammalia in the Marsh collection, 345.

Z

ZOOLOGY.

Catalogue of Birds' Eggs, British Museum, 400.
Hand-list of Birds, Sharpe, 400.

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(Thesis presented before the Faculty of Sciences, Paris, June, 1903.)

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7	Autunite	19	" "
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9	"	21	Tantalite
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