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CONTENTS TO VOLUME XXI.

Number 121.

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics.—The Hydrides of the Alkaline Metals, MOISSAN, 77.— The Boiling-points of the Alkaline Metals, RUFF and JOHANNSEN : The Rusting of Iron, DUNSTAN, JOWETT and GOULDING : The Cause of Color in the Iron-Cyanogen Compounds, HOFMANN and RESENSCHECK, 78.—Researches on the Affinities and on the Causes of the Chemical Similarity or Dissimilarity of Elements and Compounds, GEOFFREY MARTIN : Verflüssigtes Ammoniak als Lösungsmittel, J. BRONN, 79.—Annual Reports of the Progress of Chemistry for 1904 : A New Kind of X-Ray, W. SEITZ : Magnetizing by Rapidly Oscillating Currents, MADELUNG : Influence of the Earth in Wireless Telegraphy, J. S. SACHS, 80.—Elektrische Kraftübertragung, WILHELM PHILIPPI, 81.

Geology and Natural History.—United States Geological Survey, 81.— Geology of the Central Copper River Region, Alaska, WALTER C. MENDENHALL, 82.—Geology of the Tonopah Mining District, Nevada, JOSIAH EDWARD SPURR, 83.—The Lead, Zinc and Fluorspar Deposits of Western Kentucky, E. O. ULRICH and W. S. TANGIER SMITH, 84.—Die chemische Beschaffenheit von Eruptivgesteinen Finnlands und der Halbinsel Kola im Lichte des neuen amerikanischen Systemes, V. HACKMAN : Preliminary Announcement Concerning a New Mercury Mineral from Terlingua, Texas, W. F. HILLEBRAND, 85.—The Rodeo Meteorite, FARRINGTON : The Shelburne Meteorite, L. H. BORGSTRÖM, 86.—Bulletins of the New York State Museum : Bibliographical Index of North American Fungi, WILLIAM G. FARLOW, 87.—The Oyster, a Popular Summary of a Scientific Study, WILLIAM K. BROOKS, 88.

Number 122.

SCIENTIFIC INTELLIGENCE.

Number 123.

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics—Silicon-fluoroform, RUFF and ALBERT : Decomposition of Ammonium Sulphate by Hot Sulphuric Acid in the Presence of Platinum, DELÉPINE, 247.—Determination of Tellurous and Telluric Acids, BERG : Manganese as a Fertilizer for Plants, BERTRAND : Conversations on Chemistry, W. OSTWALD, 248.— Experimental Electro-Chemistry, N. M. HOPKINS : Radiation from Ordinary Materials, N. B. CAMPBELL : Spark Potentials, M. TOEPLER, 249.—Measures of Radiation in relation to Resonators in the Region of Short Electric Waves, M. PAETZOLD : Electrical Rectifier, A. WEHNELT, 250.

Geology and Mineralogy—United States Geological Survey, C. D. WALCOTT, 250.—U. S. Geological Survey; Recent Publications, 251.—Triassic Cephalopod Genera of America, A. HYATT and J. P. SMITH : Miocene Foraminifera from the Monterey Shale of California, R. M, BAGG, Jr. : North Carolina Geological Survey, J. H. PRATT and J. V. LEWIS, 253.—Cancrinite-Syenite from Kuolajärvi, I. G. SUNDELL : Opal Pseudomorphs from White Cliffs, New South Wales, C. ANDERSON and H. S. JEVONS, 254.— Physical Geography, Geology, Mineralogy and Paleontology of Essex County, Massachusetts, J. H. SEARS : Lead and Zinc Deposits of Virginia, T. L. WATSON : Asbestos : its Occurrence, Exploitation, and Uses, F. CIRKEL, 255.—Cobalt-Nickel Arsenides and Silver Deposits of Temiskaming, W. G. MILLER : Economic Geology of the United States, H. RIES, 256. —Handbuch der Mineralogie, C. HINTZE, 257.

Miscellaneous Scientific Intelligence—Scientific Results of the Expedition to the Eastern Tropical Pacific, 257.—Carnegie Institution of Washington, 258.—Report of Secretary of the Smithsonian Institution, S. P. LANGLEY : Superintendent of the Coast and Geodetic Survey, O. H. TITTMANN, 259.— Publications of the United States Naval Observatory, C. M. CHESTER : Bureau of American Ethnology: Bulletins of the United States National Museum : Mazama : A Record of Mountaineering in the Pacific Northwest : Elementary Mechanics, G. A. MERRILL, 260.

CONTENTS.

Number 124.

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics—Determination of Sulphur in Pyrites, Hintz and Weber, 324.—Determination of Grape Sugar: Boiling of Metals of the Platinum Group, Moissan, 325.—Rapid Preparation of Hydriodic Acid, Bodroux: Radio-activity of Polonium, Curie: Electrochemical Equivalent of Silver, G. van Dijk: Electrolytic Coherer, Gundry, 326.—Ionization by Röntgen and Cathode Rays, J. Herweg, 327.—Modern Theory of Physical Phenomena: La Théorie Moderne des Phénomènes Physique, A. Righi, 328.

Geology and Mineralogy—Red Beds of Southwestern Colorado and their Correlation, W. Cross and E. Howe, 328.—Annales de Paléontologie, 329. —Arthrophycus and Dædalus of Burrow Origin, and Preliminary Note on the Nature of Taonurus, C. J. Sarle: Echinoderma, F. A. Bather: Osteology of Champsosaurus Cope, B. Brown, 330.—Maryland Geological Survey, Vol. V, 1905, W. B. Clark: Les Tremblements de Terre; Géographie Séismologique, F. de M. de Ballore, 331.—Copper Deposits of the Clifton-Morenci District, Arizona, W. Lindgren, 332.

Miscellaneous Scientific Intelligence—Contribution to the Oceanography of the Pacific, J. M. Flint, 333.—Microscopy of Vegetable Foods, A. L. Winton, 335.—Philippine Journal of Science, P. C. Freer: Guide to the Invertebrates of the Synoptic Collection in the Boston Society of Natural History, J. M. Arms Sheldon, 336.—Monograph of the Isopods of North America; Bulletin of the U. S. National Museum, No. 54, H. Richardson: Account of the Crustacea of Norway, G. O. Sars: Birds of the Southern Lesser Antilles, A. H. Clark: Additions to the Avifauna of Dominica, A. H. Verrill: Beiträge zur chemischen Physiologie, F. Hofmeister, 337. —Life and Matter; An Answer to Haeckel's "Riddle of the Universe," O. Lodge: Joseph Leidy Memorial: Memorial to Prof. Ernest Abbe, 338.

Number 125.

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics—Carbon Suboxide, DIELS and WOLF : New Method for the Quantitative Determination of Halogens in Organic Compounds, VAUBEL and SCHEUER, 396 —Distillation of Metals of the Iron Group, MOISSAN : Atomic Weight of Radium, H. C. JONES, 397.—Mechanical Separation of Organic Substances, BORDAS and TOUPLAIN : Constitution of the Electron, W. KAUFMANN, 398.—Retardation of the Velocity of the *a* Particles in passing through Matter, RUTHERFORD : Electrical Conductivity of Flames containing Salt Vapors for alternating currents, WILSON and GOLD : Electrically prepared Colloidal Solutions, BURTON : Recombination of Ions in Air and other Gases, BRAGG and KLEEMAN, 399.—Nucleation of the Atmosphere, 400.

Geology and Mineralogy—Geology, CHAMBERLIN and SALISBURY, 400.—Traité de Géologie, A. DE LAPPARENT, 401.—Coon Butte, Arizona, and the Canyon Diablo Meteorites, BARRINGER and TILGHMAN, 402.—Geology of the New Hebrides, MAWSON, 403.—Salient Geological Features of British New Guinea, MAITLAND : Geological Survey of Canada, 404.—Mica : its Occurrence, Exploitation and Uses, F. CIRKEL : Beiträge zur Mineralogie von Japan : Studies in Fluorite, H. W. MORSE, 405.—International Geological Congress, 406.

Miscellaneous Scientific Intelligence—National Academy of Sciences : Franklin Bi-Centenary, 406.—Chemistry of the Proteids, G. MANN : Wilhelm Fliess und Seine Nachentdecker, O. Weininger und H. Swoboda, R. PFENNIG : Lagoon of Venice, 407.—The Philippine Journal of Science : Field Columbian Museum, 408.

Obituary—JAMES MILLS PEIRCE, NATHANIEL S. SHALER, M. P. CURIE, LIONEL SMITH BEALE.

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ART. I.—*The Heating Effects produced by Röntgen Rays in Different Metals, and their Relation to the Question of Changes in the Atom;* by H. A. BUMSTEAD.

THE study of the phenomena of radio-activity during the past five or six years, and, in particular, the brilliant series of experiments and deductions which we owe to Rutherford, have left little room for doubt that a certain proportion of the atoms of radio-active elements are continually breaking up, and that the constant emission of energy by these bodies is a result of this atomic disintegration. This process in any given radio-active body appears to be going on at a fixed and definite rate which is characteristic of the particular substance studied and which is quite uninfluenced by any external circumstances whatever. Although radio-active substances have been subjected to the greatest extremes of temperature available in the laboratory, and to great variations in other physical and chemical conditions, no certain results have been obtained (so far as the writer is aware) which point to any corresponding change in the rate of decay of the substance. In fact the process of atomic disintegration has appeared to be quite beyond human control.*

On the other hand, all substances when illuminated with Röntgen rays, or with Becquerel rays of the γ-type, give out a complex secondary radiation, part of which at least is wholly different in character from the primary radiation. For example, the secondary radiation due to Röntgen rays consists in part of negatively charged corpuscles or electrons which are not present in primary rays. This suggests that there may be some

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* The apparent change (due to high temperature) in the rate of decay of radium-excited activity, discovered by Curie and Danne, has been shown to be due to the fact that the successive products of radium volatilized at different temperatures. Cf. Bronson, this Journal, July 1905.

1

breaking up of the atom of the secondary radiator; but it is only a suggestion, for it by no means follows that the presence of β-rays involves atomic disintegration. The modern theories of electrical conduction imply the existence in conductors (and all bodies are conductors to a greater or less extent) of large numbers of corpuscles not closely bound up in the atomic structure; and it is quite conceivable that some of these may constitute the secondary β-rays, the necessary energy having been, in some way, imparted to them by the primary radiation. The most direct way of descriminating between these two possibilities is to investigate the energy relations when, for example, Röntgen rays are absorbed by matter. If none of the atoms are broken up, then the conservation of energy, in the ordinary sense, will hold; if, on the other hand, some of the atoms are exploded by the Röntgen rays, as dynamite is exploded by a shock, then the total energy after the absorption of the rays may be considerably greater than the energy of the rays themselves. This excess of energy might be expected to manifest itself mainly in the form of heat in the absorbing body; for it is known that a large fraction of the secondary Röntgen rays are very easily absorbed indeed;* and Sagnac found that tertiary rays were more easily absorbed than secondary rays.† Thus only the secondary rays which are produced very near the surface of the absorber would carry their energy away with them; those which are set up thoughout the mass of the body would be absorbed before reaching the surface, and eventually would warm the absorber.

Assuming for the moment that Röntgen rays are able to cause atoms to break up, it is very improbable that the atoms of different substances are equally susceptible to this effect; and we should expect to find an inequality in the amount of heat produced when Röntgen rays are equally absorbed in different substances. If, on the contrary, there is no atomic disintegration, the quantities of heat should be equal. It was from this point of view that the problem was proposed to me by Professor J. J. Thomson, during my stay in Cambridge last year, and the experiments which I am about to describe were carried out in the Cavendish Laboratory under his direction, and owe much to his advice and coöperation.

In considering the various experimental means by which this problem could be attacked, the radiometer seemed to promise certain advantages over other heat-measuring instruments. For measuring ordinary radiation with this instrument (the development of which is chiefly due to E. F. Nichols) the usual method is to have opaque vanes with a transparent wall near

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* J. J. Thomson: The Conduction of Electricity through Gases, p. 263.
† Ibid. p. 273.

them upon one side; when one of the vanes is illuminated, it is heated, and the molecular reaction causes it to be repelled from the neighboring wall. But it is quite possible to reverse this procedure and have the wall opaque and the vanes transparent, and, although the attainable sensitiveness is probably less than in the other case, it has obvious advantages when one is dealing with Röntgen rays instead of ordinary light. The walls can be made of the metals under investigation, and of suitable thickness to absorb a considerable fraction of the rays incident upon them; while the vanes may be made very transparent to the rays and be thus far less in the way, and be less heated by the rays (independently of the heating of the substances under examination) than would be possible with the thermopile or bolometer. In the construction of the radiometer and its gradual adaptation to the present purpose, I was particularly fortunate in having the advice and assistance of Professor E. F. Nichols, who was also in Cambridge, and who most kindly put at my disposal the results of his long experience with the radiometer. I wish here to express my thanks to him for a much shorter period of apprenticeship to the instrument than would have been possible without his help.

Apparatus.

The radiometer and its adjuncts passed through many preliminary and tentative forms before a satisfactory arrangement was obtained. The final form, which proved fairly sensitive and manageable, is here described.

The vanes were made of aluminium foil which weighed about 1^{mg} per sq. centimeter. Each vane measured 8×10 millimeters with its greatest dimension vertical, and the two pieces of foil were stretched between two very thin horizontal rods of glass at top and bottom, which in turn were kept at the proper distance apart by their attachments to the central rod of the suspended system. The inner edges of the vanes were 4^{mm} apart. The various joints were made by very small drops of alcoholic shellac, which were baked on with a hot glass rod. The system was put together on a flat brass table and, after a few trials, it was not difficult to get one in which the aluminium vanes were very fairly smooth, plane, and parallel to the central rod. The mirror, for use with telescope and scale, was attached to the central rod 3^{cm} above the middle of the vanes; it was usually about 5^{mm} square and was made of specially selected microscope cover glass. All the mirrors used gave very satisfactory definition. In the final system the weight of the mirror was 13 milligrams, that of the rest of the suspended system 5 milligrams; the moment of inertia was

approximately 0·002 grm. cm². The two aluminium vanes were electrically connected by means of a bit of light phosphor-bronze strip. The other details of the suspension are shown
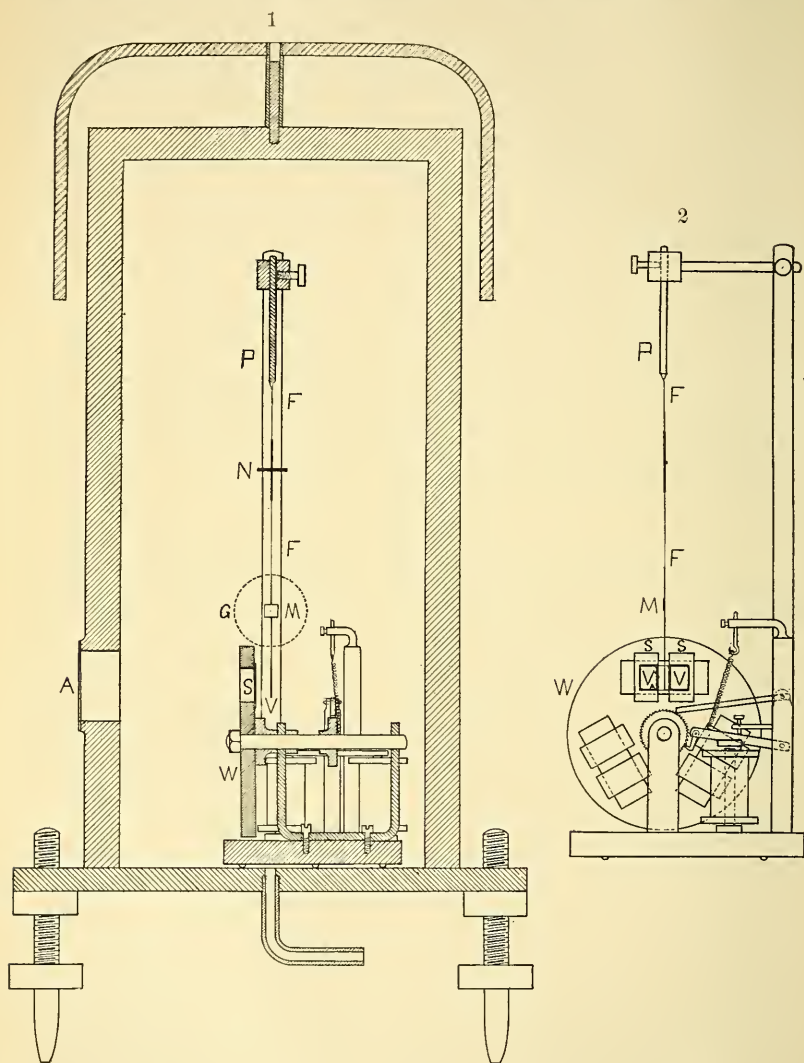
in figs. 1 and 2. The working quartzfiber, F, is 3^{cm} long, and is suspended from a glass rod carrying a small magnetic needle, N : as this, in turn, is suspended by a second fiber, F′, it may be caused to rotate by means of the bent magnet out-

side the case ; it thus serves as a sort of torsion head for controlling the zero of the radiometer. This very elegant device is borrowed from the work of Nichols and Hull on the pressure of radiation.

The metals whose heating effects were to be compared were mounted upon an ebonite disc (W, figs. 1 and 2) 6^{mm} thick and $7\cdot8^{cm}$ in diameter. Three rectangular holes, $3\cdot6 \times 1\cdot4^{cm}$, were cut in this disc, at an angular distance from each other of 120°. Across these holes strips of the metals under investigation were fastened with a little soft wax; the strips were 2^{cm} long and $\cdot1^{cm}$ wide and their inner edges were 4^{mm} apart. Up to the present, I have had time to compare only two metals, lead and zinc. The lead strips were $0\cdot30^{mm}$ thick and the zinc strips $0\cdot82^{mm}$, these thicknesses being chosen because they gave nearly the same absorption of the Röntgen rays used, as will appear later. The thinner lead strips were blocked up from the wheel on small bits of card, so that the surface of lead and zinc toward the radiometer vanes were in the same plane. The arrangement of the metal strips on the ebonite disc was as follows : across one of the rectangular openings two lead strips were placed ; this was for testing the balance of the radiometer when both vanes were influenced by the same metal ; across the second opening a lead and a zinc strip were placed side by side, while the third opening also contained a lead and a zinc strip but in reversed order. The shaft which carried the ebonite disc was provided with a ratchet wheel with sixty teeth ; and the disc could be rotated from one position to another by an electromagnet inside the radiometer case. The current for this purpose was led in by means of wires passing through small glass tubes sealed with sealing-wax, into holes in the base-plate of the instrument. Certain marks on the edge of the ebonite disc which could be seen through the observing window enabled one to be sure that the disc was in proper position in any given case. All the metal strips, before being mounted on the disc, were covered on both sides with leaf aluminium, which was held by the thinnest possible layer of soft wax, put on when the metal was hot. This was to give both metals the same surface, so that the loss of heat from the surface for a given rise in temperature might be the same in both cases. The ebonite disc was also covered with aluminium leaf to avoid electrostatic effects ; to the same end a small quantity of an impure radium salt was put inside the case in a small open dish. All the metal strips were connected to the shaft of the wheel by thin copper wires ; the shaft in turn was connected to the case and to earth.

The portions of the apparatus hitherto described stood upon a brass base-plate turned flat and smooth, which rested on

three levelling screws. Through this plate passed the tube which led to the P_2O_5 bulb, pump, and McLeod gauge. The whole was covered with a heavy, cylindrical, brass casting, 12.5^{cm} in internal diameter, 29^{cm} high, and with walls 1.4^{cm} thick. This heavy metal case was found to be necessary owing to the sensitiveness of the radiometer to thermal disturbances; with a blackened glass bell-jar, which was first tried, the zero was so unsteady that nothing could be done with the instrument. As a further protection against thermal disturbance, the cover and base were surrounded with cotton-wool and a felt jacket drawn over the whole. The case was provided with two windows, 2.9^{cm} in diameter; one of these (A, fig. 1) was covered with sheet aluminium 1.2^{mm} thick and served to admit the beam of Röntgen rays; the other was of glass for observing the deflections. Both were put on with sealing wax and the joints covered with soft wax. The inside of the cover was painted with lampblack in alcohol, with a little shellac to make it stick. The bottom of the cover was turned flat, and the joint between it and the brass plate was surrounded by a mixture of equal parts by weight of vaseline, paraffin and rubber, which, after being put on, was glazed over with a small gas flame. When all the joints were carefully made, little difficulty was experienced in maintaining the vacuum for considerable periods; the rise in pressure due to leakage was usually less than 0.002^{mm} per day.

In the preliminary experiments for testing the working conditions of the radiometer, the ebonite wheel and its metal strips were replaced by a light ebonite frame which carried two strips of platinum foil (one opposite each vane), through either of which a known current could be sent. By this means one could readily find the pressure of maximum sensitiveness, and compare different quartz fibers and different forms of the suspended system. The best pressure appeared to be between 0.03 and 0.08^{mm}, and within this region the variation of sensitiveness with pressure was slow; in the subsequent work a pressure between these two limits was usually employed. From a knowledge of the resistance of the platinum strips and of the current employed, it appeared that a deflection of one millimeter (scale distance, 196^{cm}) corresponded to an emission of about 0.04 ergs per second from each square centimeter of platinum surface. The deflections were also found to be proportional to the energy generated in the strips. Of course the radiometer action depends primarily on the temperature of the surface, and with a surface of different emissivity, the deflection for a given emission of energy will be different.

The Röntgen bulb finally employed was a very large one made by Müller and obtained from Isenthal & Co. The diam-

eter of its spherical portion was 17^{cm} and the electrodes were big enough to bear a very heavy discharge. The anti-cathode was sealed into the bottom of the water tube so that it was in direct contact with the water, and I have frequently caused the water in the tube to boil without seriously heating the rest of the tube. It was provided with an automatic vacuum adjuster which worked well; the focus was sharp and the Röntgen rays obtained were very powerful and fairly steady in intensity and "hardness." The bulb was driven by an 18-inch Apps coil and a rotating mercury-jet interrupter. The coil was in an adjoining room and about 6 meters from the radiometer; its orientation was adjusted so that it produced very little effect upon the magnetic "torsion head" of the instrument—less than 4^{mm} with the largest currents used; this was always in one direction and could be applied as a correction. The secondary leads were gutta-percha covered and supported by silk ribbons; where they passed from one room to the other, through the wooden frame over a door, they were enclosed in long glass tubes. As the rays used were not very hard, there was little difficulty with the insulation, though there was often a good deal of brush discharge from the leads. The earthed metallic case of the radiometer protected it completely from any electrostatic disturbance. A lead screen, 2^{mm} thick, which hung by a quadrifilar suspension from the ceiling about 2^{cm} in front of the aluminium window, permitted both strips to be exposed to the Röntgen rays, or both screened, or either exposed while the other was screened. A large cardboard screen was kept between the Röntgen bulb and the radiometer to diminish the effects upon the instrument due to the heating of the bulb.

Measurements of the absorption of the lead and zinc were carried on simultaneously with the radiometer observations. For this purpose an electroscope was set up 270^{cm} from the bulb; it had an aluminium window 2^{cm} in diameter and the remainder was covered with sheet lead 2^{mm} thick. As this did not sufficiently protect it from the rays, a lead wall was built up of blocks two inches thick between the electroscope and bulb, with a hole opposite the window; this gave satisfactory protection, when the window was screened. Observations were made with a micrometer microscope and stop-watch in the usual manner.

Experiments.

The experimental method was based upon the following considerations: the Röntgen rays absorbed in the strips will generate heat throughout the mass of the metals and a steady state of temperature will be reached when the heat generated

per second is equal to the heat lost per second through the two surfaces by radiation and convection. (The possibility of any appreciable loss by conduction through the ebonite support of the strips will be considered later.) The heat lost through any surface is proportional to its emissivity and, for such small temperature differences, to its excess of temperature above its surroundings. The lead and zinc strips had the same surface— aluminium leaf—and it is natural to assume that the emissivity is the same in both cases; this assumption, however, will be justified experimentally. Moreover, it will appear from theoretical considerations that, in the steady state, the difference in temperature between the front and back surfaces of either metal is a small fraction of the excess of its temperature above its surroundings; and this too will be confirmed experimentally. It follows therefore, that, very approximately, half the heat generated in either strip is lost through each of its two surfaces, and that the total heat generated per second will be proportional to the temperature of either surface in the steady state, and hence to the repulsion of the radiometer vane exposed to that surface.

The first step in a series of experiments was to test the balance of the radiometer by exposing the two lead strips simultaneously to the Röntgen rays. The balance was usually found to be fairly good and could be to some extent adjusted by moving the bulb horizontally before the window; the stand carrying the bulb could be moved by a horizontal screw for this purpose. In two of the series of experiments (quoted below) it was found impossible to get a good balance by moving the bulb; in these cases the lack of balance was determined and applied as a correction. The wheel was then clicked round to the second position, in which one vane of the radiometer was opposite to a lead strip and the other opposite to a zinc strip. This was a somewhat delicate operation, as each click caused a violent disturbance of the radiometer (partly magnetic and partly thermal) and it was necessary to get it under control by means of a subsidiary magnet before making another click; otherwise the vanes might have become entangled in the moving wheel and the suspension broken. After the shift from one position to another, several hours had to elapse before the radiometer was again fit for use. Several exposures to Röntgen rays were then made in which the zinc and lead strips were exposed separately and both together. The wheel was then moved to the third position, in which the zinc and lead strips were in reversed order, and similar observations taken. It may be said at once that the reversed position of the lead and zinc did not alter the character of the results.

The general nature of the results may be most readily set

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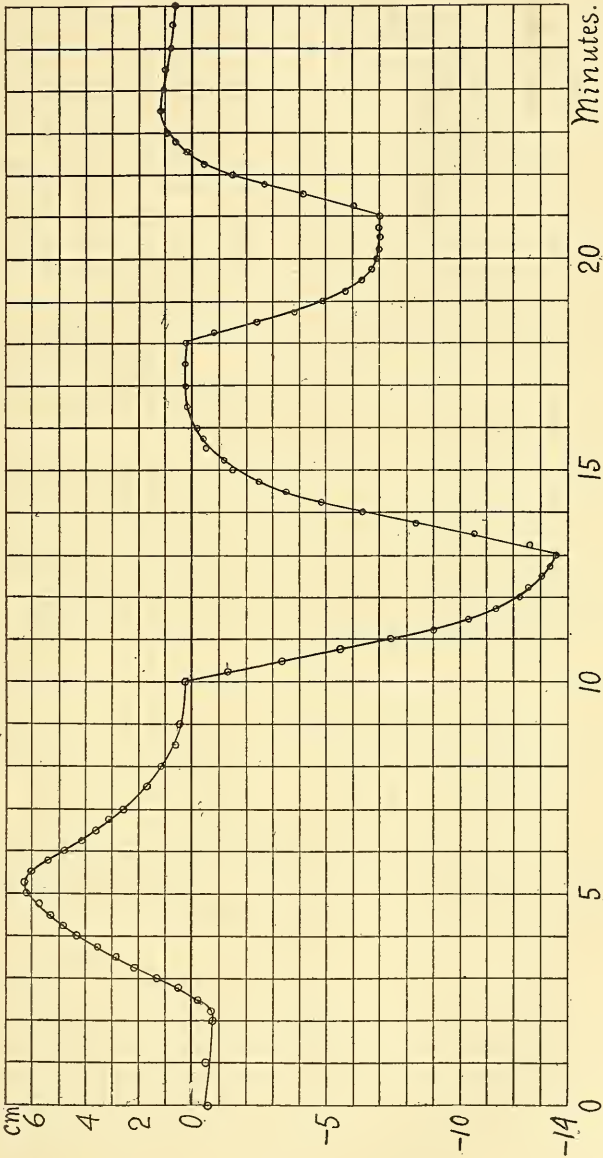
forth by considering a particular experiment as an example. In fig. 3 the results of this experiment are shown graphically;

the abscissæ represent time in minutes, the ordinates deflections of the radiometer in centimeters on the scale; the position of the wheel was such that a positive deflection means a repulsion by the zinc of its vane, a negative deflection a repulsion by the lead of its vane.   Between 2^m and 5^m, the zinc strip was exposed to the rays; the rays were then cut off and the zinc allowed to cool for 5 minutes (5^m–10^m), the lead was then exposed for 3 minutes (10^m–13^m); it, in turn, was allowed to cool for 5 minutes (13^m–18^m) and then both strips exposed simultaneously for 3 minutes (18^m–21^m) after which the rays were again cut off.   It is plain from the figure that neither metal was exposed long enough to the rays for the steady state to be attained; but it is also plain that the great preponderance of the lead over the zinc is not due to this cause.   In fact we may from these curves get an approximate idea of what the steady deflections would have been if it had been safe to continue running the bulb at the rate necessary for such large deflections.

If λ is the coefficient of absorption of the metal for the rays used, then the energy of the rays at any point in the interior of the strip whose distance is x from the front face is $I_o e^{-\lambda x}$ and the energy absorbed in an element of thickness, dx, is $\lambda I_o e^{-\lambda x} dx$. Let us assume that the heat generated in the element is proportional to this, say $a\lambda I_o e^{-\lambda x} dx$.   The equation of the flow of heat under these circumstances is:

$$c\frac{d\,V}{dt} = k\frac{d^2 V}{dx^2} + a\lambda I_o e^{-\lambda x},$$

with the boundary conditions

$$k\left(\frac{d\,V}{dx}\right)_{x=o} = h V_o\,;\quad -k\left(\frac{d\,V}{dx}\right)_{x=l} = h V_l$$

where V is the temperature (measured above the surroundings), t the time, c the specific heat of unit volume, k the conductivity, h the emissivity of the surface, and l the thickness of the strip.   The solution of this will have the form

$$V = V_\infty - \Sigma A e^{-\gamma t}$$

where V_∞ is the steady value and is the solution of the differential equation with the left hand member put equal to zero; the successive values of γ in the sum are determined by a certain transcendental equation, and the A's are functions of x into which γ enters.   What is observed is the temperature of the surface where $x=l$.   The variation of this temperature with the time is represented fairly well (except at the very beginning) by a single term of the series of exponentials so that we may write as a rough approximation

$$V = V_\infty (1 - e^{-\gamma t}).$$

The variation of the temperature with the time during cooling will have different values of the A's and γ's, but (again excepting the initial part) the curves of heating and cooling will have very nearly the same form. This is seen in the figure, and it also appears mathematically that with the values of the conductivity and emissivity involved, there is a nearly uniform temperature throughout the metal within less than a minute after the rays are turned on. We may therefore, for such

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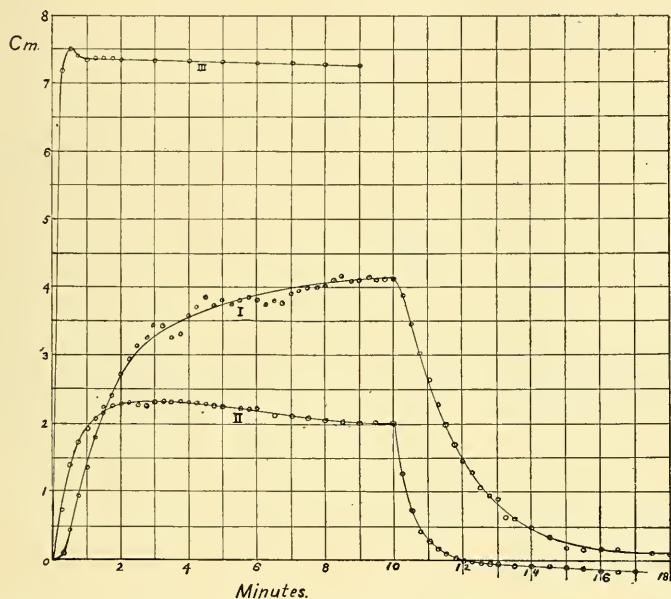
accuracy as is needed in this discussion take the curve of cooling to be represented by

$$V = V_o e^{-\gamma t},$$

the time being counted from the moment the rays are cut off. In this equation

$$\gamma = -\frac{1}{V}\frac{dV}{dt},$$

and one may get rough values of γ for lead and for zinc by drawing tangents to the curves of cooling. In the following tables are several values found for different points of the curves in fig. 3; the zero for the zinc curve was taken as the mean of the position at 2^m and 10^m and, for lead, the mean of 10^m and 18^m.

	Zinc				Lead		
V	$\dfrac{dV}{dt}$	γ		V	$\dfrac{dV}{dt}$	γ	
3·0	1·8	0·6		6·0	6·2	1·0	
2·0	1·6	0·8		3·0	4·0	1·3	
1·5	1·05	0·7		1·5	2·5	1·7	
0·8	0·50	0·6		0·8	1·3	1 6	
	Average	0·68			Average	1·4	

In order to determine the steady value from the value at the end of three minutes we have

$$V_\infty = \frac{V}{1 - e^{-\gamma t}}$$

which gives, for lead $V_\infty = 13.95$, and for zinc $V_\infty = 7.4$.

Approximately the same rates of cooling and heating were obtained in all the experiments made upon this point. A second example is given in figure 4, in which weaker rays were used for ten minutes instead of three. Curve I is for zinc, curve II for lead; the two experiments were made at different times and with rays of different intensity, so that the *magnitudes* of the deflection have nothing to do with each other. To show that the inertia and damping of the suspended system have no sensible effect upon the determination of the rates of heating and cooling, curve III is added for comparison. This was obtained by suddenly moving the controlling magnet at the time $t = 0$; it represents the response of the suspension to a sudden impulse. The following values for γ for zinc and lead were obtained from the cooling portions of these curves:

	Zinc				Lead		
V	$\dfrac{dV}{dt}$	γ		V	$\dfrac{dV}{dt}$	γ	
2·0	1·2	0·6		1·0	1·5	1·5	
1·0	0·58	0·58		0·5	0·8	1·6	
0·5	0·38	0·76		0·3	0·48	1·6	
	Average	0·65			Average	1·6	

Later in the course of the experiments, the aluminium window was replaced by a one of glass and the strips heated by means of a beam of light; the result of such an experiment is shown in fig. 5 below. The following values of γ are obtained in the same manner from these curves:

	Zinc				Lead		
V	$\dfrac{dV}{dt}$	γ		V	$\dfrac{dV}{}$	γ	
4·0	2·15	0·54		4·0	5·2	1·3	
2·0	1·22	0·61		2·0	2·6	1·3	
1·0	0·57	0·57		1·0	1·1	1·1	
	Average	0 57			Average	1·23	

It will be seen that the agreement is as good as could be expected from the very rough nature of the determinations.

Returning now to the experiment plotted in fig. 3 it is to be observed that the steady deflection for lead is nearly twice as great as that for zinc. The fractions of the incident rays absorbed by the two strips were determined by means of the electroscope with the pieces of metal from which the strips had been cut; the pieces of lead and zinc were placed behind a sheet of aluminium of the same thickness as the window of the radiometer. It was found that the lead absorbed 79 per cent and the zinc 78 per cent of the rays which got through the aluminium; in this particular case the spark gap in the automatic adjuster of the Röntgen bulb was $7 \cdot 5^{cm}$ long.

Thus (unless there has been some error in the experimental method or in the interpretation of the result) it appears that for practically equal absorptions of Röntgen rays in lead and in zinc, about twice as much energy is generated in the lead as in the zinc. It may be said at once that essentially the same result was obtained in all the experiments, with rays of different hardness, with both positions of the strips and with the radiometer vanes sometimes between the window and the strips, as well as in the position indicated in fig. 1. Before giving, however, the numerical results of all the experiments, it will, I think, be conducive to clearness to consider the possible sources of error (so far as they have occurred to me) and their influence upon the results.

Possible Sources of Error.

1. After it had been found that the lead strips predominated, and before the rates of heating and cooling of the strips had been worked out, an effect was observed which caused considerable perplexity. The slight drift of the zero-point due to the warming up of the room after the observer entered was found to be always in the direction indicating a repulsion from the lead; its direction reversed with the reversal of the order of the strips. As the aluminium window was the only part much exposed to changes of temperature, the effect of slightly warming it was investigated. When an incandescent lamp, or a warm soldering iron, was held six inches from the aluminium window, the radiometer was deflected away from the lead strip—at first slowly, then more and more rapidly until it went off the scale and usually bumped against the zinc strip. As this was in the same direction as the effect when both strips were exposed to the Röntgen rays, it appeared that the whole effect might be spurious. By putting the lamp about two feet away from the window, less violent effects were produced, and it was possible to follow the progress of the

deflection. This was sluggish in comparison with that produced by the rays, and (as might have been expected from varying air currents in the room) was irregular and somewhat erratic in its course. In one respect, however, the behavior was consistent; if the lamp was left glowing for one or two hours, the radiometer always returned to the neighborhood of its zero-point and staid there until the lamp was turned off. It then made another slow and wandering excursion in the

5
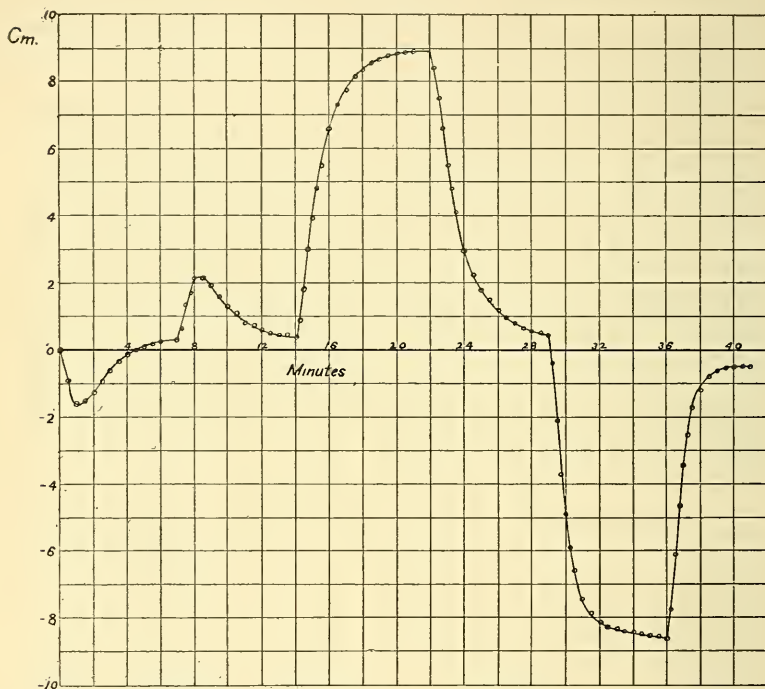
opposite direction (repulsion by zinc) and eventually again returned to the middle of the scale. The application of ice to the aluminium window also caused repulsion by the zinc.

The determination of the different rates of heating and cooling of the two strips furnished the explanation of this behavior. While the window and adjacent parts of the case are slowly warming up, they radiate to the two strips more and more, and cause the temperatures of the latter to rise steadily; but the lead having a smaller time-constant than the zinc, has the higher temperature and maintains it until the amount of radiation reaching the strips no longer varies with the time—

that is until the window has reached its stationary temperature. When this takes place the zinc has time to overtake the lead, both temperatures become the same, and the radiometer returns to zero. When the lamp is turned off and the window begins to cool, the lead cools more rapidly than the zinc and hence there is a similar deflection in the opposite direction which again lasts only so long as the temperature of the window is variable.

Although this explanation is reasonable and, in fact, inevitable, the matter here discussed touches so vitally the main conclusion of this investigation that it was desirable to test in a decisive manner the behavior of the instrument when the strips were heated by ordinary radiation. For this purpose, a glass window was substituted for the one of aluminium and (everything else being left exactly as before) a beam of light was admitted from an eight candle-power incandescent lamp, 125^{cm} from the window. The result of such an experiment is shown graphically in fig. 5, where, as before, the abscissæ represent time in minutes; the ordinates, deflections in centimeters ; a positive deflection means repulsion by the zinc, a negative deflection, repulsion by lead. From 0^{m} to 7^{m} both strips were exposed to the light and the curve clearly shows the temporary deflection in favor of the lead, returning to zero as the zinc overtakes the lead ; from 7^{m} to 14^{m} the window was covered by the lead screen so that both strips cooled, the zinc lagging behind as before and so giving a similar temporary deflection in the opposite direction. From 14^{m} to 22^{m}, the zinc strip was exposed while the lead was shielded, and from 29^{m} to 36^{m} the lead alone was exposed. It will be observed that the behavior is perfectly in accord with the above explanation of the heating effect, and that the deflections, when the lead and zinc are separately illuminated, are equal. The contrast with the effects of the Röntgen rays is sufficiently marked. I have exposed both strips at once to weak Röntgen rays (giving a deflection of about 2^{cm}) for 30 minutes without observing any tendency of the radiometer to return to zero.

2. At first sight, there appears to be a possibility that (on account of different heat-conductivities, etc.) one of the metals might lose more heat through the front surface and the other through the rear surface, thus giving rise to different surface temperatures, even though the quantities of heat generated were the same in both cases. A number of considerations show that this cannot account for the effects observed. It is easy to show that, when all the heat enters through the front surface, the ratio of the temperature of the front face to that of the rear face will be (when the steady state is attained)

$$\frac{V_0}{V_l} = 1 + \frac{hl}{k}$$

and the difference will be less than this when the heat is gene-
rated thronghont the interior of the metals.   Now a superior
limit to the value of h may be readily obtained, from the rates
of cooling of the strips, by assuming infinite conductivity in the
metals so that the whole strip has at any instant the same tem-
perature as the surface.   Under these circumstances, we have

$$-\frac{1}{2}C\rho l \frac{dV}{dt} = hV$$

Where C is the specific heat, ρ the density and l the thickness
of the metal.   Also

$$-\frac{dV}{dt} = \gamma V$$

so that

$$h = \frac{1}{2}\gamma C\rho l$$

With a given curve of cooling of the surface and finite conduc-
tivity, the value of h will be less than this; because when the
surface has cooled to any temperature the interior will have a
higher temperature and thus not so much heat need be emit-
ted in a given time as when the conductivity is infinite.   In
this way we find for the lead strip

$$h < \cdot 007$$

and for the zinc strip

$$h < \cdot 002$$

and taking $h = 0\cdot 1$ we find, in the worst case

$$\frac{V_a}{V_l} < 1\cdot 004$$

More direct experimental evidence upon this point was
obtained by reversing the position of the ebonite disc with
reference to the case and putting the vanes on the side of the
strips next the window instead of on the further side.   The
effects observed were the same as in the other position.

3. The possibility of unequal values of the emission coeffici-
ent for the aluminium-covered surfaces of the two metals is
negatived by the experiments with light in which the two
metals produced equal effects.

4. If much heat were lost by conduction through the ebonite
support, or the copper wire by which the strips were earthed
(diameter, $1/4^{mm}$), the central part of the zinc strip would be
cooler than the lead on account of its greater conductivity and
thickness.   If this were the cause of the higher temperature
of the lead it would act also when the strips are warmed by
light, which is not the case.   Experiments with light were

made with the full aperture of the circular window, so that the ebonite was illuminated as well as the strips; and also with a cardboard screen in front of the window with a rectangular hole which allowed the light to fall on the strips alone and not on the ebonite. No difference was observed in the two cases.

5. The observed results cannot be due to electrostatic effects produced by the negative corpuscles of the secondary rays. The strips were earthed, and the two vanes were connected by a conductor; under these circumstances, no electrostatic effect could be produced except an instability due to *both* vanes having a different potential from the two strips. Such an instability was frequently observed after the vanes had become electrified by bumping against the strips, but no other electrical effect. Moreover, the coincidence of the rates of motion of the radiometer, when illuminated by Röntgen rays and by ordinary light, shows that the deflections produced by the rays were caused by changes of temperature and not by electrical forces.

6. The last consideration also excludes the (somewhat remote) possibility that the effect is produced by direct impact of the secondary rays.

7. It is conceivable that a slight difference in the distance of the lead and zinc strips from the vanes might cause a considerable difference in sensitiveness of the two vanes and thus account for the preponderance of the lead. If this were the case, however, the effect should have appeared in the experiments with ordinary light. I also tested the effect upon the sensitiveness of varying the vane-distance by taking deflections with the zero near the top and near the bottom of the scale. For a variation in the vane-distance of 0.48^{mm} the change in sensitiveness was less than 12 per cent. The positions of the surfaces of the lead and zinc strips were afterward tested by means of a point gauge and they certainly did not differ by more than 0.1^{mm}.

8. It might also be imagined that the measurement of the absorptions by means of the electroscope did not give the relative amounts of energy absorbed by the lead and zinc; that the ionization in the electroscope was not a measure of the energy of the rays. One may express this possibility in slightly different form by saying that, accompanying the rays which ionize the gas, there may be other rays which do not cause ionization but which do carry energy; and that these latter may be more absorbed in the lead than in the zinc. In order to test this, measurements of the absorption were made with the radiometer itself. One strip was shielded so that as large a deflection as possible might be obtained with

the rays and an aluminium screen of the same thickness as the window was set up in front of the window ; the lead and zinc of the thickness of the strips were introduced behind this screen.   The following deflections in succession were obtained by a three-minute exposure to the rays in each case :

$$
\begin{array}{llr}
\text{Al} & \text{------------------} & 8\cdot4 \\
\text{Al}+\text{Pb} & \text{----------------} & 0\cdot8 \\
\text{Al}+\text{Zn} & \text{----------------} & 0\cdot9 \\
\text{Al}+\text{Pb} & \text{----------------} & 0\cdot6 \\
\text{Al} & \text{------------------} & 6\cdot6 \\
\end{array}
$$

It is plain that the rays did not remain very constant during this somewhat prolonged use, but it is also plain that, whatever agent it may be which affects the radiometer, it is practically equally absorbed by the lead and the zinc.   Taking the means of the readings as they stand, we find that, of the energy which gets through the aluminium, 88 per cent is absorbed by the zinc and 91 per cent by the lead.

9. Even if one assumed the substantial correctness of the energy measurements, there still remains the possibility that the difference between the two metals may not be due to atomic disintegration.   It is known that secondary rays are generated by the absorption of the primary rays and it may be supposed that these carry away from the metal a considerable fraction of the energy of the primary rays—a much greater fraction in the case of zinc than in the case of lead, thus giving rise to the observed difference.   An examination of this possibility is therefore necessary.

The secondary rays from such metals as lead and zinc consist of two well-defined groups, one of which is completely absorbed in less than 10^{mm} of air, the other being much more penetrating.   Let us consider first the less penetrating rays.   It is stated in the introductory portion of this paper that these rays must form a large fraction of all the secondary rays generated ; this statement appears at first sight to be in contradiction with the experimental result obtained by H. S. Allen,[*] who found that the ionization produced by these easily absorbed secondary rays from brass is $1/1900$ of that which would be produced by complete absorption of the primary rays in the gas. A little consideration, however, shows that, with rays so easily absorbed, a large number must be generated in the metal to permit even so small a fraction to escape.

Let the intensity of the primary rays which have penetrated a distance x into the metal be $I_1 = \bar{I}_1 e^{-\lambda_1 x}$.   The absorption in an element of thickness dx will be $\lambda_1 I_1 dx$ and we may assume that this is proportional to the intensity

[*] Phil. Mag. iii, p. 126 (1902).

of the secondary rays (of the more absorbable type) generated in this element; say

$$I_2 dx = a\lambda_1 I_1 dx$$

The question is as to the value of the fraction a necessary to produce the observed secondary rays outside the metal. Let us assume that half of the secondary rays so generated are propagated straight back to the surface; this will give us an over-estimate of the rays which escape with a given value of a, or an under-estimate of a necessary to account for the observed secondary rays. The effect, at the surface, of the secondary rays generated in the element dx will be then

$$\frac{1}{2} I_2 dx e^{-\lambda_2 x}$$

and the total intensity of the secondary rays at the surface of the metal will be

$$\bar{I}_2 = \tfrac{1}{2}\int_0^\infty I_2 e^{-\lambda_2 x} dx = \tfrac{1}{2} a\lambda_1 \bar{I}_1 \int_0^\infty e^{-(\lambda_1 + \lambda_2)x} dx$$

$$= \tfrac{1}{2} a\bar{I}_1 \frac{\lambda_1}{\lambda_1 + \lambda_2}$$

The value of the coefficient of absorption in air, of the secondary rays from brass, may be obtained from Townsend's experiments* and is 6·9; he did not measure the absorption in air of the primary rays, but an estimate of its value may be got from the statement that the number of ions produced by the primary rays when they traverse a layer of air 1^{cm} thick is about half as great as the number produced by complete absorption of the secondary rays; combining this with Allen's result that complete absorption of the primary rays produced 1900 times as many ions as complete absorption of the secondary rays, we get, for the coefficient of absorption in air of the primary rays used by Townsend, approximately $3 \cdot \times 10^{-4}$. Assuming that the ratio of the coefficients of absorption in the metal is of the same order as that of the coefficients in air, we have roughly

$$\frac{\lambda_1 + \lambda_2}{\lambda_1} = 2 \cdot \times 10^4$$

and as

$$\frac{\bar{I}_2}{\bar{I}_1} = \frac{1}{2000}$$

we get

$$a = 10.$$

* Camb. Phil. Soc. Proc., x, p. 217 (1899).

Now if the conclusion, toward which the present experiments point, be accepted, it is not surprising that the "fraction" a should be greater than unity; for if atomic energy is set free it is not unlikely that it is through the mechanism of these easily absorbed secondary rays. Of course the data from which the above calculation has been made are not sufficiently accurate to give any weight to the actual number obtained for a; but it is sufficiently clear that a considerable number of these easily absorbed secondary rays must be generated, of which only a very small fraction can escape from the metal.

This conclusion in itself makes it somewhat improbable that a large part of the energy could be transformed into the *more* penetrating secondary rays and so carried away; but it is desirable to consider the question of this type of rays independently. Sagnac, who has made an extensive series of experiments upon secondary rays[*] finds that heavier metals in general give out more intense, and more easily absorbed, rays (of the type now under consideration) than lighter metals; and, in particular, that this is true of lead as compared with zinc. On the other hand, Townsend (loc. cit.) finds that lead is an exception among the heavier metals and, as a matter of fact, gives out less intense and more penetrating rays (of this type) than zinc, and this result has recently been confirmed by Eve[†]. If Sagnac's result were true in general, it would of course dispose of all possibility of explaining the present experiments by means of the energy of the secondary rays; and even from Townsend's observations (when allowance is made for the difference of absorption by air) it is impossible to conclude that the total ionizing power of the secondary rays from zinc is much greater than (or even as great as) that of the rays from lead. But leaving these results out of account, I think it is possible to show that, with the rays which I used and under the experimental conditions, it is not possible to attribute the results obtained to this cause.

The secondary rays from metals are always more easily absorbed than the primary rays which generate them. Barkla[‡] has shown that the secondary radiation from gases and light solids is practically identical in character with the primary radiation; and this had previously been found to be the case for such substances as paraffin by Sagnac (loc. cit.). But all experimenters, so far as I am aware, are agreed that the secondary radiation from lead, zinc and other similar metals is less penetrating than the primary; and no evidence has been obtained of any secondary rays more penetrating than the rays

[*] Ann. Chim. Phys., xxii, p. 493, 1901.
[†] Phil. Mag., viii, p. 674, 1904.
[‡] Proc. Roy. Soc., lxxiv, p. 474, 1905.

which produce them.   Thus if λ_1 and λ_2 are the coefficients of absorption in zinc of the primary and secondary rays respectively, we have

$$\lambda_2 > \lambda_1$$

Now in the experiment described at length above, the absorption by the zinc strip was about $0\cdot8$; the two-tenths observed behind the zinc included not only the primary rays which got through but also some of the more penetrating secondary rays from the rear surface. Hence $e^{-\lambda_1 l} < 0\cdot2$, and as $l = 0\cdot08^{\text{cm}}$

$$\lambda_2 > \lambda_1 > 20.$$

If we assume, as before, that one-half of the secondary rays generated in any element are propagated straight back toward the front surface (which will exaggerate the intensity of the secondary rays), we get for the intensity of the secondary rays escaping from the front surface

$$\bar{I}_2 < \tfrac{1}{2}\,a\bar{I}_1\,\frac{\lambda_1}{\lambda_1 + \lambda_2}\left(1 - e^{-(\lambda_1 + \lambda_2)l}\right)$$

Writing this

$$\tfrac{1}{2}\,a\,\bar{I}_1\lambda_1 l\,\frac{1 - e^{-(\lambda_1 + \lambda_2)l}}{(\lambda_1 + \lambda_2)l}$$

the fraction is seen to be of the form

$$\frac{1 - e^{-x}}{x}$$

which (for positive values of x) increases as x diminishes. Hence

$$\bar{I}_2 < \tfrac{1}{4}\,a\,\bar{I}_1\left(1 - e^{-40l}\right)$$

The primary rays absorbed in the zinc strip

$$A_1 = \bar{I}_1\left(1 - e^{-\lambda_1 l}\right) > \bar{I}_1\left(1 - e^{-20l}\right); \text{ hence}$$

$$\frac{\bar{I}_2}{A_1} < \tfrac{1}{4}\,a\,\frac{1 - e^{-40l}}{1 - e^{-20l}} = \tfrac{1}{4}\,a\left(1 + e^{-20l}\right); \text{ or } \frac{\bar{I}_2}{A_1} < 0\cdot3\,a$$

in which of course, if there is to be no generation of fresh energy, a must be less than unity.

   We may make a similar calculation for the rear surface, but it is sufficient to observe that even if all the effect observed behind the metal is due to secondary rays, the ratio of these to the primary rays absorbed cannot be greater than $0\cdot2$. So that by considerably exaggerating all possibilities in favor of the production and escape of secondary rays we are unable to give to the secondary rays which escape an intensity one-half as great as that of the primary rays absorbed. Now in order

to account in this way for the observed difference in the heating of the lead and the zinc, we must assume that at least half of the energy of the primary rays absorbed in the zinc escapes in the form of secondary rays; this is on the supposition that none so escapes from the lead; if the lead loses any energy in this manner then the fraction for the zinc must be greater than one-half. It appears therefore that the experimental results cannot be accounted for in this way.

Numerical Results.

The measurements of the absorptions of lead and zinc ran so nearly parallel throughout the course of the experiments, with rays differing considerably in penetration, that it was eventually considered unnecessary to make a separate correction to each measurement with the radiometer. The absorptions were measured from time to time during the investigation and the results are given in the following table; the numbers give the fractions of the primary rays absorbed by aluminium of the same thickness as the window, and by lead and zinc of the same thickness as the strips, the latter being behind the aluminium except in the first three experiments when no aluminium was interposed. The last experiment in the table is the one made with the radiometer instead of the electroscope.

Absorptions,

Exp.	Al	Pb	Zn	$\frac{Pb}{Zn}$
I	- - -	0·925	0·924	1·001
II	- - -	0·926	0·920	1·007
III	- - -	0·944	0·947	0·997
IV	0·57	0·862	0·856	1·007
V	0·45	0·790	0·780	1·013
VI	0·47	0·830	0·803	1·034
VII	0·45	0·809	0·805	1·005
VIII	0·31	0·684	0·684	1·000
IX	0·34	0·676	0·648	1·043
X	0·32	0·675	0·655	1·031
XI	- - -	0·907	0·880	1·030
		Average		1·016

The average value of the ratio is applied as a correction in the energy measurements below.

The energy measurements are given in the following table. Column I gives the time of exposure of the strips in minutes. Columns II and III give the deflections in centimeters, produced by exposure of the lead and zinc respectively. These are the observed deflections, corrected for the effect of the induction coil upon the magnetic "torsion head"; this was always

down-scale and varied from 0·1 to 0·3^{cm}; it was determined each time by allowing the coil to run with the lead screen in front of the window of the radiometer. The plus and minus signs indicate the direction of the deflection; thus a change of sign in either column represents a shift of the wheel, so that the positions of the strips are interchanged. Columns IV and V contain the deflections corrected for lack of balance of the radiometer. In experiments 1, 2, 3 and 9, the radiometer was sensibly balanced when tested by the two lead strips; in 4, 5 and 6, there was a lack of balance of 15 per cent in the positive direction; in 7 and 8 the lack of balance was 10 per cent in the same direction. Accordingly, in the first case the positive deflections (zinc) are reduced 15 per cent, in the second case the positive deflections (lead) are reduced 10 per cent. The changes in the conditions are explained by the fact that between the groups of experiments mentioned the radiometer, for one reason or another, had to be taken down and readjusted.

Columns VI and VII contain the deflections reduced to the steady state, by dividing by $(1 - e^{-\gamma t})$. The values of γ used were, for lead 1·5, for zinc 0·67. Column VIII contains the ratios of VI to VII; it is the ratio of the heat generated per second in the lead strip to that generated in the zinc strip.

The first three experiments were made with the vanes between the window and the strips; the last six with the strips between the window and the vanes.

Exp.	I	II	III	IV	V	VI	VII	VIII
1	1·5	−3·45	+1·30	----	----	−3·85	+2·06	1·87
2	1·5	−6·84	+2·26	----	----	−7·65	+3·58	2·13
3	1·5	+5·20	−1·90	----	----	+5·82	−3·01	1·93
4	1·5	−5·51	+2·43	----	+2·16	−6·18	+3·41	1·81
5	1·5	−6·67	+2·64	----	+2·25	−7·46	+3·55	2·10
6	1·5	−7·07	+2·96	----	+2·51	−7·90	+3·96	2·00
7	1·5	+7·09	−2·30	+6·39	----	+7·12	−3·63	1·96
8	1·5	+9·76	−3·21	+8·80	----	+9·85	−5·07	1·94
9	3·0	−13·75	+6·4	----	----	−13·95	+7·40	1·88

The average of the ratios in Column VIII is 1·96; reducing to equal absorptions, we get, as the result of these measurements, that when Röntgen rays are equally absorbed in lead and in zinc, the quantity of heat generated in the lead is 1·93 times the quantity generated in the zinc.

The necessity of the writer's returning to America has temporarily interrupted this investigation. Further experiments are, however, now under way in which other metals will be compared, and the experimental conditions varied as

much as possible. An attempt will be made to detect the effect with a thermopile as well as with the radiometer ; and to ascertain whether cathode rays produce similar effects, as might be expected. If the present results are due to some hitherto unsuspected source of error, it is hoped that the error may reveal itself as the conditions are varied.

It is in no perfunctory spirit that I wish to express my thanks to Professor J. J. Thomson for permission to work in the Cavendish Laboratory and for the help which I constantly derived from his advice and suggestions, some of which were vital to the success of the experiments. I take pleasure in acknowledging my great indebtedness to him.

Conclusions.

The present experiments indicate that when Röntgen rays are equally absorbed in lead and in zinc, approximately twice as much heat is generated in the lead as in the zinc. It does not appear possible to attribute this result to errors in the measurements or in the theory underlying the experimental method.

To account for this effect the writer has been able to think of only one hypothesis which is not in more or less direct conflict with experimental facts. This hypothesis is that, by means of Röntgen rays, the atoms of certain elements may be artificially broken up and that the energy thus liberated forms a part (and perhaps the greater part) of the energy which appears when the rays are absorbed by matter.

New Haven, Conn., Oct. 20, 1905.

ART. II.—*On a Method of Determining the Specific Gravity of Soluble Salts by Displacement in their own Mother-liquor; and its Application in the case of the Alkaline Halides;*[*] by J. Y. BUCHANAN.

DURING the summer of 1904 I was occupied with the determination of the specific gravity of various saline solutions by the hydrometric method, which I designed for use on board the " Challenger " and have perfected in the course of years, since that date. The most important condition of success with this method is to operate always at the same temperature, and during an operation to keep that temperature perfectly constant. The temperature which I used was 19·5°, both because a great quantity of similar work has been done at this temperature and because, in the room which it was my privilege to occupy in the Davy-Faraday Laboratory, this temperature is one which is very easily produced and kept constant, so long as the temperature of the air outside does not exceed it. This work was put a stop to by the arrival of the great anticyclone of the summer of 1904 which persisted over northern Europe for nearly six weeks and produced tropical conditions, which were evidenced alike by the high temperature of the air and by its insignificant diurnal variation.

In these circumstances I decided to make use of the time by putting into practice a method of determining the specific gravity of soluble salts which I have long intended to try.

The specific gravity of an insoluble substance is determined by the amount of distilled water which a known weight of it displaces. In the case of soluble salts it has been the custom to replace the water by a hydrocarbon or mineral oil. The objections to the use of this liquid are numerous, especially when the salt, the specific gravity of which it is desired to determine, is rare or costly. Moreover, to judge by the want of agreement among the values of the specific gravity of the same salt found by different chemists, there is greater uncertainty about the numerical results than there should be. One reason for this may be that the salts are not insoluble, but only sparingly soluble in the oil, and that sufficient attention has not been given to this point.

There is one liquid in which every soluble salt is quite insoluble, and that is its own mother-liquor at the temperature at which the one parted from the other. By immersing the salt in its own mother-liquor at the temperature of what we

[*] Read at the meeting of the Chemical Society of London on 6th April, 1905.

may call its birth, and by making the maintenance of this temperature a *conditio sine quâ non* of every manipulation during which the two are brought together again, errors due to uncertain solubility are eliminated, and contamination of valuable preparations is avoided.   It is therefore by the immersion of each salt in its own mother-liquor that I determine its displacement ; and this, combined with the weight of the salt and the specific gravity of the mother-liquor, gives the specific gravity of the salt.

It is obvious that the method is applicable only to salts which *have* a mother-liquor, such as KCl ; RbBr ; $CaCl_2$,-$6H_2O$; $BaCl_2 2H_2O$; it is inapplicable to salts such as $CaCl_2$; $BaCl_2$; and the like, which have no legitimate mother-liquor.

The anticyclonic meteorological conditions which prevailed during the greater part of July and August 1904 were very favorable to this class of work.   The anticyclone began to give way when the work was nearly finished, and it was evident that, in the absence of artificial arrangements for the preservation of a constant laboratory temperature, this class of work cannot be carried on easily or satisfactorily except in the hottest summer weather.

It is an essential condition of success that the work be carried on in a room, for the time being, especially devoted to the purpose, and occupied by one investigator.   He must have in it everything that he requires, including his balance.   The window of the room must face the north, and the precautions generally to be observed are similar to those prescribed by Bunsen for the practice of his gasometric method.

The salts used in this research were the chlorides, bromides and iodides of potassium, rubidium and cæsium.   The rubidium and cæsium preparations were from the works of Schuchardt in Goerlitz and were of the highest degree of purity.   The potassium salts were also unexceptionable as regards quality and were supplied by Merck.   All of these salts dissolve easily, and most of them abundantly, in water.   They also crystallize with great readiness.

The first operation is to prepare a hot solution of the salt such that, after standing over night, or for such length of time as may be deemed sufficient, it shall furnish about 60^{cc} of mother-liquor and about 15^{cc} of crystals.   In the case of the potassium salts there was no difficulty, as their solubility at all temperatures is well known.   The solubility of the rubidium and cæsium salts had to be determined, at least approximately, in each case, in order to economize the costly material. The following simple method furnished the required information easily and expeditiously.   A suitable vessel, beaker or flask, is weighed empty, and then with 25 grams of distilled

water, of the temperature of the air. The salt is then gradually added and the mixture stirred with the thermometer. In the case of every one of these salts the temperature falls rapidly and by as much as from 15° to 20°. The salt is added as rapidly as it is taken up by the water. When the fall of temperature slackens, a minimum is soon reached, while some salt still remains undissolved at the bottom of the vessel. It is then continually stirred; the temperature rises slowly while the salt gradually passes into solution, until, at a certain temperature the amount of salt remaining undissolved is such that a further rise of one degree of temperature will evidently cause it to disappear. The vessel is now weighed and, as result, we have the weight of salt dissolved in 25 grams of water at about the last observed temperature. With a little care it is easy to arrange that this temperature shall be in the neighborhood of that of the air. The vessel with its contents is now heated, and salt added by degrees, while the temperature rises and finally reaches the boiling point or whatever other temperature may have been determined on. Salt is added until the liquid is saturated at this temperature. The vessel is again weighed and the salt dissolved at the higher temperature is ascertained. These simple experiments, which are completed in very few minutes, furnish all the information that is required for the economical employment of the material. In the absence of more detailed information the following results obtained in the above way are worth quoting:

100 GRAMS OF WATER DISSOLVE

Grams	98	164	264	225	51	157	93	121	156	222
of	RbBr	RbI	RbI	CsCl	CsI	CsI	CsBr	CsBr	CsBr	CsBr
at °C	12	20	boiling	25	12	107	7·5	24·5	50	93·5

With this information there is no difficulty in preparing the solution which shall, after allowing for unavoidable loss in preparation, give the required amount of mother-liquor and of crystals. The water is warmed and the pure salt is added while the temperature is raised to that of ebullition, or to any lower temperature that may have been selected. When the salt has all passed into solution, the liquid is poured into a flat crystallizing dish and crystallization begins immediately. The area of the dish should be such that the layer of solution shall not be more than half a centimeter thick. The mother-liquor is then everywhere in close touch with the crystals. The dish is then put away in a cupboard for the night.

In the morning, the temperature of the contents of the crystallizing dish and that of the air were taken very carefully. The mother-liquor was then poured off clear into a stoppered

bottle, while the crystals were collected, allowed to drain, and
dried in the ordinary way. The temperature which the mix-
ture had when separated is noted as that at which the crystals
and the mother-liquor were in equilibrium; and it is exactly
at this temperature that they have to be brought together
again in order to determine the specific gravity of the salt.
It is at this temperature also that the specific gravity bottle is
weighed when filled with distilled water and with mother-
liquor respectively. In fact the temperature of equilibrium
and of separation is the only temperature used.

In Table I, the experimental details are given in full in the
case of one salt, namely, cæsium chloride. For the other salts
the results only are given, and they are collected in Table II.

All the weights given in this paper represent the weight
in vacuo.

The specific gravity bottle which was used was one of the
common and convenient form which has a thermometer for a
stopper and a lateral capillary tube for the adjustment of level.
Its nominal capacity was fifty cubic centimeters. On three
occasions one of 25^{cc} capacity was used for determining the
displacement of the mother-liquor.

The concentration (m) of the mother-liquor is determined by
titration with tenth-normal silver nitrate solution. This solu-
tion was made with the greatest care and contained exactly 17
grams of silver nitrate in one liter, at the ordinary temperature
of the laboratory at the time. The burette used was divided
into tenths of a cubic centimeter and had a capacity of 50^{cc}.
The determination of the halogen was not made until the
specific gravity had been determined, and, if the concentra-
tion was not already known within narrow limits, a prelimin-
ary titration was made, after which the volume of mother-
liquor was weighed, which would certainly require 40 ± 1^{cc} for
titration. The capacity of the burette from 0 to 40^{cc} was
determined by weight with great care. The concentration is
stated in gram-molecules salt per 1000 grams of water.

For weighing out the salt and passing it directly into the
specific gravity bottle a special and convenient form of weigh-
ing tube was used. It was made out of a stoppered specimen
tube with an internal diameter of 2 centimeters and a length
of 7 or 8 centimeters. The lower end of this tube was opened
and a piece of thin glass tube joined to it before the blowpipe.
This tube, which had a length of about 3 centimeters, had an
external diameter such that it could just pass freely through
the neck of the specific gravity bottle. The wide end was
closed with a glass stopper and the narrow end with a small
india rubber cork.

It was the custom to work so as to have about 15^{cc} of dry

TABLE I.—*Experimental Details in the Case of Cæsium Chloride.*

Formula and molecular weight of salt	MR	$CsCl = 168.5$
Temperature	T	$23.1°$ C.

MOTHER-LIQUOR.

Determination of Specific Gravity.

Weight of specific gravity bottle	w_1	38.8900gms.
Weight of specific gravity bottle filled with distilled water	w_2	89.2399
Weight of water which fills it...... ....$w_2 - w_1$	w_3	50.3499
Weight of sp. gr. bottle + mother-liquor........	w_4	135.0620
Weight of mother-liquor ....$w_4 - w_1$	w_5	96.1720
Specific gravity of mother-liquor........... $\dfrac{w_5}{w_3}$	S	1.9104

Analysis.

Weight of mother-liquor taken	w_6	1.0334gms.
Cb. cents. $\frac{1}{10}$ $AgNO_3$ solution used	w_7	41.21 cc.
Weight of salt equivalent to silver used $\dfrac{w_7 \times MR}{10000}$	w_8	0.6944gms.
Weight of water in W gms. mother-liquor $w_6 - w_8$	w_9	0.3390
Concentration of mother-liquor expressed in gm. molecules salt per thousand gms. water $0.1 \dfrac{w_7}{w_9}$	m	12.1563

SALT IN CRYSTAL.

Determination of Specific Gravity.

A. Weight of first portion of salt	w_{10}	22.1229gms.
Weight of sp. gr. bot. + salt + mother-liquor	w_{11}	146.5514
Weight of mother-liquor......$w_{11} - (w_1 + w_{10})$	w_{12}	85.5385
Weight of water displaced by mother-liquor................................ $\dfrac{w_{12}}{s}$	w_{13}	44.7828
Weight of water displaced by salt $..w_3 - w_{13}$	w_{14}	5.5671
Specific gravity of salt .... $\dfrac{w_{10}}{w_{14}}$	D_1	3.9739
B. Weight of second portion of salt	w_{15}	26.6220gms.
Sum of weights of the two portions $w_{10} + w_{15}$	w_{16}	48.7449
Weight of sp. gr. bottle + salt + mother-liquor	w_{17}	160.4249
Weight of mother-liquor .....$w_{17} - (w_1 + w_{16})$	w_{18}	72.7900
Weight of water displaced by the mother-liquor................................ $\dfrac{w_{18}}{s}$	w_{19}	38.1085
Weight of water displaced by the salt $w_3 . w_{19}$	w_{20}	12.2414
Specific gravity of salt .... $\dfrac{w_{16}}{w_{20}}$	D_2	3.9820
C. Weight of water displaced by salt $..w_{20} - w_{14}$	w_{21}	6.6743gms.
Specific gravity of salt .... $\dfrac{w_{15}}{w_{21}}$	D_3	3.9890
Accepted specific gravity of salt	D	3.982

salt to be added in two charges to the specific gravity bottle. These charges were intended to be nearly, though not quite, equal. The available supply was distributed between two weighing tubes by approximate weight, after which the exact weight of each portion was determined in the usual way. The two portions of cæsium chloride weighed respectively 22·1229 and 26·6220 grams, so that in the first determination of specific gravity 22·1229 grams and in the second 48·7449 grams were concerned. It is not immaterial whether the first portion is charged into the empty specific gravity bottle and the mother-liquor poured over the dry powder, or is charged into the bottle which is already about half full of mother-liquor. In the former case the elimination of the entangled air is difficult and takes time, during which it is not easy to prevent the temperature getting out of hand. By the latter process very little air is carried past the surface of the liquid and very little stirring with the thermometer, which is required on other grounds, suffices to eliminate it.

Owing to the readiness with which these salts crystallize and to the slowness with which all salts dissolve in an almost saturated solution, the temperature of the mixture of salt and mother-liquor, during the adjustment of level in the specific gravity bottle, must on no account be permitted to fall below T by even 0·01°, nor should it be allowed to rise above it by more than 0·1°. The regulation of temperature was effected entirely with a standard thermometer divided into tenths of a degree, each tenth occupying a length of rather more than one millimeter on the stem. The thermometer which forms part of the specific gravity bottle is used chiefly as a stopper of convenient form. So soon as the level of the liquid has been adjusted in the bottle, it is weighed. The temperature and pressure of the air are kept account of for the reduction of all weights to the vacuum.

When the first weighing has been completed, about 20 or 25^{cc} of the clear mother-liquor are drawn off and the second charge of dry salt is added and mixed, after which the level is adjusted, and the weight determined. In the absence of experience it might be thought that it would be difficult to draw off so much of the liquid without some of the solid salt; but no matter how much they may be stirred up, these crystallized salts settle at once and completely to the bottom when immersed in their saturated solutions, and the operation presents no difficulty. It was at first intended to make a series of three determinations with each salt, but two were found to be sufficient. During all these manipulations the temperature of the air in the laboratory never differed from that of crystallization (T = 23·1°) by more than one or two tenths of a degree,

and it is only in such conditions that operations of this kind can be carried out successfully.

Before bringing the crystals together with the mother-liquor in the specific gravity bottle, the operator must realize that their common temperature when mixed is to be as nearly as possible exactly that of crystallization or equilibrium (T); and he must take such measures as his experience dictates to arrive at this end. Preliminary experiments on a somewhat extensive scale are absolutely necessary, and the success of an operation depends almost entirely on the operator and the trouble that he is prepared to take.

Table II gives for each salt, MR, the temperature, T, of equilibrium between crystals and mother-liquor, and, in condensed form, the experimental *data* of the determination of S, the specific gravity at T of the mother-liquor, that of water at the same temperature being unity; of m, the concentration of the mother-liquor in gram molecules salt per 1000 grams water, and of D_1, D_2, D_3, the three observed values, as well as D, the finally accepted value, of the specific gravity of the salt, all at T and referred to that of water at the same temperature as unity.

The letters and suffixes have the same significance as in Table I.

The figures in line T show how uniform the temperature was during the period over which the experiments were spread. All the experiments were made between the 12th and 22d of July, 1904, with the exception of those on cæsium bromide, which were made on August 10th. By that time the anticyclone had begun to break and the value of T for this salt is 21·4°. For all the other salts, T lies between 22·8° and 24·3°.

During the whole of the period the barometer was very steady, varying between 758 and 761 millimeters, and the relative humidity of the air varied between 40 and 50 per cent.

Of the three values D_1, D_2, D_3 for the specific gravity of the salt, D_1 is obtained directly from the first portion of the salt, D_2 from the sum of the two portions, and D_3 is derived from D_1 and D_2 by subtraction.

D_2 represents very nearly the mean of D_1 and D_3 and is the accepted value for the majority of the salts. It is expressed to three places of decimals, of which units in the second place are exact.

It will be noticed that in the case of rubidium chloride the value of D_1 is accepted. The second determination depends on the approximate weight of the second portion of salt when the tube was being filled, the exact weighing on the balance of precision having been accidentally omitted. The operation was however completed, and the calculation made with the approximate

TABLE II.

Experimental Results Regarding each Salt in the Ennead.

	KCl.	KBr.	KI.	RbCl.	RbBr.	RbI.	CsCl.	CsBr.	CsI.
Salt: Formula MR									
Salt: Mol. weight	74·6	119·1	166·1	121·0	165·5	212·5	168·5	213·0	260·0
Temperature, T°	23·4°	23·4°	24·3°	22·9°	23·0°	24·3°	23·1°	21·4°	22·8°
Specific Gravity. **Mother-Liquor.**									
Weight taken, grms. w_5	59·4068	34·3044	85·9636	74·7356	81·3282	46·2696	96·1720	42·3756	78·0087
Displacement, gms. w_3	50·3524	24·9554	49·9140	49·9188	49·9196	24·9478	50·3499	24·9744	50·3658
Specific gravity, $\frac{w_5}{w_3}$ S	1·1798	1·3746	1·7222	1·4971	1·6292	1·8548	1·9101	1·6968	1·5488
Concentration.									
Gm.-mols. p. 1000 gm. H₂O, M	4·7619	5·7250	8·9344	7·7670	6·7229	8·2307	12·1563	5·3057	3·5454
Specific Gravity. **Salt in Crystal.**									
A. Weight of salt, gms. w_{10}	13·3684	36·7928	27·1751	19·0112	27·0906	26·4777	22·1239	27·8926	26·3890
Displacement, gms. w_{14}	7·3371	13·7498	8·9703	7·0256	8·4700	7·7248	5·5671	6·2453	5·8545
Specific gravity, $\frac{w_{10}}{w_{14}} = D_1$	1·8245	2·676	3·0295	2·706	3·198	3·428	3·974	4·466	4·5075
B. Weight of salt, gms. w_{12}	27·4258	52·5142	52·1768	43·7750	51·5438	50·6025	48·7449	57·5390	53·3916
Displacement, gms. w_{20}	14·5322	19·6005	17·1465	15·9627	16·0568	14·7658	12·2414	12·9466	11·8423
Specific gravity, $\frac{w_{16}}{w_{20}} = D_2$	1·887	2·679	3·043	(2·74)	3·210	3·428	3·982	4·455	4·5085
C. Weight of salt, gms. w_{15}	14·0574	15·7214	25·0017	(24·76)	24·4532	24·1248	26·6220	29·6464	27·0026
Displacement, gms $w_{20}-w_{14}=w_{21}$	7·2051	5·8501	8·1762	8·9371	7·5868	7·0410	6·6743	6·7013	5·9878
Sp. gravity, $\frac{w_{15}}{w_{21}}$ D₃	1·951	2·688	3·058	(2·77)	3·223	3·426	3·989	4·424	4·509
Accepted sp. gravity, D	1·951	2·679	3·043	2·706	3·210	3·428	3·982	4·455	4·508

weight was used as a control. The result shows that the value of D_1 may be safely accepted. In case of potassium chloride the value of D_2 (1·951) is accepted, and the reason for this is as follows : The first portion of salt was in very coarse powder, and in mixing it with the mother-liquor numerous crystalline particles were observed which contained gaseous enclosures, easily perceptible by the naked eye. As was expected, the observed specific gravity proved to be low. The second portion was much more finely powdered and the specific gravity resulting from the two was higher (1·8872). But this result is affected to the full extent by the gaseous enclosures in the first portion. We therefore calculate the specific gravity from the second portion alone, which gives 1·9510 for the specific gravity.

Discussion.—It is an advantage of the method just described that it furnishes more than the mere determination of the specific gravity of the salt. Thus, by ascertaining almost simultaneously the specific gravity of the mother-liquor and the displacement in it of the crystals, both being at the temperature of equilibrium, *data* are obtained for the determination of the relation between the displacement of the salt in crystal and its apparent displacement in saturated solution at that temperature. It has not hitherto been permissible to make exact comparisons of this kind owing to the independence of the observations on the salt and on the solution, which have been available.

In discussing the results of observation it is convenient to arrange them in a more articulate form than that of Table II so as to bring each feature forward prominently and by itself.

The group of salts which forms the subject of these experiments is one of the most remarkable in nature. The salts are nine in number and include all the possible binary combinations of the members of the electro-positive triad K, Rb, Cs with those of the electro-negative triad Cl, Br, I. The two triads of simple bodies make three triads, or one *ennead* (*) of binary compounds. The relations of the different members of the ennead are best shown in a table of the form of Table III. In it the salts of the same metal, M, are all in one column, and those of the same metalloid, R, all in one line. The symbol MR represents both the formula and the molecular weight of the salt.

TABLE III.

Values of MR.

K	Rb	Cs	
(a)		Formula	
KCl	RbCl	CsCl	Cl
KBr	RbBr	CsBr	Br
KI	RbI	CsI	I

* From the Greek ἐννεάς, which signifies a body of nine.

(b)		Molecular weight.		
74·6	121·0	168·5	Cl
119·1	165·5	213·0	Br
166·1	212·5	260·0	I

Compartment (*a*) of Table III contains the formula and compartment (*b*) the molecular weight of each salt. The latter is the fundamental attribute of a substance, on which all its properties depend. The molecular weights of the salts which occur in one column differ by the amount of the difference of the atomic weights of the metalloids which they contain, that is, by 44·5 or 47. Similarly, contiguous salts in one line have molecular weights which differ by 46·4 or 47·5. If we consider the two diagonal triads in the ennead, we see that they are characterized by the fact that both the elements in each unit are different from those in either of the other units. Further, along the diagonal KCl–CsI the molecular weights of the units differ as much as possible from each other, while the atomic weights of the components of each unit are as nearly as possible identical, being close neighbors in the atomic series. On the other diagonal, KI–CsCl, the molecular weights of the units agree with each other as nearly as possible, while the atomic weights of the constituents of the units differ from each other as much as possible.

TABLE IV.

The Salt in Crystal.

	K	Rb	Cs	
(*a*)		Values of T (C°).		
	23·4°	22·9°	23·1°	Cl
	23·4°	23·0°	21·4°	Br
	24·3°	24·3°	22·8°	I
(*b*)		Values of D.		
	1·951	2·706	3·982	Cl
	2·679	3·210	4·455	Br
	3·043	3·428	4·508	I
(*c*)		Values of $\dfrac{MR}{D}$.		
	38·233	44·710	42·310	Cl
	44·460	51·553	47·820	Br
	54·580	61·986	57·670	I
(*d*)		Values of $\dfrac{MR}{18D}$.		
	2·124	2·489	2·350	Cl
	2·470	2·864	2·657	Br
	3·032	3·444	3·204	I

The Crystal.—Table IV contains four compartments. In the first (*a*) we have the values of T, the temperature at which the crystals and mother-liquor of each salt were in equilibrium, and that at which the various displacements were observed.

Under the experimental conditions, which have been minutely described above, it is impossible to fix in advance the exact temperature of equilibrium of the crystallizing liquid. This is given by the meteorological conditions, modified by the structural features of the laboratory and of the apartment or enclosure where crystallization takes place.

In the second compartment (*b*) we have the values of D, or the specific gravity of the salt in crystal at T, referred to that of distilled water of the same temperature as unity. The *data* in this compartment are in most cases for different, but always neighboring, temperatures. The differences of the values of T are, however, so small and those of D are so great that we may discuss the specific gravities as if they had been made at one common temperature.

On examining the values of D, we see that they increase with those of MR in Table III; but the increase is not continuous, it is remittent. It takes place *triad-wise ;* and this holds whether we take the triads in column or in line. Comparing salts in the same line, we see that replacing Rb by Cs causes a rise of specific gravity which is twice as great as that caused by the substitution of Rb for K. Comparing salts in the same column, the replacement of Cl by Br causes more than double the rise caused by the substitution of I for Br. However we regard it, we see that *the specific gravity of the salts is a periodic function of their molecular weight, within the ennead.*

In the third compartment (*c*) we have the values of $\dfrac{MR}{D}$ or the displacement of one molecule (MR) of salt stated in grams of water, and in compartment (d) the same constant is stated in gram molecules of water $\left(\dfrac{MR}{18D}\right)$. In dealing with the specific gravities, we saw that, whether we follow the columns or the lines, they increase with increase of molecular weight. In the case of the molecular displacements this holds for the columns but not for the lines. In these the salts of rubidium have the greatest molecular displacement, the potassium salts have the least, and the cæsium salts occupy an intermediate position. As we shall see later, this irregularity is due to a specific peculiarity of the cæsium salts. Meantime it may be noted that the *volumetric equivalent* of one gram molecule of any of the salts of the ennead varies from 2·124 H_2O to 3·204 H_2O, the iodides having the highest and the chlorides the

lowest equivalents. The average difference between the volumetric equivalents of the iodides and bromides is 0·563 H_2O, and that between the bromides and chlorides is 0·343 H_2O.

The Mother-liquor.—The values of T are the same for the mother-liquor as for the crystals, and are presented in Table IV (*a*). In Table V (*a*) we have the values of *m* or the molecular concentration of the mother-liquor. This is expressed in gram molecules salt per 1000 grams water. It represents also with great exactness the solubility of the salt in water at T, and we shall consider it for a moment from this point of view.

Table V.

The Salt in Mother-liquor.

	K	Rb	Cs	
(*a*)		Values of *m*.		
	4·7619	7·7670	12·1563	Cl
	5·7250	6·7229	5·3057	Br
	8·9344	8·2307	3·5454	I
(*b*)		Values of S.		
	1·1798	1·4971	1·9101	Cl
	1·3746	1·6292	1·6968	Br
	1·7222	1·8548	1·5488	I
(*c*)		Values of $\frac{v}{m}$		
	31·223	38·069	49·021	Cl
	39·038	44·131	48·137	Br
	49·506	58·575	67·907	I
(*d*)		Values of $\frac{v}{18m}$		
	1·735	2·115	2·723	Cl
	2·169	2·452	2·674	Br
	2·750	3·257	3·773	I

The least soluble of the nine is cæsium iodide, which has the highest molecular weight, and potassium chloride, which has the lowest molecular weight, comes next to it. Next to cæsium iodide, in molecular weight and in solubility, we have cæsium bromide; and, similarly, next to potassium chloride, in molecular weight and in solubility, we have potassium bromide. In the latter case the solubility increases with the molecular weight while in the former it decreases with it. But, if Table III be referred to, it will be observed that, as regards molecular weight, KCl and CsI occupy singular positions in the ennead. On the other hand, KBr (119·1) and RbCl (121) have almost identical molecular weights, as have also CsBr (213) and RbI (212·5), yet the solubilities in each

pair respectively are very different. The lowest solubilities are on the diagonal KCl–CsI and the highest solubilities on the diagonal KI–CsCl. RbBr, which occupies the middle place on both these diagonals, is also in the middle of the middle column and of the middle line, and is the center of the ennead. Its solubility, besides being nearly the average of the group, has a symmetrical position with respect to those of the other salts. On one diagonal the solubility of its neighbors is lower, on the other higher than its own. In its column the solubility of its neighbors is higher, in its line it is lower than its own.

In compartment (b) of Table V we have the values of S, the specific gravity of the mother-liquor at T, referred to that of distilled water of the same temperature as unity. These numbers cannot, as they stand, be compared with each other because they refer to solutions of such different concentrations. They enable us, however, to arrive at the average apparent displacement of one gram molecule of salt in the saturated solution which contains 1000 grams of water at T. Thus, taking again cæsium chloride as an example, we have for the weight of salt dissolved in 1000 grams of water

$$w = \text{m. } CsCl = 2048 \cdot 34 \text{ grams.}$$

Adding 1000 grams to this we have for the weight of the solution

$$W = 1000 + w = 3048 \cdot 34 \text{ grams.}$$

The specific gravity (S) being 1·9101, the displacement of the solution is

$$V = \frac{W}{S} = 1595 \cdot 92 \text{ grams of water,}$$

whence the gross apparent displacement of the salt in solution is

$$v = V - 1000 = 595 \cdot 92 \text{ grams,}$$

and the mean apparent displacement per molecule is

$$\frac{v}{m} = 49 \cdot 021 \text{ grams.}$$

In compartment (c) we have the value of $\frac{v}{m}$ for each member of the ennead. This expresses, in grams of water, the average apparent displacement of one gram molecule of salt in its saturated solution at T. In compartment (d) the same constant is expressed in terms of gram molecules of water $\left(\frac{v}{18m}\right)$.

Before commenting on the numbers in the table, it is important to form a clear conception of their physical meaning.

We shall best arrive at this by returning to our detailed example of chloride of cæsium. As the quantity of saturated solution which contains 1000 grams of water weighs 3048·34 grams and displaces 1595·92 grams of water, we may imagine it to have been prepared in the following way : —1595·92 grams of water are taken and cæsium chloride is dissolved in it so that each portion, as it is added, forms a saturated solution with the exact quantity of water which it requires for this purpose and the remainder of the water remains uncontaminated. Parallel with the dissolution of the salt, pure water is removed at such a rate as to keep the displacement or bulk of the liquid always the same. When no more salt will dissolve we have a saturated solution which contains 1000 grams of water. The weight of cæsium chloride which has entered the solution is 2048·34 grams and the weight of water which has left it is 595·92 grams, whilst the displacement of the liquid is the same at the end of the operation as it was at the beginning. In thus describing the preparation of the saturated solution, we have described an operation of substitution. *It is therefore permissible to regard solutions as products of substitution*. If we give to the above numbers their molecular interpretation, we see that the mean apparent displacement of one molecule of cæsium chloride in its saturated solution at 23·1° is equal to that of 2·723 gram molecules of water, and therefore, that, in these conditions, *CsCl is volumetrically equivalent to 2·723 H_2O*.

If we study Table V (*d*), we see that the average molecular displacement of the salts increases with their molecular weight, whether we follow the columns or the lines. The only exception is furnished by cæsium bromide, the displacement of which is very slightly lower than that of cæsium chloride. The greatest molecular displacement is that of cæsium iodide, which has the highest molecular weight; and the least molecular displacement is that of potassium chloride, which has the lowest molecular weight. The pair, potassium bromide and rubidium chloride, which have almost equal molecular weights, have also almost equal molecular displacements. The same is true of the pair, potassium iodide and cæsium chloride, but rubidium bromide has a markedly lower displacement. Finally, the pair, rubidium iodide and cæsium bromide, which have almost identical molecular weights, present no resemblance in their apparent molecular displacements.

Comparison of the Displacement of the Salt in Crystal and in Mother-liquor.—The molecular displacement $\frac{MR}{D}$ of the salts in crystal is given in Table IV (*c*) in terms of grams of water; that of the salts in mother-liquor is similarly given in Table V (*c*).

If we compare these two tables, we find the remarkable result that while in the case of the potassium and the rubidium salts the figures for the displacement in crystal are greater than those for the displacement in mother-liquor, in the case of the cæsium salts the reverse is the case.

TABLE VI.

The Salt in Crystal and in Mother-liquor.

	K	Rb	Cs	
(a)		Values of $\dfrac{MR}{D} - \dfrac{v}{m}$.		
	7·010	6·641	− **6·711**	Cl
	5·422	7·422	− **0·317**	Br
	5·074	3·411	**−10·237**	I
(b)		Values of $\dfrac{MR}{D} \cdot \dfrac{m}{v}$.		
	1·225	1·175	0·863	Cl
	1·139	1·168	0·993	Br
	1·103	1·059	0·849	I

In Table VI (a) we have the difference $\left(\dfrac{MR}{D} - \dfrac{v}{m}\right)$ of the molecular displacement of the salt in crystal from its mean molecular displacement in mother-liquor. In compartment (b) we have the ratio $\left(\dfrac{MR}{D} \cdot \dfrac{m}{v}\right)$ of these quantities.

Taking the figures in compartment (a) we see that in the case of the salts of potassium and rubidium crystallization is accompanied by considerable expansion, and this is what is usually met with. In the case of the cæsium salts the reverse is the case, and very decidedly so in the case of the chloride and of the iodide, much less so in the case of the bromide, which, in this, as in other particulars, maintains its singular position.

In this connection it should be noted that among the ratios $\left(\dfrac{MR}{D} \cdot \dfrac{m}{v}\right)$ given in compartment (b), the two which are nearest to unity are those for RbI (1·059) and for CsBr (0·993) respectively; and their molecular weights are almost identical. Further the salts situated *co-diagonally* to them, namely RbBr and CsI, have ratios whose difference from unity are almost equal, namely +0·168 for RbBr and −0·151 for CsI.

Taking a general view of the figures in (b) which give the ratios of displacement in crystal and in mother-liquor, we see great differences. The most striking examples are, as in the case of solubility, the extreme members of the ennead KCl

and CsI. The former expands by more than 25 per cent, and the latter contracts by 15 per cent on crystallizing.

These figures accentuate the peculiarity of the cæsium salts, that crystallization is accompanied by contraction. An interesting conclusion can be drawn from the behavior of the different salts in this respect, namely, that *the crystalliza-tion of the potassium and rubidium salts of the ennead must be hindered by increased pressure, while that of the cæsium salts must be helped by the same agency.*

Conclusion.—The method of determining the specific grav-ity of a soluble salt in its own mother-liquor, as described in the first part of the paper, involves manipulations of too deli-cate a character to permit it to pass into general practice in competition with other methods for the same primary pur-pose. When, however, the specific gravity of the salt has been ascertained in this way, the relation between its apparent displacement in the state of crystal and in that of saturated solution have been ascertained at the same time. In the sec-ond part of the paper the observations are discussed from this point of view, but owing to exigencies of space the dis-cussion has been limited to the accentuation of the salient features. One of the most important of these is the connec-tion which reveals itself between the molecular weight of the salts and their specific gravity and displacement in crystal and in saturated solution, in definite conditions. The authority of the periodic law makes itself as clearly felt in the limited area of the ennead as it does in the realm of the elements. It is true that the cæsium salts introduce some irregularity into the periodicity, but this is not to be looked on as an exception, but as an interference, the nature of which it will be interesting to trace.

ART. III.—*Further Work on the Interaction of Hydrochloric Acid and Potassium Permanganate in the Presence of Various Inorganic Salts ;* by JAMES BROWN.

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

In a previous paper[*] I have shown that the effect attributed by Wagner[†] to the catalytic action of ferric chloride in the reaction between hydrochloric acid and potassium permanganate is in reality due to oxidation of oxalic acid, added to reduce the residual oxides of manganese, by the chlorine formed during the reaction. Wagner's results of a similar nature with the chlorides of chromium, cadmium, gold, and platinum, from which he argues that these salts also act catalytically in the reaction under consideration, have recently been investigated, and it has been found that with the chlorides of gold and cadmium the assumed catalytic effect is due entirely to the chlorine retained in solution, while with the chlorides of platinum and chromium the observed differences are largely due to the chlorine retained in solution, but partly also to an excessive reduction of the permanganate, as will be shown.

Care was taken in this work to use pure salts, and for this purpose chromic chloride, platinic chloride, and auric chloride were especially prepared and purified. The chromic chloride was prepared by totally reducing potassium dichromate with strong hydrochloric acid, precipitating chromic hydroxide with ammonium hydroxide, filtering off and washing the precipitate until free from all soluble material. The chromic hydroxide was then dissolved in dilute hydrochloric acid and the excess of the acid removed by evaporating several times to small volume, replacing the water as it evaporated. In this way a solution was obtained showing slight excess of chlorine over that corresponding to the chromic chloride. The platinic chloride provided commercially was found to contain a considerable quantity of ferric chloride. This was removed by precipitating the platinum as the chlor-platinate with a concentrated solution of ammonium chloride and alcohol, filtering off and washing with alcohol until free from all iron. The ammonium chlor-platinate was then ignited to spongy platinum, the latter dissolved in aqua regia, the excess of nitric acid volatilized by continued heating with hydrochloric acid, and the large excess of hydrochloric acid in turn removed by evaporating to small volume several times. The commercial auric

* This Journal [4], vol. xix, 31.
† Maassanalytische Studien, Habilitahonsschrift, Leipzig, 1898.

chloride also contained iron. This was removed by heating with a strong solution of oxalic acid, filtering off the gold thus precipitated, and washing until free from iron and oxalic acid. The gold was then dissolved in aqua regia, and the excess of nitric and hydrochloric acids removed as with platinum.

Wagner[*] states that in experimenting with the various metallic chlorides which he regards as catalyzers, he used tenth-normal solutions of the same content in chlorine. This with chlor-platinic acid would mean a solution containing $\frac{19 \cdot 5}{6} = 3 \cdot 25$ grams of platinum to the liter since chlor-platinic acid contains six atoms of chlorine to the molecule. With chlor-auric acid it means $\frac{19 \cdot 73}{4} = 4 \cdot 9322$ grams of gold to the liter since chlor-auric acid contains four atoms of chlorine to the molecule.. Similarly tenth-normal solutions of chromic chloride, cadmium chloride, and ferric chloride must contain $1 \cdot 7366$ grams chromium, $5 \cdot 6$ grams cadmium, and $1 \cdot 8666$ grams iron, respectively. The solutions used in the experiments about to be described were standardized in this way in respect both to chlorine and metal, and in no case showed a noticeable excess of chlorine, the excess never exceeding the equivalent of one or two hundredths of a cubic centimeter of normal hydrochloric acid.

Experiments were then conducted in the following manner: To a 300^{cm^3} flask were added 100^{cm^3} of normal hydrochloric acid, and in addition either $9 \cdot 90^{cm^3}$ of tenth-normal ferric chloride, cadmium chloride, chromic chloride, chlor-platinic acid, or chlor-auric acid. Of approximately twentieth-normal potassium permanganate $9 \cdot 90^{cm^3}$ were then added, and the flask fitted in a ground joint to a return condenser approximately 60^{cm^3} in length, was heated for one hour, or thirty minutes, on the Ostwald thermostat at a temperature of $50°$ C. Of approximately tenth-normal oxalic acid $9 \cdot 90^{cm^3}$ were then added, and permanganate run in to color. Calculations of the amount of permanganate "apparently reduced" were then made by subtracting the permanganate equivalent of the oxalic acid from the total permanganate used, (that is the " $KMnO_4$ before digestion" plus the " $KMnO_4$ to color.") Similarly the " $KMnO_4$ apparently unreduced " is obtained by subtracting the " $KMnO_4$ apparently reduced " from the " $KMnO_4$ before digestion."

[*] Loc. cit., p. 85.

The results follow :

<div align="center">TABLE I.</div>

$[20^{cm3} \frac{N}{20} (H_4N)_2C_2O_4 = 20 \cdot 09^{cm3}$ KMnO$_4$. Oxygen value KMnO$_4$ = 0·0003982 grm. per cm^3. $9 \cdot 90^{cm3}$ H$_2$C$_2$O$_4$ = 19·62^{cm3} KMnO$_4$.]

$\frac{N}{1}$HCl cm^3.	$\frac{N}{10}$HCl cm^3.	KMnO$_4$ before digestion cm^3.	Temperature C°.	Time of digestion min.	H$_2$C$_2$O$_4$ cm^3.	KMnO$_4$ to color cm^3.	KMnO$_4$ apparently reduced during digestion cm^3.	KMnO$_4$ apparently unreduced during digestion cm^3.
100	9·90	9·90	50	60	9·90	12·28	2·56	7·34
100	9·90	9·90	50	60	9·90	12·11	2·39	7·51
100	9·90	9·90	50	60	9·90	12·53	2·81	7·09
100	9·90	9·90	50	60	9·90	12·69	2·97	6·93
100	9·90	9·90	50	60	9·90	12·61	2·89	7·01
100	9·90	9·90	50	60	9·90	12·51	2·79	7·11
100	9·90	9·90	50	60	9·90	12·70	2·98	6·92
	$\frac{N}{10}$CdCl$_2$ cm^3.							
100	9·90	9·90	50	60	9·90	13·35	3·63	6·27
100	9·90	9·90	50	60	9·90	13·20	3·48	6·42
100	9·90	9·90	50	60	9·90	13·23	3·51	6·39
100	9·90	9·90	50	60	9·90	13·75	4·03	5·87
100	9·90	9·90	50	60	9·90	13·79	4·07	5·83
	$\frac{N}{10}$CrCl$_3$ cm^3.							
100	9·90	9·90	50	60	9·90	12·88	3·16	6·74
100	9·90	9·90	50	60	9·90	12·84	3·12	6·78
100	9·90	9·90	50	60	9·90	12·71	2·99	6·91
100	9·90	9·90	50	60	9·90	13·18	3·46	6·44
100	9·90	9·90	50	60	9·90	13·28	3·56	6·34
	$\frac{N}{10}$ $\frac{H_2PtCl_6}{6}$ cm^3.							
100	9·90	9·90	50	60	9·90	14·77	5·05	4·85
100	9·90	9·90	50	60	9·90	14·13	4·41	5·49
100	9·90	9·90	50	60	9·90	13·95	4·23	5·67
100	9·90	9·90	50	60	9·90	14·35	4·63	5·27
100	9·90	9·90	50	60	9·90	13·77	4·05	5·85

<center>TABLE I (continued).</center>

$[20^{cm3} \dfrac{N}{20} (H_4N)_2C_2O_4 = 20\cdot09^{cm3}$ KMnO$_4$.   Oxygen valve KMnO$_4 = 0\cdot0003982$ grm. per cm^3. $9\cdot90^{cm3}$ H$_2$C$_2$O$_4 = 19\cdot62^{cm3}$ KMnO$_4$.]

$\frac{N}{1}$HCl cm^3.	$\frac{N}{10}\frac{HAuCl_4}{4}$ cm^3.	KMnO$_4$ before digestion cm^3.	Temperature C°.	Time of digestion min.	H$_2$C$_2$O$_4$ cm^3.	KMnO$_4$ to color cm^3.	KMnO$_4$ apparently re-duced during digestion cm^3	KMnO$_4$ apparently un-reduced during digestion cm^3
100	9·90	9·90	50	60	9·90	13·97	4·25	5·65
100	9·90	9·90	50	60	9·90	13·73	4·01	5·89
100	9·90	9·90	50	60	9·90	13·35	3·63	6·27
100	9 90	9·90	50	60	9·90	14·27	4·55	5·35
100	9·90	9·90	50	60	9·90	13·02	3·30	6·60
	$\frac{N}{10}$FeCl$_3$ cm^3.							
100	9·90	9·90	50	60	9·90	13·46	3·74	6·16
100	9·90	9·90	50	60	9·90	14·45	4·73	5·17
100	9·90	9·90	50	60	9·90	13·72	4·00	5·90
100	9·90	9·90	50	60	9·90	14·01	4·29	5·61
100	9·90	9·90	50	60	9·90	13·92	4·20	5·70

From these results it may be seen that in accordance with Wagner's views, there is more permanganate required to bring about final coloration in those experiments in which the various chlorides which he regards as catalyzers are used than in their absence.   To ascertain whether these differences are due to the interfering action of the chlorine as shown with ferric chloride in the previous paper,[*] the experiments of Table II were performed in a manner identical with those of Table I, except that a current of air dried and purified was passed through the liquid while digesting to remove the chlorine.

The results of these experiments are outlined in Table II.

<center>TABLE II.</center>

[KMnO$_4$ and H$_2$C$_2$O$_4$ solutions same as used in Table I.]

$\frac{N}{1}$HCl cm^3.	$\frac{N}{10}$HCl cm^3.	KMnO$_4$ before digestion cm^3.	Temperature C°.	Time of digestion min.	H$_2$C$_2$O$_4$ cm^3.	KMnO$_4$ to color cm^3.	KMnO$_4$ apparently re-duced during digestion cm^3	KMnO$_4$ apparently un-reduced during digestion cm^3
100	9·90	9·90	50	60	9·90	18·14	8·42	8·48
100	9·90	9·90	50	60	9·90	18·12	8·40	8·50
100	9·90	9·90	50	60	9·90	18·08	8·36	8·54
100	9·90	9·90	50	60	9·90	18·09	8·37	8·53
100	9·90	9·90	50	60	9·90	18·10	8·38	8·52

<center>* Loc. cit., p. 36.</center>

TABLE II (continued).

[$KMnO_4$ and $H_2C_2O_4$ solutions same as used in Table I.]

$\frac{N}{1}$HCl cm³.	$\frac{N}{10}$CdCl₂ cm³	$KMnO_4$ before digestion cm³.	Temperature C°.	Time of digestion min.	$H_2C_2O_4$ cm².	$KMnO_4$ to color cm².	$KMnO_4$ apparently reduced during digestion cm³.	$KMnO_4$ apparently unreduced during digestion cm³.
100	9·90	9·90	50	60	9·90	18·11	8·39	8·51
100	9·90	9·90	50	60	9·90	18·09	8·37	8·53
100	9·90	9·90	50	60	9·90	18·13	8·41	8·49
100	9·90	9·90	50	60	9·90	18·08	8·36	8·54
100	9·90	9·90	50	60	9·90	18·05	8·33	8·57
	$\frac{N}{10}$CrCl₃ cm³							
100	9·90	9·90	50	60	9·90	16·72	7·00	2·90
100	9·90	9·90	50	60	9·90	16·99	7·27	2·63
100	9·90	9·90	50	60	9·90	17·01	7·29	2·61
100	9·90	9·90	50	60	9·90	16·76	7·04	2·86
100	9·90	9·90	50	60	9·90	16·71	6·99	2·91
	$\frac{N}{10}\frac{H_2PtCl_6}{6}$ cm³							
100	9·90	9·90	50	60	9·90	19·62	9.90	0·00
100	9·90	9·90	50	60	9·90	19·67	9·90	0·00
100	9·90	9·90	50	60	9·90	19·69	9·90	0·00
100	9·90	9·90	50	60	9·90	19·65	9·90	0·00
100	9·90	9·90	50	60	9·90	19·51	8·79	0·11
100	9·90	9·90	50	60	9·90	19·51	8·79	0·11
	$\frac{N}{10}\frac{HAuCl_4}{4}$ cm³							
100	9·90	9·90	50	60	9·90	18·12	8·40	1·50
100	9·90	9·90	50	60	9·90	18·07	8·35	1·55
100	9·90	9·90	50	60	9·90	18·14	8·42	1·48
100	9·90	9·90	50	60	9·90	18·09	8·37	1·53
100	9·90	9·90	50	60	9·90	18·15	8·43	1·47
	$\frac{N}{10}$FeCl₃ cm₃							
100	9·90	9·90	50	60	9·90	18·14	8·42	1·48
100	9·90	9·90	50	60	9·90	18·05	8·33	1·57
100	9·90	9·90	50	60	9·90	18·07	8·35	1·55
100	9·90	9·90	50	60	9·90	18·09	8·37	1·53
100	9·90	9·90	50	60	9·90	18·15	8·43	1·47

Here it is shown, as with ferric chloride in the previous paper, that the chlorine held in solution is responsible for the low indications of the amount of permanganate apparently reduced during digestion when no means are used to remove this chlorine. With cadmium chloride and chlor-auric acid the same amount of permanganate is here shown to be reduced as when the permanganate is digested with hydrochloric acid alone, and it is further seen that the maximum effect is accomplished by thirty minutes heating. In all experiments in which chlor-platinic acid was used the oxides of manganese, noticeable in those experiments in which ferric, cadmic, and chromic chlorides were used, were entirely reduced, and the liquid at the close of the digestion was perfectly clear, showing only the color due to the chlor-platinic acid; when the chlorine is removed in these experiments the permanganate required to bring about final coloration is substantially equal to the oxalic acid added, the slight excess over this value being due probably to difficulty of distinguishing the end color. In the last two experiments the values are a little below that corresponding to the oxalic acid; this may be due to a slight residue of manganese oxides which appeared not to be entirely reduced at the end of the half hour's digestion. This point, however, has not been sufficiently investigated to be definitely decided. With chromic chloride we find a variety of phenomena. In all experiments shown in Tables I and II the permanganate is entirely reduced and the chromic chloride is partially oxidized, leaving at the end of the digestion a clear liquid greenish-yellow in color. When the oxalic acid is added the chromic acid is reduced totally or in part, tending to restore the original green color to the solution, but the chromic chloride does not seem to be oxidized to any noticeable extent on running in permanganate to color, the end reaction showing a green liquid colored faintly by the permanganate. In an experiment showing such a variety of reactions, most of which are indefinite, concordance of results is not to be expected even when the chlorine is removed, and the experiments of Tables I and II, in which chromic chloride were used, show wide variation.

Wagner[*] has noted the separation of hydrated oxides of manganese with all his " catalyzers " except gold and platinum. The exception holds for platinum but not for gold, in my experience, as with the latter the same residual oxides of manganese are noticeable as with ferric and cadmic chlorides. With chromic chloride I found no residual oxides, as already stated, Wagner's statement to the contrary notwithstanding.

It will be seen by a comparison of the results of Table I of this paper with those of Table I of the previous paper, that although in both tables the " $KMnO_4$ apparently reduced during digestion " is greater in the presence of the metallic chlor-

[*] Loc. cit., page 87.

ides than in their absence, the readings of the present paper are considerably greater than corresponding readings in the previous paper. These differences can be explained on the evident supposition that the oxidation of the oxalic acid by the chlorine was more extensive in the experiments recorded in this paper than in those of Table I of the previous paper, for these differences disappear when the chlorine is removed from the sphere of action, the differences between the readings of Tables II and III of the previous paper on the one hand and those of Table II of the present paper on the other being small and in all probability due to differences in the strength of the permanganate solution used. The experiments of this paper were made with as little shaking as possible to avoid expulsion of chlorine mechanically, and allow the chlorine to exert its maximum oxidizing effect on the oxalic acid during the time of the titration. These variations show still more conclusively the non-concordance likely in Wagner's process, and the dependence of results on the oxidizing action of the chlorine.

The conclusion must be drawn, then, that Wagner's results with each of the salts which he regards as catalyzers are in all cases largely dependent on the oxidizing action of the chlorine held in solution. With ferric chloride, cadmium chloride, and chlor-auric acid, the assumed catalytic effect of chlor-metal acids formed by the union of the metallic chlorides with hydrochloric acid, which are more easily oxidized by potassium permanganate than is hydrochloric acid, is unsubstantiated. With these three compounds the apparent catalytic effect is due entirely to the chlorine retained in solution. With chromic chloride and chlor-platinic acid the observed differences are due partly to the chlorine retained in solution but partly also to the total reduction of the residual oxides of manganese. With platinic chloride the action is apparently catalytic, this compound exerting a reducing action on the higher oxides of manganese formed in the presence of the other compounds. With chromic chloride the action is not catalytic, the assumed catalyzer being oxidized to chromate, thus losing its identity, as is not the case with a true catalyzer.

Another series of experiments was made to ascertain whether any difference in the amount of higher oxides of manganese formed in the presence of ferric chloride, cadmium chloride, or chlor-auric acid, or in the amount of chromate formed in the presence of chromic chloride, is caused by the removal of chlorine in the experiments of Table II. Experiments were made as were those of Table I, the digestion being continued one hour without the removal of chlorine, and the chlorine then removed by blowing a current of air through the solution for one-half hour. Oxalic acid was then added and perman-

ganate run in to color as before. The results showed all desired
agreement with those of Table II, proving that the removal of
chlorine during the hour's digestion has no effect on the
oxidizing material other than chlorine retained.   As these
experiments were merely confirmatory, they are not given here.

Wagner has also shown the diminishing effect of manganous
chloride[*] and sulphate in the amount of permanganate appar-
ently reduced by hydrochloric acid after the above method of
experimentation. This part of his work has also been investi-
gated and gives results as shown in Table III, in which the
chlorine was not removed during digestion, and Table IV, in
which the chlorine was thus removed. Difficulty was encoun-
tered in maintaining the solutions of manganous salts at con-
stant value in neutral solution, basic manganese salts settling
out on standing a few days. One hundred and twenty cubic
centimeters of normal hydrochloric acid to the liter were
therefore added in making up the tenth-normal manganous
salts. This would make an excess of approximately $1·20^{cm^3}$ of
normal hydrochloric acid in $9·90^{cm^3}$ of the solutions, the amount
used in the experiments; allowance was made for this excess,
and only $98·80^{cm^3}$ of normal hydrochloric acid used.

TABLE III.

$[20^{cm^3} \frac{N}{10}(H_4N)_2C_2O_4 = 40·99^{cm^3}$ KMnO$_4$ Oxygen value KMnO$_4 = 0·0003903$
grm. per cm^3. $9·90^{cm^3}$ H$_2$C$_2$O$_4 = 20·75^{cm^3}$ KMnO$_4$.]

$\frac{N}{1}$HCl cm^3.	$\frac{N}{10}$HCl cm^3.	KMnO$_4$ before digestion cm^3.	Temperature C°.	Time of digestion min.	H$_2$C$_2$O$_4$ cm^3.	KMnO$_4$ to color cm^3.	KMnO$_4$ appar- ently re- duced during digestion cm^3.	KMnO$_4$ appar- ently un- reduced during digestion cm^3
100	9 90	9·90	50	60	9·90	13·08	2·23	7·67
100	9·90	9·90	50	60	9·90	13·18	2·33	7·57
100	9·90	9·90	50	60	9·90	13·33	2·48	7·42
100	9·90	9·90	50	60	9·90	13·17	2·32	7·58
100	9·90	9·90	50	60	9·90	13·22	2·37	7·53
	$\frac{N}{10}$MnCl$_2$ cm^3							
100	9·90	9·90	50	60	9·90	12·45	1·60	8·30
100	9·90	9·90	50	60	9·90	12·38	1·53	8·37
100	9·90	9·90	50	60	9·90	12·59	1·74	8·16
100	9·90	9·90	50	60	9·90	12·35	1·50	8·40
100	9·90	9·90	50	60	9·90	12·36	1·51	8·39

[*] Loc. cit., p. 88.

TABLE III (continued).

$[20^{cm3}\frac{N}{10}(H_4N)_2C_2O_4 = 40.99^{cm3}$ KMnO$_4$. Oxygen value KMnO$_4$=0.0003903 grm. per cm. 9.90^{cm3} H$_4$C$_2$O$_4$=20.75^{cm3} KMnO$_4$].

$\frac{N}{1}$HCl cm³.	$\frac{N}{10}$MnSO$_4$ cm³.	KMnO$_7$ before digestion cm³.	Temperature C°.	Time of digestion min.	H$_2$C$_2$O$_4$ cm³.	KMnO$_4$ to color cm³.	KMnO$_4$ apparently reduced during digestion cm³.	KMnO$_4$ apparently unreduced during digestion cm³.
100	9.90	9.90	50	60	9.90	12.48	1.63	8.27
100	9.90	9.90	50	60	9.90	12.45	1.60	8.30
100	9.90	9.90	50	60	9.90	12.51	1.66	8.24
100	9.90	9.90	50	60	9.90	12.55	1.70	8.20
100	9.90	9.90	50	60	9.90	12.25	1.40	8.50

TABLE IV.

[KMnO$_4$ and H$_2$C$_2$O$_4$ solutions same as used in Table III.]

$\frac{N}{1}$HCl cm³.	$\frac{N}{10}$HCl cm³.	KMnO$_4$ before digestion cm³.	Temperature C°.	Time of digestion min.	H$_2$C$_2$O$_4$ cm³.	KMnO$_4$ to color cm³.	KMnO$_4$ apparently reduced during digestion cm³.	KMnO$_4$ apparently unreduced during digestion cm³.
100	9.90	9.90	50	60	9.90	19.59	8.74	1.16
100	9.90	9.90	50	60	9.90	19.55	8.70	1.20
100	9.90	9.90	50	60	9.90	19.48	8.63	1.27
100	9.90	9.90	50	60	9.90	19.66	8.81	1.09
100	9.90	9.90	50	60	9.90	19.64	8.79	1.11
100	9.90	9.90	50	60	9.90	19.53	8.68	1.22
	$\frac{N}{10}$MnCl$_2$ cm³.							
100	9.90	9.90	50	60	9.90	16.61	5.76	4.14
100	9.90	9.90	50	60	9.90	17.09	6.24	3.66
100	9.90	9.90	50	60	9.90	16.38	5.53	4.37
100	9.90	9.90	50	60	9.90	16.92	6.07	3.83
100	9.90	9.90	50	60	9.90	16.68	5.83	4.07
100	9.90	9.90	50	60	9.90	16.89	6.04	3.86
	$\frac{N}{10}$MnSO$_4$ cm³.							
100	9.90	9.90	50	60	9.90	16.68	5.83	4.07
100	9.90	9.90	50	60	9.90	16.89	6.04	3.86
100	9.90	9.90	50	60	9.90	16.65	5.80	4.10
100	9.90	9.90	50	60	9.90	16.77	5.92	3.98
100	9.90	9.90	50	60	9.90	16.43	5.58	4.32
100	9.90	9.90	50	06	9.90	16.57	5.72	4.18

Here it is seen that, as shown by Wagner, less permanganate is required to bring about final coloration in those experiments in which manganous sulphate or chloride was used than in their absence.   From the experiments recorded in Table IV, it must be concluded that this diminishing effect is due to the intervention of the Guyard reaction so that the higher oxides of manganese are formed in larger proportion by the introduction of the manganous salt, thus giving more material (if we disregard the volatile and indefinitely reacting chlorine when it is retained in solution) to oxidize the oxalic acid.   Wagner has attributed this diminishing effect to a slowing of the reaction between hydrochloric acid and thinks such is the protecting influence of a manganous salt in titrations of ferrous salts by potassium permanganate in the presence of hydrochloric acid.   It is a diminishing of the reaction between hydrochloric acid and potassium permanganate, but this diminishing is due to the formation of higher oxides of manganese, which, as is well known, are less easily reduced by hydrochloric acid than is the permanganate itself.   Such action is unquestionably the intervention of the Guyard reaction, as first suggested by Zimmermann.*

It has been found that with each of the salts which Wagner regards as catalyzers the apparent catalytic effect is entirely or largely due to the chlorine retained in solution.   The question therefore arises: In what way does the chlorine affect the result?   It is evidently effective in oxidizing the oxalic acid. It seemed likely, therefore, that the lesser oxidation of the oxalic acid, necessitating a greater amount of permanganate to bring about final coloration, in the presence of the various chlorides used, is due to a lesser retention of chlorine in the presence of these salts.   It was decided, therefore, to determine the chlorine retained in solution under the varying conditions, and also the residual higher oxides of manganese or with the chromic chloride the chromate formed during digestion, thus obtaining the total oxidizing value of the material retained in solution at the close of the hour's digestion.   For this purpose potassium permanganate was digested with hydrochloric acid in the presence and absence of the various salts used in the preceding experiments of this paper for one hour at a temperature of 50° C. as there indicated.   The flask containing the ·liqnids was sealed to a Voit flask, to which was fitted in a ground joint a return condenser approximately 60^{cm} in length and with a bore approximately 3^{cm} in diameter.   At the close of the hour's digestion this condenser was removed,

* Ann. Chem., ccxiii, 311 (1882).

and the Voit flask connected with a Drexel washing-bottle containing about 300^{cm^3} of an approximately two per cent solution of potassium iodide, the Drexel washing-bottle being joined to Will and Varrentrapp bulbs also containing a strong solution of potassium iodide to absorb escaping iodine fumes. The chlorine retained in solution in the flask was driven into the potassium iodide by means of a strong current of air dried and purified in the usual manner, the liberated iodine titrated by means of an approximately twentieth-normal solution of sodium thiosulphate, and its equivalent in permanganate calculated. In those experiments in which the digestion was made with hydrochloric acid alone, and in the presence of cadmium chloride and chromic chloride, the "oxidizing material not chlorine" was determined by adding potassium iodide to the digestion liquid after the removal of the chlorine, and titrating the liberated iodine with sodium thiosulphate. Its permanganate equivalent was then estimated as indicated in the table. By adding together the "$KMnO_4$ equivalent" of the chlorine retained in solution during digestion and the "$KMnO_4$ equivalent" of the "oxidizing material not Cl formed during digestion" we have the "total $KMnO_4$ found." The difference between this last value and the "$KMnO_4$ before digestion" gives the "$KMnO_4$ lost" as indicated in Table V. Since, however, potassium iodide could not be added to the solution containing ferric and auric chlorides because of the reduction of these salts with liberation of iodine, an action probably indefinite under the conditions of experimentation, the average of the permanganate equivalent of the "oxidizing material not Cl" obtained with hydrochloric acid alone and with cadmium chloride was taken as indicating the same value with ferric and auric chloride. The results of Table II have shown that the residual oxides of manganese are substantially constant with hydrochloric acid alone and with cadmium, ferric, and auric chlorides. So no error is introduced by the procedure here adopted. Calculations of "$KMnO_4$ found" and "$KMnO_4$ lost" were then made as with hydrochloric alone, and with cadmium chloride. The results follow :

TABLE V.

$20^{cm^3} \frac{N}{10}(H_4N)_2C_2O_4 = 40 \cdot 98^{cm^3}$ KMnO$_4$.   Oxygen value KMnO$_4 = 0 \cdot 0003904$ grm. per cm³.
Iodine value, Na$_2$S$_2$O$_3 = 0 \cdot 005726$ grm. per cm³. $9 \cdot 90^{cm^3}$ KMnO$_4 = 10 \cdot 17^{cm^3}$ Na$_2$S$_2$O$_3$.
1^{cm^3} Na$_2$S$_2$O$_3 = 0 \cdot 923^{cm^3}$ Na$_2$S$_2$O$_3$.

$\frac{N}{1}$HCl cm³	$\frac{N}{10}$HCl cm³	KMnO$_4$ cm³	Time Digestion min.	Temperature C°	Time to expel Cl min.	Cl retained during digestion Na$_2$S$_2$O$_3$ cm³	KMnO$_4$ Equiv. cm³	Oxidizing material not Cl formed during digestion Na$_2$S$_2$O$_3$ cm³	KMnO$_4$ Equiv. cm³	Total KMnO$_4$ found cm³	KMnO$_4$ lost cm³
100	9·90	9·90	60	50	30	8·62	7·95	1·48	1·36	9·31	0·59
100	9·90	9·90	60	50	30	8·69	8·02	1·48	1·36	9·38	0·52
100	9·90	9·90	60	50	30	8·64	7·97	1·41	1·30	9·27	0·63
100	9·90	9·90	60	50	30	8·69	8·02	1·47	1·35	9·37	0·53
100	9·90	9·90	60	50	30	8·82	8·14	1·47	1·35	9·49	0·41
100	9·90	9 90	60	50	30	8·64	7·97	1·41	1·30	9·27	0·63
100	9 90	9·90	60	50	30	8·67	8·00	1·48	1·36	9·36	0·54
100	9·90	9·90	60	50	30	8·83	8·15	1·41	1·30	9·45	0·45
100	9·90	9·90	60	50	30	8·79	8·11	1·47	1·35	9·46	0·44
	$\frac{N}{10}$CdCl$_2$ cm³										
100	9·90	9·90	60	50	30	7·66	7·07	1·42	1·31	8·38	1·52
100	9·90	9·90	60	50	30	7·68	7·08	1·40	1·29	8·37	1·53
100	9·90	9 90	60	50	30	7·64	7·05	1·39	1·28	8·33	1·57
100	9·90	9·90	60	50	30	7·69	7·09	1·45	1·33	8·42	1·48
100	9·90	9·90	60	50	30	7·65	7·06	1·39	1·28	8·34	1·56
	$\frac{N}{10}$CrCl$_3$ cm³										
100	9·90	9·90	60	50	30	7·64	7·05	2·07	1·91	8·96	0·94
100	9·90	9·90	60	50	30	7·57	6·98	2·09	1·92	8·90	1·00
100	9·90	9·90	60	50	30	7·50	6·92	2·06	1·90	8·82	1·08
100	9·90	9·90	60	50	30	7·62	7·03	2·09	1·92	8·95	0·95
100	9·90	9·90	60	50	30	7·64	7·05	2·08	1·91	8·96	0·94
	$\frac{N}{10}$FeCl$_3$ cm³										
100	9 90	9·90	60	50	30	8·59	7·92	----	[1·32]	9·24	0·66
100	9·90	9·90	60	50	30	8·89	8·20	----	[1·32]	9·52	0·38
100	9·90	9·90	60	50	30	8·69	8·02	----	[1·32]	9·34	0·56
100	9·90	9·90	60	50	30	8·64	7·97	----	[1·32]	9·29	0·61
100	9 90	9·90	60	50	30	8·88	8·19	----	[1·32]	9·51	0·39
	$\frac{N}{10}$ $\frac{H_2PtCl_6}{6}$ cm³										
100	9·90	9 90	60	50	30	10·08	9·30	----	----	9·30	0·60
100	9·90	9 90	60	50	30	10·14	9·35	----	----	9·35	0·55
100	9 90	9·90	60	50	30	10·01	9·23	----	----	9·23	0·67
100	9·90	9·90	60	50	30	10·12	9·34	----	----	9·34	0·56
100	9·90	9·90	60	50	30	10·07	9·29	----	----	9·29	0·61

TABLE V (continued).

20^{cm3} $\frac{N}{10}(H_4N)_2C_2O_4 = 40\cdot98^{cm3}$ KMnO$_4$.   Oxygen value KMnO$_4 = 0\cdot0003904$ grm. per cm^3.
Iodine value, Na$_2$S$_2$O$_3 = 0\cdot005726$ grm. per cm^3. $9\cdot90^{cm3}$ KMnO$_4 = 10\cdot71^{cm3}$ Na$_2$S$_2$O$_3$.
1^{cm3} Na$_2$S$_2$O$_3 = 0\cdot924^{cm3}$ Na$_2$S$_2$O$_3$.

$\frac{N}{1}$HCl cm³	$\frac{N}{10}\frac{HAuCl_4}{4}$ cm³	KMnO₄ cm³	Time Digestion min.	Temperature C°	Time to expel Cl min.	Cl retained during digestion		Oxidizing material not Cl formed during digestion		Total KMnO₄ found cm³	KMnO₄ lost cm³
						Na₂S₂O₃ cm³	KMnO₄ equiv. cm³	Na₂S₂O₃ cm³	KMnO₄ equiv. cm³		
100	9·90	9·90	60	50	30	8·62	7·95	- - - -	[1·32]	9·27	0·63
100	9·90	9·90	60	50	30	8·77	8·09	- - - -	[1·32]	9·41	0·49
100	9·90	9·90	60	50	30	8·80	8·12	- - - -	[1·32]	9·44	0·46
100	9·90	9·90	60	50	30	8·83	8·15	- - - -	[1·32]	9·47	0·43
100	9·90	9·90	60	50	30	8·83	8·15	- - - -	[1·32]	9·47	0·43
	$\frac{N}{10}$MnCl₂ cm³										
100	9·90	9·90	60	50	30	4·81	4·43	5·51	5·08	9·51	0·39
100	9·90	9·90	60	50	30	5·71	5·27	4·86	4·48	9·75	0·15
100	9·90	9·90	60	50	30	5·63	5·19	4·74	4·37	9·56	0·34
100	9·90	9·90	60	50	30	5·52	5·09	4·88	4·50	9·59	0·31
100	9·90	9·90	60	50	30	5·85	5·39	4·63	4·27	9·66	0·24
100	9·90	9·90	60	50	30	5·77	5·32	4·81	4·43	9·75	0·15
	$\frac{N}{10}$MnSO₄ cm³										
100	9·90	9·90	60	50	30	5·72	5·27	4·79	4·42	9·69	0·21
100	9·90	9·90	60	50	30	5·66	5·22	4·83	4·45	9·67	0·23
100	9·90	9·90	60	50	30	5·42	5·00	5·09	4·69	9·69	0·21
100	9·90	9·90	60	50	30	5·78	5·33	4·73	4·36	9·69	0·21
100	9·90	9·90	60	50	30	4·23	3·90	6·36	5·87	9·77	0·13

Here it is seen that the total oxidizing material retained in solution, or the "total KMnO$_4$ found" is substantially the same with hydrochloric acid alone, and in the presence of auric and ferric chlorides. With cadmium chloride there is a considerable falling off in the chlorine retained in solution while the residual oxides of manganese show on the average only a slightly smaller value than with hydrochloric acid alone. There is, therefore, a deficiency of about $1\cdot00^{cm3}$ in "total KMnO$_4$ found" as compared with the value found with hydrochloric acid alone. With platinic chloride the "total KMnO$_4$ found," or oxidizing material retained in solution, in this case all chlorine, is substantially equal to that found with hydrochloric acid alone. With chromic chloride there is a deficiency after adding together the permanganate equivalents of the chlorine retained in solution and the "oxidizing material not Cl," presumably in this case chromic acid. With manga-

nous chloride and sulphate the " $KMnO_4$ found " is slightly greater than with the hydrochloric acid alone, due probably to a lesser formation of the more volatile and indefinitely reacting product chlorine, more permanganate going to form the more definitely reacting oxides of manganese than in the digestion with hydrochloric acid alone. The amount of manganese oxides represented by "oxidizing material not Cl" in the above table is seen to vary widely. This is in accordance with Volhard's[*] assertion that acids hinder the reaction between manganous salts and permanganate to give higher oxides of manganese. This action, rather indefinite under even the most favorable conditions, might be expected to be especially so in the presence of the large amount of acid used in these experiments.

With all the salts above used, and especially with cadmium chloride, the "total $KMnO_4$ found" is less than the permanganate added before digestion. The natural supposition seemed to be that this deficiency was due to the escape of chlorine during the digestion. On adding potassium iodide solution, however, to the Voit flask during the hour's digestion, no appreciable escape of chlorine was noticeable, while the oxidizing material showed the same values as in Table V. This was true whether the digestion was made with hydrochloric acid alone or in the presence of any one of the salts used in Table V. It appeared evident, therefore, that the chlorine disappeared in the digestion liquid, and that the greater or less extent of this disappearance accounted for the greater or less amount of chlorine found to be present in the digestion liquid at the close of the hour's heating. Thinking that possibly these various salts might interfere in some way with the iodine liberated by permanganate from potassium iodide in the presence of hydrochloric acid, experiments were made to ascertain whether any of the observed differences were due to such interference. These experiments were conducted as follows: Into a flask were introduced 100^{cm^3} of normal hydrochloric acid, and in addition either 9.90^{cm^3} of tenth-normal hydrochloric acid, or 9.90^{cm} of one of the tenth-normal salt solutions there indicated. An excess of potassium iodide was then added, 9.90^{cm^3} of permanganate run in and the iodine liberated estimated with sodium thiosulphate.

These experiments showed that normal values are obtained by titrating iodine by thiosulphate in the presence of hydrochloric acid and any one of the various salts used, thus excluding the possible inference that the large amount of acid or possibly the metallic chlorides interfered in the reaction.

[*] Ann. Chem., cxcviii, 337 (1879).

The variations above noted must therefore be due to some secondary reaction occurring during the digestion. The experiments outlined in Table VI were therefore made with varying periods of digestion, to note more carefully the progress of these variations. The manner of experimentation was to digest solutions made up as were those of Table V on the water bath during varying periods of time with the Voit flask trapped with potassium iodide solution to prevent escape of chlorine. After the digestion an excess of potassium iodide solution was added and the liberated iodine determined by use of sodium thiosulphate. In this way the total oxidizing material formed during digestion is estimated in one operation rather than in two, as was the case in the experiments of Table V. Results are indicated in Table VI.

TABLE VI.

Oxygen value, $KMnO_4=0\cdot0003894$ grm. per cm³.   Iodine value $Na_2S_2O_3=0\cdot005671$ grm. per cm³. $9\cdot90^{cm3}$ $KMnO_4=10\cdot80^{cm3}$ $Na_2S_2O_3$. 1^{cm3} $Na_2S_2O_3=0\cdot917^{cm3}$ $KMnO_4$.

$\frac{N}{1}$HCl cm³.	$\frac{N}{10}$HCl cm³.	H_2O cm³.	$KMnO_4$ cm³.	Time digestion min.	Temperature C°.	$Na_2S_2O_3$ cm³.	$KMnO_4$ equiv. cm³.	$KMnO_4$ lost cm³.
100	9·90	0.00	9·90	5	50	10·71	9·82	0·08
100	9·90	_ _	9·90	10	50	10.58	9·70	0·20
100	9·90	_ _	9·90	15	50	10·48	9·61	0·29
100	9·90	_ _	9·90	30	50	10·42	9·55	0·35
100	9·90	_ _	9·90	45	50	10·39	9·52	0·38
100	9·90	_ _	9·90	60	50	10·21	9·36	0·54
100	$\frac{N}{10}CdCl_2$ cm³.							
100	9·90	_ _	9·90	5	50	10·35	9·49	0·41
100	9·90	_ _	9·90	5	50	10·39	9·52	0·38
100	9·90	_ _	9·90	10	50	9·70	8·89	1·01
100	9·90	_ _	9·90	10	50	9·75	8·94	0·96
100	9·90	_ _	9·90	15	50	9·31	8·53	1·37
100	9·90	_ _	9·90	15	50	9·43	8·64	1·26
100	9·90	_ _	9·90	15	50	9·50	8·71	1·19
100	9·90	_ _	9·90	15	50	9·52	8·72	1·18
100	9·90	_ _	9·90	30	50	9·39	8·61	1·29
100	9·90	_ _	9·90	45	50	9·36	8·58	1·32
100	9·90	_ _	9·90	60	50	9·07	8·31	1·59
100	25·00	_ _	9·90	60	50	7·34	6·73	3·17
100	50·00	_ _	9·90	60	50	4·64	4·25	5·65
100	[2 grms.]	9·90	9·90	60	50	0·81	0·74	9·16*

TABLE VI (continued).

Oxygen value $KMnO_4 = 0.0003894$ grm. per cm³.   Iodine value $Na_2S_2O_3 = 0.005671$ grm. per cm³. $9.90^{cm^3} KMnO_4 = 10.80^{cm^3} Na_2S_2O_3$. $1^{cm^3} Na_2S_2O_3 = 0.917^{cm^3} KMnO_4$.

$\frac{N}{1}$HCl cm³.	$\frac{N}{10}$CrCl₃ cm³.	H_2O cm³.	$KMnO_4$ cm³.	Time digestion min.	Temperature C°.	$Na_2S_2O_3$ cm³.	$KMnO_4$ equiv. cm³.	$KMnO_4$ lost cm³.
100	9·90	_ _	9·90	5	50	10·61	9·72	0·18
100	9·90	_ _	9·90	10	.50	10·33	9·47	0·43
100	9·90	_ _	9·90	15	50	9·89	9·06	0·84
100	9·90	_ _	9·90	30	50	9·65	8·84	1·06
100	9·90	_ _	9·90	45	50	9.61	8·81	1·09
100	9·90	_ _	9·90	60	50	9·61	8·81	1·09
	$\frac{N}{10}$MnCl₂ cm³.							
100	9·90	_ _	9·90	5	50	10·73	9·83	0·07
100	9·90	_ _	9·90	10	50	10·69	9·80	0·10
100	9·90	_ _	9·90	15	50	10·67	9.78	0·12
100	9·90	_ _	9·90	30	50	10·52	9·64	0·26
100	9·90	_ _	9·90	45	50	10·43	9·56	0.34
100	9·90	_ _	9·90	60	50	10·50	9·62	0·28
	$\frac{N}{10}$MnSO₄ cm³.							
100	9·90	_ _	9·90	5	50	10·72	9·83	0·07
100	9·90	_ _ ·	9·90	10	50	10·70	9·81	0·09
100	9·90	_ _	9·90	15	50	10·56	9·68	0·22
100	9·90	_ _	9·90	30	50	10·48	9·61	0·29
100	9·90	_ _	9·90	45	50	10·49	9·61	0·29
100	9·00	_ _	9·90	60	50	10·50	9·62	0·28

Here may be noted a greater loss of permanganate during equal periods of time with cadmium and chromic chlorides than with hydrochloric acid alone, the excess loss in the former case increasing with the time of digestion.   This phenomenon is especially noticeable with cadmium chloride, and to deter- mine whether this excess loss of permanganate is in any way proportionate to the amount of cadmium chloride used, amounts of this salt greater than that represented by 9.90^{cm^3} of a tenth- normal solution were used.   The result was as anticipated ; the loss of permanganate increased with the increase in the amount of cadmium chloride used, until with 2 grams of this salt the

total $KMnO_4$ found showed a permanganate equivalent of only 0.81^{cm^3} as indicated in experiment marked *. It would appear, therefore, that with cadmium chloride, and to a lesser extent with chromic chloride, the permanganate is reduced without leaving anything like a proportionate amount of chlorine in solution at the close of the hour's digestion. This may be due to reduction of the permanganate with liberation of oxygen, which does not act on the hydrochloric acid to produce chlorine, or to action of chlorine first liberated on the water giving oxygen. By either of these actions there would be a loss of the chlorine which goes to oxidize oxalic acid in Tables I to IV and to liberate iodine from potassium iodide in Tables V and VI. To ascertain whether this loss is occasioned by formation of oxygen, the following experiment was made : To 100^{cm^3} of normal hydrochloric acid were added 2 grams of cadmium chloride, 10^{cm^3} of water and the solution transferred to a 100^{cm^3} burette, enough water added to completely fill the burette, which required about 10^{cm^3} additional, and the burette inverted in a porcelain dish filled with water, the upper end of the burette being carefully stoppered. Almost immediately gas began to accumulate and continued to accumulate slowly for about three hours, at the end of which the permanganate color had disappeared. The amount of gas collected was too small to admit either of qualitative or quantitative tests with the crude apparatus here used. Additional experiments must, therefore, be made to determine definitely whether oxygen is evolved in this way. The evidence, however, so far as it goes, consistently points to evolution of oxygen in the interaction of hydrochloric acid and potassium permanganate in the presence of cadmium chloride. The author intends to investigate this point further, as well as the action of the other salts which Wagner regards as catalyzers. Gooch and Danner* have shown that oxygen is evolved from potassium permanganate acidified with sulphuric acid. Some such action, it seems, occurs in the experiments of this paper when permanganate is acidified with hydrochloric acid in the presence of cadmium chloride, part of the oxygen of the permanganate being evolved directly instead of liberating chlorine from hydrochloric acid, or the chlorine first liberated acting on the water to set free oxygen.

The author is indebted to Prof. F. A. Gooch for much advice and assistance in the preparation of this paper.

Art. IV. — *Some Western Klamath Stratigraphy;* by
Oscar H. Hershey.

In his paper in the May (1905) number of this Journal, Mr.
J. S. Diller presents strong evidence in support of his contention
that the Bragdon formation in northwestern California is a
member of the Carboniferous series. Although I recognize
that good paleontologic evidence must be the final arbiter in
all discussions such as this concerning the Bragdon sediments,
I am as yet not willing to fully accede to his conclusions, but
without further field-work am unable to combat them. I
make this explanation for the reason that this paper may
appear to be an indirect reply to Mr. Diller, whereas it is an
endeavor to record some important observations before the
vividness of their memory be dulled by time.*

The objects of this paper are to introduce another formation
from the Klamath region, and to show how thrust faulting
may have given rise to apparently inexplicable problems in
the geology of northern California.

The folding of the strata characteristic of the southern Kla-
math region is largely replaced northward by thrust faulting,
breaking the rocks into four great eastwardly tilted fault
blocks. Four important members of the fault system are now
known. The most westerly was discovered and elucidated by
Mr. Diller. It bounds the Klamath province on the southwest
and is marked by the abutment of easterly dipping typical
Franciscan sediments against the ancient schists of South Fork
and Redwood Mountains; hence, it may be designated the
Redwood Mountain fault. The next easterly (second magni-
tude faults ignored), which most directly concerns this paper,
passes about two miles east of Orleans on the Klamath River,
and may be known as the Orleans fault. The third has its
finest development in Eddy gulch, near the Black Bear mine
and postoffice and may be known as the Black Bear fault. In
this portion of its course it dips easterly at a low angle, prob-
ably 15° or 20°, the ancient schists of the Abrams formation
having been thrust for possibly five miles over on to the cherty
shales considered of Devonian age; but in passing northward
and southward it straightens up and becomes nearly or quite
vertical, although for scores of miles it continues a prominent
break in the strata. The fourth great fault is marked by east-
wardly dipping sediments with strong Cretaceous character-
istics apparently overhung by Devonian limestones and cherty

* Writing in the field, in eastern Nevada, without notes, maps or refer-
ences, I must ask the reader's indulgence to informalities and to possible
slight inaccuracies in figures.

shales, near the southern end of Scott Valley, as discovered by Dr. A. C. Lawson and the writer several years ago. This may be designated the Callahans fault.

These faults are profound breaks comparable with the first magnitude faults the world over, and may extend entirely through the Klamath province, although this is said with less confidence concerning the Callahans fault. The throw appears to be generally not less than a mile and may in many places exceed two miles, even where the dip is steep. The age as indicated in the case of the Redwood Mountain and Callahans faults by the strata involved, and perhaps in the Orleans fault by its persistent accompaniment by serpentine dikes, seems to be Cretaceous or later but not as late as the opening of the Quaternary, Indeed, it is my impression that on the south, Horsetown sediments lap across the Orleans and Black Bear faults without dislocation.

The territory to be especially considered lies along the Orleans fault for ten miles northerly and southerly from the Klamath River. Here it marks a remarkable change in the stratigraphy. I will first describe the rocks east of the fault.

With the exception of a small area of possible Salmon hornblende schist several miles south of the Klamath River, the formation first encountered east of the fault in the vicinity of Orleans is a great series of black shales, limestones and blue cherts which, for the purpose of this paper, I will designate the Blue Chert series, from its most characteristic constituent. This occurs in beds from fifty to several hundred feet in thickness, made up of thin regular layers. The prevailing dark blue-black color seems to have been bleached in places, some outcrops having a whitish or light gray color. Also, isolated areas of very limited extent possess red chert very closely resembling typical Franciscan chert; the invariable presence of igneous rock suggests reddening of the blue chert by heat. Between the chert beds are somewhat thinner layers of soft black shale, much of which has been crushed to a schistose structure. The limestones occur in small lentils, either isolated or developed along certain lines parallel to the strike of the shales. They probably represent definite horizons, of which there may be several in the series. They are generally thoroughly recrystallized and without recognizable fossils. Indeed, the only fossils known between the Orleans and Black Bear faults, in the Salmon River basin, which is largely occupied by this series, are radiolaria in the cherts. The age, therefore, can only be determined upon lithologic grounds. It is presumed to be Devonian because similar rocks elsewhere in the Klamath region carry Devonian fossils.

The peculiar bluish bedded cherts occur throughout the area of outcrop of this series, but in some localities are more strongly developed than in others. They are especially prominent south of the Black Bear mine, where I estimate the thickness of the formation to be about 5000 feet, of which probably 3000 feet is chert.

Beginning at the Orleans fault, two miles east of Orleans, and proceeding thence up the valley of Pearch Creek, climbing the western flank of Orleans Mountain, we find first a belt of quartz schist (produced by the shearing of chert) and associated with it lentils of limestone, the whole dipping easterly 45° to 60°. This is succeeded by ordinary cherts and shales in alternating layers, all dipping eastward at angles not less than 30°. But the formation has been very thoroughly shattered by the intrusion of igneous material. In places, this occurs in a network of small dikes traversing the sedimentary rocks in all directions; in others it is in large masses almost excluding the shales and cherts. Inclusions of the latter are exceedingly common and vary in size from infinitesimal fragments to masses a quarter of a mile in length. All the larger fragments more or less preserve the original easterly dip. By means of them one can trace, in Pearch Creek valley, the outlines of a succession of strata at least 3000 feet thick, everywhere dipping easterly at a comparatively steep angle.

This thorough intrusion of the Blue Chert series by apparently dioritic and diabasic material is general throughout its extensive outcrop areas in the western Klamath region. Probably no quarter section of it is without these dikes and in many square miles there is much more igneous than sedimentary rock. I want to strongly impress the fact that this intrusion is not local.

In Pearch Creek valley, the intruded igneous material appears to pass upward into a volcanic series of andesites and rhyolites, which, if I rightly remember, is 800 to 1200 feet thick. An important member in the lower part of the series is an andesite characterized by small block-like crystals of hornblende probably originally a pyroxene. This may be partly in the form of large dikes penetrating deep into the complex of sedimentary and intruded rocks, but it also spreads out in the form of a thick sheet. The upper portion of the series consists of gently dipping beds of white rhyolite, some of which is fragmental, suggesting tuffs. Specimens of different phases were submitted to Mr. Diller for microscopic examination and he conceded the probability of this being a volcanic series. Certainly its attitude and texture oppose the idea of its having been intruded beneath the great thickness of sedimentary rocks above it.

The volcanic series dips at a much lower angle than the Blue Chert series beneath it, suggesting marked nonconformity by reason of pre-volcanic uplift and great erosion. Elsewhere in the western Klamath region masses of volcanic rocks rest nonconformably on the Blue Chert series. I have never seen any evidence of volcanic rocks interbedded with this series. In one place, below Cecilville in the valley of the South Fork of Salmon River, tuffs and lavas occur under Paleozoic limestone and chert, but the contact is a nonconformity reversed by overturning. It is my impression that in the western portion of the Klamath region, all the clearly volcanic rocks are younger than the Devonian Blue Chert series.

Above the rhyolite in Pearch Creek valley, there is a formation of black slaty shale whose maximum thickness I estimate at 3000 feet. At the base there is a slight development of coarse sandstone, apparently made up of debris from the underlying quartz-bearing rhyolite. It hardly anywhere attains a thickness of 50 feet, but may be traced along the contact for several miles; and there is little doubt of its having been laid down on the surface of the volcanic series. I have found no evidence of nonconformity at this contact and it is my impression that the deposition of the sandstone followed closely that of the rhyolite.

Excepting this thin basal sandstone, the formation contains no conglomerate, sandstone and limestone, and only a few thin layers of chert. Its most characteristic feature is that it is largely composed of layers of the thickness of coarse paper. It resists weathering so well that it stands in high rugged ridges and peaks, often bare of soil, and having a rusty color on outcrop. The reddish brown high ridge at the head of Pearch Creek, a prominent feature in Orleans scenery, is largely of this formation.

So far as known, it is confined to a basin-like depression in the surface of the older rocks, in an area possibly 20 miles long (north-south) and 10 miles wide, lying west of Knownothing Creek, south of Salmon River, east of the Orleans fault and north of "Trinity Summit." As the valley of Nordheimer Creek is largely cut in it, I propose to designate it the Nordheimer formation.

Its dips are prevailingly toward the center of the basin but usually not at high angles, contrasting with the dips of the Blue Chert series lower. Their relation is certainly that of marked nonconformity although they are separated by igneous rocks.

The Nordheimer formation is badly shattered by intrusive rocks. They are clearly plutonic, being largely in the form of batholithic masses of gray and greenish, fine-grained crystal-

lines, probably in part metagabbro, diabase and diorite. In part of the area that properly belongs to the Nordheimer, the shale exists only as large inclusions. Ten miles south of Orleans, the plutonics have so thoroughly usurped the area that I gave up tracking the shales. These igneous masses must extend down into the Blue Chert series, but there is also a great amount of igneous material in the latter that has no representative in the Nordheimer. I am compelled to admit that the western portion of the Klamath region has had at least two marked epochs of igneous activity between early Devonian and late Jurassic times.

No traces of fossils having yet been discovered in the Nordheimer, its age can only be conjectured. It may be late Devonian, but that would imply a strong nonconformity in the Devonian series. It is more likely Carboniferous. Some of its characters suggest the Baird formation. It might also be a western representative of the Triassic Pit shales, but it is not likely to be any younger. These suggestions show that there is nothing definite upon which to base an argument as to its age.

On the western side of the fault, a belt from four to seven miles wide is occupied, so far as sediments are concerned, by a series which I have heretofore described as a portion of the Bragdon formation. It is about 5000 feet thick and consists of a rapid alternation of soft black slates (produced by the shearing of thin-bedded shales) and of gray crushed coarse sandstones. The latter occur from top to bottom of the formation and it is difficult to determine that they are more abundant in one quarter than in another. The coarser grains are largely various colored cherts like those common in the Bragdon conglomerates of the eastern area. In fact, this alleged western Bragdon is identical in essential characters with the eastern Bragdon except that the conglomerates of the latter are here replaced by coarse sandstones, and that it is more highly altered by shearing. I have treated the subject at such length in former papers on this region that it is unnecessary to repeat the comparison any further. Perhaps this western formation is not the Bragdon, but I am as yet so far from convinced of it that I will continue to refer to it under that name; at any rate, its identity with the original Bragdon is not essential to this paper. It has yielded no fossils except some apparent seaweed impressions several miles north of Orleans.

The original bedding planes are clearly apparent in the Orleans region so that there is no difficulty in determining the structure. In the central portion of the belt it lies at low angles, inclined to form a slight syncline. Within a quarter of a mile of the fault, near the Klamath River, it dips steeply

eastward, bent down by the thrust. Farther south the strata come up with nearly horizontal attitude to the almost vertical fault plane, leaving no doubt of the reality of the fault.

In approaching the western border of the belt, the strata are bent up and presently there appears under them a formation made up of white sericitic and green chloritic schists that are evidently sheared rhyolites and andesites. In a very short distance another fault brings down the Bragdon slates. This may be repeated several times in 20 miles, but far the larger portion of the area is Bragdon. The shearing becomes more pronounced toward the west until traces of the bedding planes are virtually destroyed. I now consider the Weitchpec schists, formerly classed as pre-Bragdon, as a portion of this series. Indeed, the apparent ancient schists of Redwood Mountain on the Korbel-Hoopa trail are probably Bragdon, although undoubted pre-Devonian schists occur in South Fork Mountain. The fact is that the Bragdon spreads over an immense area west of the Orleans fault, running as a broad belt far to the north and as a narrowing belt (in places several belts) southward to the Sacramento Valley. Along the trail from Orleans to Hoopa, one is scarcely off it except when on serpentine.

Wherever the base of this western Bragdon is exposed, it is underlaid by igneous rocks which have characters suggesting a volcanic series. In addition to fragmentals (which appear to be tuffs) and vesicular lavas, the other textures and structural relations of the members certainly oppose the idea that they have been intruded under 5000 feet of sediments. No dikes rise from the igneous rocks into the slates and there are no inclusions of the latter in the former. Furthermore, the slates pass so readily from contact with one to that with another member as to suggest an erosion interval between the two formations.

Below the volcanic series there is a great complex of intruded igneous material and of shales, bedded blue cherts and limestones identical in character with the Blue Chert series east of the Orleans fault. Its outcrop begins west of Hoopa Valley as a narrow belt and extends southward, gradually widening, to the border of the Sacramento Valley. The limestone lentils which it contains are in places quite fossiliferous, containing, if I remember rightly, early and middle Devonian faunas.

Thus we seem to have on both sides of the Orleans fault a great series (or two lithologically identical series) of shales, cherts and limestones that has everywhere been excessively intruded by igneous material. Over the complex is volcanic rock that may represent two formations on opposite sides of the fault, possessing similar characters. Over this is altered shale thousands of feet thick. *But the upper sedimentary*

*formation east of the fault is not the same as the upper forma-
tion west of the fault.* Which is the older?

It is beyond question that the Bragdon and Nordheimer can-
not be equivalents. The plane of the Orleans fault is so steep
that the horizontal displacement cannot exceed half a mile.
Five miles south of Orleans, the two formations would contact
along the fault if the serpentine dike were absent. Equiva-
lence would imply that a formation which preserved its char-
acter of alternating sandstone and shale over an area at least
20×50 miles, within half a mile lost all its sandstones except
the basal one, and then preserved invariable its new character
over 10×20 miles.

The Bragdon formation comes up to the Orleans fault on
the west along a distance exceeding 50 miles, but no trace of
it has been found east of the fault short of the "eastern Brag-
don area." The Nordheimer formation comes up to the fault
on the east, but has never been identified west of it. Yet
within two miles these formations have thicknesses respectively
of 5000 and 3000 feet. There certainly is here a problem
worth considerable effort to solve.

If faulting had not occurred, it is probable that the two
formations would somewhere be found in original contact. If
the Nordheimer is the older, it is probable that a portion of it
is buried under the Bragdon just west of the fault. If the
Bragdon is the older, it was removed by erosion previous to
the deposition of the Nordheimer east of the fault or else it
lies under the Blue Chert series, a very remote possibility.
The latter would imply that there are two cherty series of
identical characters and three systems of intrusive material.

The Bragdon is more highly altered by shearing than is the
Nordheimer, but that is no criterion of relative age. The
Bragdon was softer and less able to resist a shearing stress.
Besides, the dynamical action operated only in the territory
west of the fault.

But there is one feature about this western Bragdon which
makes it practically certain that it is younger than the Nord-
heimer. *It is absolutely without a trace of any intruded
igneous material other than granite and serpentine* (originally
peridotite chiefly). I made a similar statement in connection
with the "eastern Bragdon area" and Mr. Diller has taken
exception to it, so to be cautious I will modify the above
statement as follows: In the course of several hundred miles
travel in the western Bragdon area I have never observed any
evidence of intrusive rock except a few small masses of granite
and a few serpentine dikes, the latter usually on the borders.
This does not mean that within the Bragdon area there are no
igneous rocks other than those mentioned. In going west-

ward one will frequently arrive at a point where the strata bend up and presently igneous rocks appear. They usually have the characters of surface volcanics and always are in belts parallel to the strike of the slates and sandstones. Such features as I usually accept as criteria in the determination of the fact of intrusion in the Blue Chert and Nordheimer formations are positively absent here. Even these igneous rocks do not appear in the 4- to 7-mile belt of pure Bragdon next to the Orleans fault. I have gone 12 miles north from Orleans with out seeing anything but Bragdon and have had similar experiences on long trips in other directions. The significance of this will be apparent when I say that in the course of several hundred miles travel in Blue Chert areas and several score in the Nordheimer area, I have probably not for any five minutes been out of sight of nearby igneous rocks.

The only theory in explanation of this distribution of the intrusives which seems to me to have a natural ring is that at the time of their formation (granite, peridotite and all later igneous rocks excepted), the Bragdon formation of the western area was not in existence. Otherwise, the igneous material has exercised a most remarkable selection. I am aware that intrusives will to a certain extent concentrate into certain formations which are most easily penetrated, but this objection does not apply in this case. There is nothing about the Bragdon to make it especially resistant to melted rock. On the contrary, it is the softest and most easily broken formation of pre-Cretaceous age in the Klamath region west of the Sacramento River. Granite and peridotite found little difficulty in cutting through it. My observation of intrusives in other regions such as eastern Nevada lends no encouragement to the idea that the Bragdon resisted the penetration by such material as intimately injected every other formation of the region.

The hypothesis of "localization" is not pertinent because we are dealing with a territory several thousand square miles in extent and an asserted contrast which is not based on very limited observation. Remember, we have on one side tens of thousands of dikes and scores of large batholiths and on the other side nothing.

If the Bragdon formation goes down under the Blue Chert series east of the Orleans fault, it must necessarily be intimately intruded by the igneous rock which is so abundant in all parts of the other series. This would break down any theory based on an alleged resistance to intrusion and would make it unreasonable to suppose the intrusives rapidly gave out in the half mile accounted for by the fault. (This fault is far younger than any igneous rock entering into this discussion.) Therefore, it appears to me improbable, almost to the extent of cer-

tainty, that the Bragdon formation is older than the Blue Chert series east of the fault and its superposition proves that it is younger than the similar series west of the fault.

In the case of the Nordheimer and Bragdon we have two areas of shales practically adjoining, one badly shattered by a certain system of intrusives and the other entirely free from them. It would seem to be ignoring very strong evidence to fail to consider the Bragdon the younger.

Within several miles east of the Orleans fault, extending from Patterson's in the valley of New River, to Hall City, there is a succession of limestone outcrops from which Mr. Diller's party and the writer have collected fossils representing a very late Carboniferous or perhaps Permian fauna. Associated with the limestones are shales not very greatly differing from the shales of the Blue Chert series. It is my impression that this late Carboniferous or Permian series is just as thoroughly intruded by igneous material as the Blue Chert and Nordheimer formations ; but I regret that a lack of opportunity to visit the belt during the past few years prevents me from basing this statement on clear mental pictures of igneous rocks cutting the fossiliferous limestone. However, I distinctly remember that the belt containing the late Carboniferous or Permian rocks, especially in the New River country, contains more than the usual amount of igneous material, largely in the form of small batholiths. The Bragdon area, a few miles west, has none of them (serpentine, granite and later intrusives excepted).

Between the Blue Chert series, which I have decided must be pre-Bragdon, and the late Carboniferous or Permian rocks there is nothing suggesting the Bragdon formation and no fault or known interval of deposition to account for its absence. However, the country has not yet been so thoroughly explored as to give this argument conclusive value. I am not endeavoring to settle the question now, but to show that all the known evidence points strongly to the Bragdon formation of the western area being younger than the Blue Chert series, younger than the Nordheimer formation, even younger than the late Carboniferous or Permian limestone.

Sept. 30, 1905.

Art. V.—*A Study in the Metamorphic Rocks of the St. Francis Valley, Quebec;* by John A. Dresser.

The Quebec group as originally defined embraced several comparatively narrow belts running parallel to the folding of the Appalachians throughout the extent of that system in Canada.* They were found to consist of much altered strata of Cambro-Silurian age, which had been deposited under peculiar conditions such as to strongly distinguish them from normally deposited strata of the same age. In structure they were thought to generally form synclinal folds, often highly distorted and overturned. All lay to the east of the dislocation running from the northern end of Lake Champlain to the St. Lawrence river in the vicinity of Quebec city, which is known as the Champlain and St. Lawrence fault.

It was subsequently ascertained† that within the Quebec Group thus defined there had also been included certain older measures belonging to the Cambrian and Precambrian systems, and also frequent and extensive masses of ancient and highly altered rock of volcanic origin,‡ whose igneous character had not been previously recognized. Accordingly, in the re-examination more recently made by the Geological Survey of Canada,§ these rocks along with certain of the associated volcanics have been separated from the Quebec Group, but the progress of geological investigation has not yet admitted of a very detailed subdivision.

The most extensive of the older belts thus brought to light is that which comprises the Sutton Mountain anticline, fig. 1, the course of which, in common with the other principal axes of the Appalachians is a northeast-southwesterly one. Near the St. Francis river, which crosses it about at right angles, it is rather less than six miles wide, including a small band of Trenton whose position within the older measures has been hitherto explained as "due to an intricate system of folding and faults."‖

A section across the Sutton Mountain series and the included

* " Geology of Canada," 1863, pp. 225–297, Sir W. E. Logan.
† " The Quebec Group in Geology," Transactions of the Royal Society of Canada, vol. i, 1882, Dr. A. R. C. Selwyn.
‡ " Notes on the Microscopic Structure of some Rocks of the Quebec Group," Report Geological Survey of Canada, 1880–1–2. Dr. F. D. Adams, " The Quebec Group," Appendix A to Harrington's " Life of Sir W. E. Logan," by Sir J. W. Dawson, 1883.
§ Annual Reports Geological Survey of Canada, 1880–1–2, and 1887–8, Dr. A. R. C. Selwyn ; 1886, 1887–8 and 1894. Dr. R. W. Ells.
‖ Ann. Report Geol. Survey, 1886, p. 18 J.

Trenton in the vicinity of Richmond* forms the subject of this paper. The line of the section extends between lots ten and twenty-seven in the twelfth range of the township of Cleveland, and is about a mile and a half east of the St. Francis river, to which it is approximately parallel. The direction of the sections is N. 38° W., magnetic. The adjacent rocks at both north and south have been recently mapped in the reports of the Geological Survey as Cambrian, the black limestone, No. 3 of the section, as Trenton, and the rest as Precambrian.

1
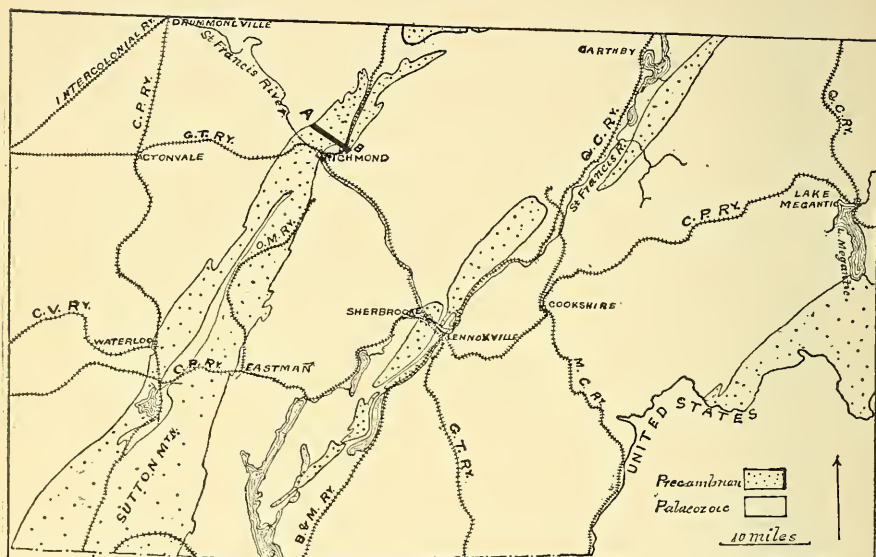
Sketch map showing the Precambrian of a portion of Southeastern Quebec as designated on the Geological Survey maps of 1886 and 1894.

1. Black Mica Schist	100	feet
2. Gray Mica Schist	1320	"
3. Black Limestone	2800	"
4. Gray Mica Schist	4590	"
5. Micaceous Dolomite	300	"
6. Black Mica Schist	600	"
7. Quartzite	180	"
8. Micaceous Dolomite	60	"
9. Gray Mica Schist	7360	"

Total Sedimentary	17310	feet
10. Amygdaloidal Trap	} 12540	"
Total Igneous		

* This locality was considered by Logan to furnish the key to the structure of the Quebec Group. Hither he returned after severing his connection with the Geological Survey, and spent four seasons in making a detailed map of the district for about five miles on either side of this section. This map, which seems to have been ready for engraving at the time of his death, was unfortunately, never published.
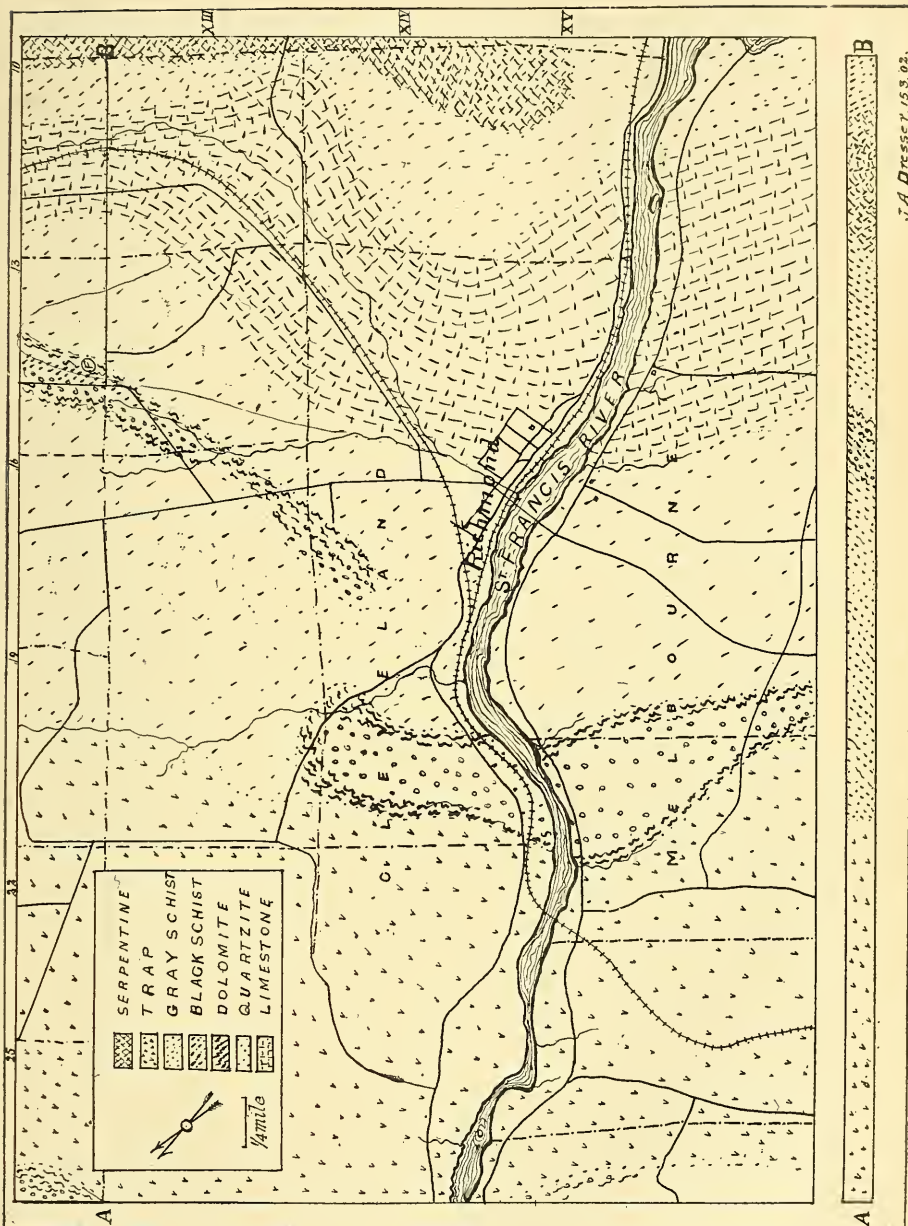
2

Map and section across the Sutton Mountain Series near Richmond, Quebec.

SERPENTINE
TRAP
GRAY SCHIST
BLACK SCHIST
DOLOMITE
QUARTZITE
LIMESTONE

¼ mile

J.A.DRESSER 15.5.02.

LITHOLOGY.

Black (Graphitic) Limestone.—This is a very dark gray, or more frequently, a black impure limestone carrying a large proportion of graphite, which is sometimes so great in amount as to give the rock somewhat of the unctuous feel of that mineral. It is consequently very soft and brittle. It is usually much wrinkled and corrugated by pressure and not infrequently has a distinct slaty structure developed at high angles to the bedding plane. It contains numerous veins of crystalline calcite and quartz, in which cases these minerals are intricately associated in the same veins without any discernible arrangement. Some of the veins carry a little pyrite.

At Melbourne village, opposite the town of Richmond, this rock is marked as fossiliferous on the Montreal sheet of the Eastern Townships map issued by the Geological Survey to accompany the Annual Report of 1894, but no determination of the fossils or indication of their age is recorded except that the notation of the map includes the rock with the 'Farnham Black Slates' of the Lower Trenton formation, D3^a.

Gray Mica Schist.—This is a schistose rock, usually much wrinkled and contorted, and cleaves very smoothly in the most intricate folds. In color it is a light or greenish gray, weathering to dark gray, or brown, tints.

Under the microscope it appears as a rather fine even-grained and much altered sandstone with a highly developed schistose structure. The grains are both feldspar and quartz and are contained in a micaceous (sericite) cement in which chlorite occurs in varying amounts. A little iron ore is present in small grains, or string-like masses, and also occasional cubes of pyrite of microscopic size. It is an undoubted clastic.

Black Mica Schist.—By an increase of dark minerals, chiefly iron, and probably by the addition of graphite, the gray mica schist passes into a black schistose rock having a submetallic lustre on its cleavage faces. Microscopically it differs little from the previous rock except in the dissemination of dark grains of the opaque minerals. In reflected light some of the larger can be easily distinguished as pyrite, or a black ore of iron, but others, the smaller and more numerous which are irregular in outline, are thought to be graphite, in part at least. The gravity of the rock is not such as to indicate any noticeable increase in heavier constituents over the preceding variety.

Occasional inclusions of dark gray or black limestone are found in the black mica schist. They vary in size from mere grains to masses several feet in each dimension. It is difficult to estimate their proportion in the rock, as they agree with it very closely in color and share in its foliation. They are not

numerous enough to warrant calling the rock a conglomerate in the usual sense of the term, yet they are quite distinct in lithological character from the enclosing rock. One of these, which occurs on Lot 15, Range xiii of the Cleveland, can be seen to occupy not less than four hundred feet, and may be considerably more extensive. Its thickness could not be ascertained, but is not less than two feet. Similar occurrences of limestone are also found in the micaceous dolomite and will be subsequently noted.

As there is no evidence of concretionary structure they must apparently be either fragments of an earlier and distintegrated limestone bed, or calcareous deposits formed contemporaneously with the enclosing rocks. The absence of any evidence of unconformity or other indication of a time-break favors the latter view.

Micaceous Dolomite.—The gray mica schist becomes dolomitic in certain parts by the intercalation of lenses of magnesian limestone. These growing more abundant and the intervening bands passing into an impure earthy magnesite, the rock eventually becomes a crystalline dolomite. In the hand specimen it is fawn-colored and shows the presence of quartz on the weathered surface. In the thin section it is made up of crystalline dolomite with about one-quarter of the slide occupied by quartz. The latter is generally well crystallized, showing that it was formed not later than the dolomite. The débris of a kiln where the dolomite was formerly burned for lime, as well as decayed portions of the rock, yield considerable numbers of well-formed, transparent quartz crystals.

Lenticular masses of rich hematite ore carrying octahedral crystals of magnetite occur in the dolomite at various places. They are found several feet in thickness and are either overlapping or nearly continuous for distances of a mile or more. Their close association with dolomite suggests their origin from altered carbonates.

The dolomite also contains pure limestone masses, as noted above, one or which is of much importance from the fact that it has long been known to contain fossils. This mass, which is found on Lot 14 in Range xii of the township of Cleveland, about three hundred yards east of the Healy schoolhouse, is some two feet in thickness and thirty in length as exposed on the face of a low escarpment of dolomitic mica schist. A communication from the late Sir William Dawson on the silicification of these fossils appeared in the Quarterly Journal of the Geological Society of London in the year 1879.* In this they were referred to as of Lower Silurian age and the genera Steno-

* "On Paleozoic Fossils mineralized with Silicates," Q. J. G. S., Feb. 1879, pp. 60–62.

pora and Ptilodictya are mentioned, but no more definite description seems to have been yet published.

Quartzite.—With the increase of quartz, the dolomite passes into a calcareous sandstone and eventually to a somewhat impure quartzite. This consists of rounded quartz grains, a few grains of feldspar, and where the rock is much deformed by pressure, or else where the original composition was slightly different, shreds of sericite are developed along the planes of foliation. The chief cementing material in typical parts has been silica, and the enlarged grains thus assume irregular interlocking forms.

A few rather large grains of feldspar, either orthoclase or microcline, are generally found in the thin section as well as occasional ones of a rhombohedral carbonate, probably dolomite. This rock is commonly interbedded with black mica schist in an intricate manner, apparently indicating transitional phases between the two classes of rocks.

Amygdaloidal Trap.—The volcanic nature of this rock, which was formerly regarded as an argillite or was more frequently designated as a chloritic schist, has been preliminarily noted[*] by the writer, but opportunity has not yet been found to complete a petrographical examination of it. It is a bluish or greenish gray rock, in some places massive, and is often highly schistose. It contains large numbers of vein-like masses of quartz and some of calcite, is amygdaloidal in many parts, and frequently contains nodular masses three or four inches in diameter which are composed chiefly of rudely concentric layers of quartz and epidote.

By the aid of the microscope, crystals of primary plagioclase can be seen whose arrangement is suggestive of the structure of diabase, but as the interstitial material is wholly secondary, chlorite, iron ore, leucoxene, etc., further evidence is desirable in order to determine its precise classification. It appears to have been somewhat variable in its original character, as fibrous hornblende occurs in considerable amount at a point about three miles west of the St. Francis river, but it may be generically classed as a basic volcanic of the andesite or diabase class. It has been extremely altered.

STRUCTURE.

The *contacts* of the various sedimentary rocks with one another are, as has been already stated, of the nature of transitions from one to another of the different types. The graphitic limestone passes upwards into mica schist by an almost insensible gradation, as can be well seen along either bank of

[*] The Ottawa Naturalist, January, 1901; this Jour., July, 1902.

the St. Francis river in the town of Richmond, or the village of Melbourne. Perhaps better evidence still is to be found in the banks of the little post-glacial gorge of the " eddy " brook in Melbourne. Here in a height of about thirty feet the rock passes from typical black limestone in the bed of the stream to black mica schist at the top of the northern bank, which owes the steepness of its slope in some measure to the differential resistance to erosion in the various strata exposed in it. Somewhat similar phenomena can be seen in the Cushing brook in Richmond, where, however, the banks are not as high. In both cases the strata dip towards the north-northwest at an angle of probably less than 30°. On the western bank of the St. Francis river* the black mica schist, which forms the transitional beds between the black limestone and the gray mica schist, contains interbedded lenses of quartzite, an association that is common in another part of the section where these two rock varieties have their chief development. The gradual passage of mica schist into micaceous dolomite and of the latter into quartzite has been already mentioned. Hence it appears conclusive that the stratified rocks of this section belong to a single cycle of deposition.

With regard to their relation to the igneous rocks in point of age, the balance of evidence thus far obtained indicates that both igneous masses are older than any of the intervening sediments. At the south the evidence is not conclusive, being wholly negative, viz., the absence of dikes, contact metamorphism, springs along the contact, or other phenomena characteristic of an intrusive contact. On the north the case is a clearer one. Besides negative evidence similar to the above, the dolomite where it approaches the trap in the township of Melbourne holds fragments of the latter rock. Also the gray mica schist on the line of section shows a marked increase in the amount of chlorite which it contains as the trap hills are approached. This is so noticeable as to make the rock difficult to distinguish from the trap in the field near the contact. As the latter is a rock that reduces to a fine debris of which chlorite is the most conspicuous mineral, this phase of the mica schist appears to have derived its character from the residual material of the trap. It is thus equivalent in evidence to a basal conglomerate.

The *dip* is naturally regarded as an observation of, at most, very doubtful value in such a highly disturbed region, unless corroborated by other evidence.

In *stratification* all the rocks on the north of the black limestone appear to dip towards the northwest, and those on

* The old ferry landing at the rear of the residence of Mrs. J. Dunbar.

the south in the opposite direction, or about southeast.   The limestone would thus form the axis of the anticline.   This view was held by Logan, while Ells takes the ground that the limestone is of much more recent formation than the other rocks of the section and has been infolded into its present position, but just in what manner has not been explained, otherwise than as by "an intricate system of folding and faults." The former placed all these rocks in the Quebec Group, of Calciferous-Chazy age, while the latter regards the limestone as Lower Trenton and all the other rocks as Precambrian.

While Logan believed all the rocks of this section to be of sedimentary origin, and also included the serpentine belt at the south in the same class, correlating it with the dolomite on the ground of the magnesian character of each, Selwyn and Ells recognized the igneous origin of the serpentine, but still included the twelve thousand feet, or more, of trap in the
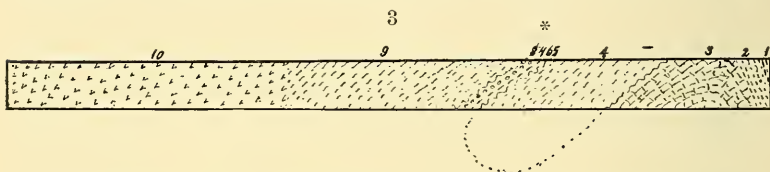
northern part of the section with the clastic rocks.   Hence the results of both investigations may be reasonably submitted for reconsideration.

There appears to the writer no reason to believe that there was any great time-break in the deposition of the sedimentary rocks of this section.   The contacts are transitional and the black limestone has suffered from dynamic metamorphism no less than the mica schists.

It is, moreover, an apparent fact that the dolomitic schist cannot be referred to the Precambrian from the presence of the fossils already referred to in the non-magnesian limestone masses included in the dolomite.   The importance of this isolated occurrence of fossils in the dolomite seems to have been lost sight of in the more recent work of the Geological Survey, by the exposure having been erroneously connected with the black limestone three-quarters of a mile distant.   For in the Sherbrooke and Montreal sheets of the Eastern Townships map of the Geological Survey of Canada (1886-1894), the locality of these fossils, Lot 14, Range xii of the township of Cleveland, is included in the Trenton area by a peculiar indentation, D-D fig. 4, in the part colored Precambrian, the boundaries of which are thus made to cross the actual stratification of the

* Fossils at this point.

rocks. The part of the dolomite, " B," immediately surrounding the locality of the fossils, and the intervening mica schists are accordingly colored Trenton in Lots 13, 14 and 15 in Ranges xii and xiii, while they, " B-B," are elsewhere mapped as Precambrian in either direction along the strike.

The *order of deposition* which best explains the structural features appears to be as follows, in ascending series :
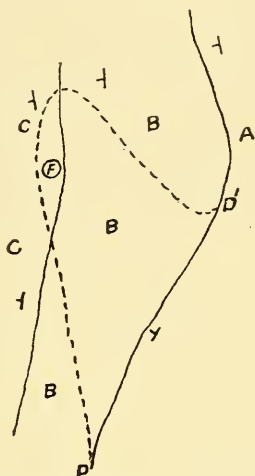
A. limestone, Trenton or Black River
B. mica schist) mapped as Precambrian
C. dolomite ∫ except within the line D-D'
F. fossils
γ. strike and dip--40°.

1. Black limestone, with black mica schist as its marginal or shallow-water equivalent.

2. Quartzite, quartzose and micaceous dolomite, which were chiefly deposited in the northern part of the section and barely extend ·to the northern side of the present exposure of the black limestone.

3. Gray or green mica schists covered the entire trough between the preëxisting igneous ridges.

Two causes present themselves to account for the real or apparent greater thickness of these schists towards the north. If, as the position of the locality with reference to the main ridges of the Appalachian uplift indicates, the Lower Silurian transgression come from the north, the original thickness probably was really greater in the northern than in the southern part of the section. Or, since all these clastics after their

deposition were crushed between the heavy masses of igneous rock on either side, an apparent thickening would naturally be produced by a succession of thrust planes, which owing to the homogeneous character of the rock would not be easily distinguished from ordinary cleavage planes. It has been shown experimentally by Cadell* that a "compressed mass tends to find relief along a series of gently-inclined 'thrust planes' which dip towards the side from which the pressure is exerted." This tendency, which was cited in explanation of the abnormal thickness of the Silurian quartzites, shales and limestones of Sutherlandshire, Scotland, seems quite applicable to the present case, where the conditions are essentially those which Mr. Cadell's experiments were designed to reproduce. The uniform cleavage, which dips towards the northwest at an angle of rather less then 40° for some three and a half miles, may be then merely one effect of a pressure exerted from the St. Lawrence valley in the process of the Appalachian uplift.

Summary.

The results of this study are therefore to show,

1. That the rocks of the Sutton Mountain anticline contain no Precambrian clastics (Algonkian), in the vicinity of the St. Francis river.

2. That Paleozoic (Quebec Group) sediments occupy a trough between two earlier igneous ridges, viz., the serpentine at the south and the trap on the north, the latter of which has not been hitherto recognized in structural examinations of the locality.

3. That the Precambrian of the region, if any, is thus confined to the volcanics, whose age has not yet been further investigated since their eruptive origin has been known.

Montreal, Canada.

* Transactions of the Royal Society of Edinburgh, 1888. "Experimental Researches in Mountain Building," H. M. Cadell.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *The Hydrides of the Alkaline Metals.*—Having previously prepared and described the colorless, crystalline hydrides of potassium and sodium, KH and NaH, MOISSAN, in continuing this line of work, has found that hydrides of cæsium and rubidium exist, CsH, and RbH, and that these have entirely similar chemical and physical properties. The author gives some general reactions of these interesting compounds. They are all powerful reducing-agents, and decompose water in the cold with the evolution of hydrogen :

$$RH + H_2O = ROH + H_2.$$
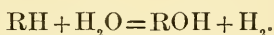
They decompose also the hydrogen acids :

$$RH + HCl = RCl + H_2$$
$$RH + HCOOH = HCOOR + H_2.$$
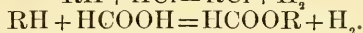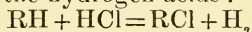
They react with gaseous ammonia :

$$RH + NH_3 = NH_2R + H_2.$$
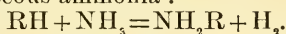
When heated very gently in the presence of carbon dioxide they yield alkaline formates :

$$RH + CO_2 = HCOOR$$
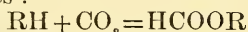
and upon slightly raising the temperature they give mixtures of formate and oxalate :

$$2KH + 2CO_2 = K_2C_2O_4 + H_2.$$
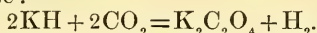
Further, an alkaline hydride when heated in an atmosphere of carbon monoxide gives a slight deposit of carbon, and is partially transformed into formate :

$$2CO + KH = HCOOK + C.$$
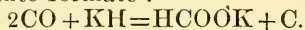
Sulphur dioxide reacts at ordinary temperatures, under certain conditions of pressure, with the production of hydrosulphites :
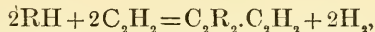
$$2RH + 2SO_2 = R_2S_2O_4 + H_2.$$
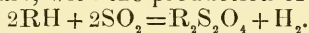
Certain organic compounds containing halogens react with the alkaline hydrides at temperatures above 150° :

$$RH + C_2H_5I = C_2H_6 + RI ;$$
$$RH + CH_3Cl = CH_4 + RCl.$$
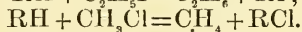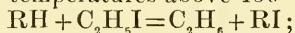
In contact with cyanogen gas in the cold they give cyanides and hydrocyanic acid :

$$RH + C_2N_2 = RCN + HCN.$$
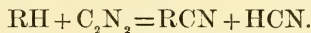
With acetylene at ordinary temperatures the following reaction takes place :

$$2RH + 2C_2H_2 = C_2R_2.C_2H_2 + 2H_2,$$

and, when gently heated, the double compound gives off acetylene and leaves a carbide, C_2R_2.

The author has shown, further, that the alkaline and alkaline earth hydrides do not conduct electricity and cannot be classed with the alloys. Consequently, in its combinations hydrogen ought not to be considered as a metal.—*Ann. Chim. Phys.*, VIII, vi, 289.   H. L. W.

2. *The Boiling-points of the Alkaline Metals.*—On account of experimental difficulties, the boiling points of sodium and potassium have not been accurately determined, and no attempts have been made to determine this constant for lithium, rubidium and cæsium. RUFF and JOHANNSEN, having found that the vapors of these metals do not act upon metallic iron, have distilled the metal in wrought-iron retorts consisting of long tubes enlarged at the bottom, and have measured the temperatures of the vapors by means of a thermo-electric couple protected by a steel tube and introduced into the vapor. Accurate results were apparently obtained in all cases except that of lithium, which boils at too high a temperature for the application of this method. The boiling-points found were as follows : cæsium, 670° ; rubidium, 696° ; potassium, $757\frac{1}{2}°$; sodium, $877\frac{1}{2}°$; lithium, higher than about 1400°. When these boiling-points are plotted with the atomic weights a curve is produced which slowly rises from cæsium, through rubidium to potassium, then becomes steeper to sodium, and finally rises very steeply to lithium. The curve is quite similar to that of the melting-points, but it does not permit the calculation of the boiling-points as a function of the atomic weights by means of a simple mathematical formula.—*Berichte*, xxxviii, 3601. H. L. W.

3. *The Rusting of Iron.*—The slow oxidation of iron at ordinary temperatures was at first regarded as a simple process, but more recently iron has been generally supposed to rust through the combined action of carbon dioxide, moisture and oxygen. DUNSTAN, JOWETT and GOULDING have recently performed numerous experiments upon this subject, and their results show conclusively that iron, oxygen and liquid water are alone necessary for the rusting of iron to take place. Under atmospheric conditions carbon dioxide plays a quite subordinate part in this process. It appears that the simplest representation of the process involves the intermediate production of hydrogen peroxide ; for example :

$$Fe + H_2O = FeO + H_2 ;$$
$$H_2 + O_2 = H_2O_2 ;$$
$$2FeO + H_2O_2 = Fe_2O_2(OH)_2.$$
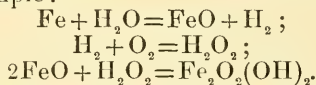
Although the authors showed that hydrogen peroxide was formed in the similar oxidation of several other metals, they did not prove the existence of this compound in the case of iron. From the analysis of a number of samples of rust, it appears that its composition corresponds closely to the formula $Fe_2O_2(OH)_2$, or in another form, $Fe_2O_3.H_2O$.—*Jour. Chem. Soc.*, lxxxvii, 1548.

H. L. W.

4. *The Cause of Color in the Iron-Cyanogen Compounds.*—After having made a study of the various blue compounds containing iron and cyanogen, HOFMANN and RESENSCHECK have reached the conclusion that the cause of the color is the presence of iron atoms in different states of oxidation in the same molecule. They call attention to the fact that an even more intensely col-

ored product is obtained when the ferrous and ferric atoms are combined, not by cyanogen but by oxygen, as in the long-known *Aethiops martialis,* which is produced by adding an alkali to a solution containing both ferrous and ferric salts. They mention also surprisingly similar instances of colored compounds in "red lead" which contains lead in the bivalent and quadrivalent conditions ; in the indigo-blue, S_2O_3, in which the sulphur is in different states of oxidation ; in uranous-urannic oxide, U_3O_8, etc. —*Liebig's Ann.* cccxlii, 364.   H. L. W.

5. *Researches on the Affinities and on the Causes of the Chemical Similarity or Dissimilarity of Elements and Compounds ;* by GEOFFREY MARTIN. 8vo, pp. 282. London 1905. (J. & A. Churchill.)—In dealing with this work the reviewer is warned to be cautious, for the author says in his preface ; " My conclusions are somewhat at variance with the current notions of chemists, and this will, perhaps, lay me upon [open] to attack. My critics will find, however, that they are dealing with a prepared opponen who will mast[er] them on their own ground." This extract gives some instances of the extraordinary number of mistakes in printing that are to be found in the book, and these with a multitude of mistakes in grammar and spelling interfere seriously with reading the work. The author has taken the periodic system of the elements and has made for each element what he calls an affinity surface by erecting perpendiculars upon the plane of the periodic system of such length that they represent the relative affinities of the other elements for the elements in question, and by passing a surface through the ends of the perpendiculars, producing an irregular form. As far as we can see, these surfaces lead to no new insight into the periodic law. Numerous conclusions are reached, not all of which are novel, among which the following may be mentioned : Chemically unstable compounds are volatile and fusible; chemically stable compounds are fixed and fusible with difficulty. Compounds of a high valency grade are more volatile than compounds of a low valency grade. The physical and chemical properties of an element depend upon the forces with which it attracts other elementary kind of atoms. Chemical similarity is invariably accompanied by physical similarity. Volatility, fusibility, etc., depend on the attractive forces the atoms exert, and not to any great extent upon their molecular weight. It seems to the reviewer that the author has shown a decided tendency to fit facts to his theories, and to overlook contradictory facts.   H. W. F.

6. *Verflüssigtes Ammoniak als Lösungsmittel ;* von J. BRONN. 8vo, pp. 252. Berlin, 1905. (Verlag von Julius Springer.)—This book gives a very full account of what is known about liquefied ammonia, particularly as a solvent. The work will be of great convenience to those who wish to obtain information on this subject, since such information has heretofore been scattered through many journals in several languages. The book furnishes also a convenient source of references to the literature.   H. L. W.

7. *Annual Reports of the Progress of Chemistry for 1904.* 8vo, pp. 280. London, 1905, Gurney & Jackson (D. Van Nostrand Co., N. Y.).—We have here the first annual volume of a condensed review of the progress of chemistry, prepared under the direction of the London Chemical Society. The branches treated are General and Physical Chemistry, Inorganic Chemistry, Organic Chemistry—Aliphatic Division, Organic Chemistry—Aromatic and other Cyclic Divisions, Stereochemistry, Analytical Chemistry, Physiological Chemistry, Agricultural Chemistry and Vegetable Physiology, Mineralogical Chemistry, Radioactivity. Each section has been prepared and is signed by a specialist in the line of work under discussion. The work is to be heartily welcomed, since it is the only thing of the kind in the English language, and it will be useful to many who are interested in the progress of the various branches of the science.

H. L. W.

8. *A New Kind of X-ray.*—W. Seitz believes that he has proved the existence of rays analogous to the X-rays which can be produced by as low voltages as 600 volts; the tube or bulbs he employed were from 5 to 7 centimetres in diameter, but he does not state the distance between the electrodes. Photographic plates were exposed to the rays in a vessel which was deprived of air; for air, as in the case of ultra-violet rays of light, greatly absorbs the new rays. A marked effect was observed on certain forms of bacilli. They were destroyed on the surface of the preparation containing them; since the preparations absorb the rays, the medical uses of the rays seem to be limited.—*Physikalische Zeitschrift*, Nov. 9, 1905, No. 208, p. 756. J. T.

9. *Magnetizing by Rapidly Oscillating Currents.*—The magnetic detector discovered by Rutherfurd and utilized in wireless telegraphy by Marconi has been investigated by E. Madelung, with reference to changes in the hyteræsis curve produced by the rapidly oscillating currents of condenser discharges. By an ingenious disposition of the magnetic detector its rapidly changing magnetism caused a movement of the fluorescent spot in a Braun tube giving the ordinary magnetizing curve with the change due to the oscillating currents superposed upon it. The author calls the magnetizing curve produced by steady currents the static magnetizing curve, and the magnetizing curve due to the rapidly changing magnetism, the dynamic curve. Curious loops are produced by the oscillating currents which fall outside the area of the static magnetizing curve which are due to eddy currents. These loops cause a discontinuity which accounts for the detector action of the bundle of fine steel wire constituting the core of the instrument.—*Ann. der Physik*, No. 10, 1905, pp. 861, 890. J. T.

10. *Influence of the Earth in Wireless Telegraphy.*—J. S. Sachs finds that with short waves it is desirable to insulate the apparatus as high as possible above the earth and to dispense with the earth connection of the apparatus. If the apparatus is in the

neighborhood of high masts it should be insulated from the earth and the resonance of the wires leading to the parts of the apparatus should be obviated. Wires which are at right angles to the antennæ and to the line connecting sending and receiving intruments exercise no influence. Trees and buildings diminish the energy received if they lie between the sending and receiving instruments ; if they lie behind the apparatus at sending and receiving stations they can in certain cases form standing waves which strengthen the result.—*Ann. der Physik,* No. 12, 1905, pp. 348–371. J. T.

11. *Elektrische Kraftübertragung ;* von WILHELM PHILIPPI. Pp. viii, 386, 321 figures, 4 plates. Leipzig, 1905 (S. Hirzel).— The literature of electricity, particularly on the technical side, owes much to the contributions which have been made from the German press. The present volume illustrates this well, being a very thorough and admirable presentation of a subject of more than usual importance. The author deserves praise not only for the clear presentation of the facts which he sets before the reader, but also for his discrimination in omitting many things which would have required much space and are of minor importance. Thus, although presenting in simple form some of the fundamental principles involved, for the benefit of the non-specialist, he omits the descriptions of individual machines and apparatus which are to be found in the catalogues of makers. Furthermore, while going very fully into the subject of the various plants in Germany and abroad, where electricity is being used as motive power, he limits himself to establishments where the conditions are peculiar and of special interest, leaving those which involve only the usual principles with brief notice only. The mining and smelting establishments and rolling mills are treated with particular fulness ; the dicussion of the two last having been prepared by Dr. Georg Meyer. A detailed account as to what the work contains would involve enumeration of the various forms of single phase and multiple phase motors, transformers, etc., but a general statment must suffice. The presentation is throughout clear and thorough and illustrations are used very freely, the comparatively large size of the page giving good opportunity for this.

II. GEOLOGY AND NATURAL HISTORY.

1. *United States Geological Survey.*—Recent publications of the U. S. Geological Survey are contained in the following list.

FOLIO : No. 126.—Description of Bradshaw Mountains Quadrangle; by T. A. JAGGAR, JR. and CHARLES PALACHE.

PROFESSIONAL PAPERS: No. 37.—The Southern Appalachian Forests ; by H. B. AYRES and W. W. ASHE. Pp. 291, with 37 plates and two figures.

No. 41.—Geology of the Central Copper River Region, Alaska; by Walter C. Mendenhall. Pp. 133, with 20 plates and 11 figures. See below.

No. 42.—Geology of the Tonapah Mining District, Nevada; by Josiah Edward Spurr. Pp. 295, with 24 plates and 78 figures. See below.

Bulletins—No. 268.—Miocene Foraminifera from the Monterey Shale of California, with a few Species from the Tejon Formation; by Rufus M. Bagg, Jr. Pp. 76, with 11 plates and 2 figures.

No. 270.—The Configuration of the Rock Floor of Greater New York; by William Herbert Hobbs. Pp. 96, with 5 plates and 6 figures.

Water Supply and Irrigation Papers.—No. 123.—Geology and Underground Water Conditions of the Jornada del Muerto, New Mexico; by Charles Rollin Keyes. Pp. 42, with 7 plates and 11 figures.

No. 137.—Development of Underground Waters in the Eastern Coastal Plain Region of Southern California; by Walter C. Mendenhall. Pp. 140, with 7 plates and 6 figures.

No. 138.—Development of Underground Waters in the Central Coastal Plain Region of Southern California; by Walter C. Mendenhall. Pp. 162, with 4 plates and 5 figures.

No. 139.—Development of Underground Waters in the Western Coastal Plain Region of Southern California; by Walter C. Mendenhall. Pp. 103, with 8 plates and 1 figure.

No. 140.—Field Measurements of the Rate of Movement of Underground Waters; by Charles S. Slichter. Pp. 122, with 15 plates and 67 figures.

No. 141.—Observations on the Ground Waters of Rio Grande Valley; by Charles S. Slichter. Pp. 83, with 5 plates and 32 figures.

No. 142.—The Hydrology of San Bernardino Valley, California; by Walter C. Mendenhall. Pp. 124, with 12 plates and 16 figures.

No. 145.—Contributions to the Hydrology of Eastern United States, 1905. Myron L. Fuller, Geologist in charge. Pp. 220, with 6 plates and 42 figures.

No. 151.—Field Assay of Water; by Marshall O. Leighton. Pp. 76, with 4 plates and 3 figures.

No. 152.—A Review of the Laws forbidding Pollution of Inland Waters in the United States; second edition; by Edwin B. Goodell. Pp. 149.

2. *Geology of the Central Copper River Region, Alaska;* by Walter C. Mendenhall. U. S. G. S. Professional Paper No. 41, 127 pp., 20 pls., 11 figures in text.—This paper gives a general description of the geology of a district which lies near the southeast corner of the main mass of Alaska. An account of the economic geology of the area is included which has been in great part reprinted from an earlier paper entitled, "The Mineral

Resources of the Mount Wrangell District, Alaska." With the paper are also published reconnaissance maps of the Copper River region.

The rocks of this district range in age from the earliest Paleozoic down to the Pleistocene. The oldest rocks are metamorphosed sedimentaries including schists, slates, conglomerates and feldspathic sandstones. The Carboniferous period is represented by a large amount of volcanic rocks both as flows and as beds of fragmental material. During the Permian marine conditions prevailed and heavy white limestones and fossiliferous black shales were formed. The study of the fossils in these rocks show that these beds are allied with the Asiatic Indian beds rather than with the eastern North American Permian. Sedimentation in a gradually shoaling sea continued into the Triassic, at the end of which time the previously formed rocks were folded and elevated. Erosion followed and finally another period of sedimentation occurred in Jura-Cretaceous time, during which coarse conglomerates were laid down. With the close of the lower Cretaceous this part of the continent became a land mass and has remained so ever since. During Tertiary time considerable movement took place accompanied by the effusion of hundreds of cubic miles of Wrangell lavas, usually of andesitic type, and causing the formation of the great central mountain group of the region. Pleistocene silts, clays and gravels are found in the valleys.

Copper is likely to prove the most important metalliferous deposit of the area. The copper deposits are found in the foothills to the south of the Wrangell Mountains and are everywhere associated with an altered igneous rock called the Nikolai greenstone. It is believed that the copper was originally disseminated in minute quantities throughout this formation and that the valuable deposits represent the concentration of this material. The richer ore bodies generally lie in the upper part of the greenstone near its contact with an overlying limestone. The deposits may be divided into two classes; tabular deposits which are continuous for some distance and "bunch" deposits which are irregular in shape and distribution.

Gold has only been found in placer deposits, the most important district being the Chistochina field which covers a small area in the northwestern part of the Copper River basin. The yield from this district from its discovery in 1900 to the end of 1902 is estimated as about $365,000. W. E. F.

3. *Geology of the Tonapah Mining District, Nevada;* by JOSIAH EDWARD SPURR. U. S. G. S. Professional Paper No. 42. 278 pp., 14 pls., 78 figures in text.—This recent publication is a timely description of a new and rapidly developing silver district of western Nevada. The ore deposits of Tonapah were first discovered in the spring of 1900 and before the end of the first year of work had produced ore with a value of several million dollars.

The rocks immediately about Tonapah are all volcanic in char-
acter. They are of Tertiary age as is proven by their relations
to the sedimentary rocks of surrounding areas. The earliest lava
is an andesite which came probably in the early Miocene and in
this rock the fracture zones were formed along which the valu-
able veins of the region were deposited. After the formation of
the veins a second eruption of an andesite of somewhat different
composition took place, following which came another period of
quiet and erosion. Eruption was resumed by ejection of sili-
ceous dacite and fragmental material. Later a more glassy
dacite was poured out on the surface as thin sheets or through
explosion deposited as tuffs. Hot waters ascending along the
contact of this lava formed quartz veins carrying gold and silver.
These veins, however, are relatively unimportant in the district.
In a lake, formed subsequent to these last eruptions, several hun-
dred feet of sediments were laid down which were later lifted,
eroded and with the whole district tilted to the west at an angle
of 20°. Then followed another period of volcanic activity,
chiefly explosive in type and subsequently the volcanic vents
themselves were filled by lava columns. At this period the rocks
were broken into blocks and faulted.

The most important veins occur in the earlier andesite and do
not extend into the overlying rocks. They were deposited by
hot waters which succeeded the intrusion of the andesite and
ascended along zones of fracturing in it. In many cases the vein
consists simply of a zone of more or less altered andesite. This
zone is cut by parallel fractures having the same strike and dip
as the walls, which in turn are nothing more than strong fractures
of the same kind. In other cases the action has proceeded fur-
ther and a part or at times the whole of the andesite is
replaced by quartz. Cross fractures evidently greatly influenced
the circulation along the main fissure zones and so in part con-
trolled the localization of the rich ore bodies.

The primary ore minerals are chiefly sulphides of silver, anti-
mony, copper, iron, lead and zinc, silver selenide and gold, while
the chief gangue minerals are quartz and adularia. Where the
veins have been exposed to the oxidizing action of surface waters
some alteration of the original minerals has taken place, cerargy-
rite becoming plentiful and some secondary silver sulphides being
found.   W. E. F.

4. *The Lead, Zinc and Fluorspar Deposits of Western Ken-
tucky;* by E. O. ULRICH and W. S. TANGIER SMITH. U. S. G. S.
Professional Paper, No. 36, 218 pp., 15 pls., 31 figs.—This paper
is a description of the general geology and mineral deposits of
an area situated in western Kentucky and extending into the
southern portion of Illinois. The region is one of Carboniferous
sedimentaries, made up chiefly of limestones with subordinate
amounts of sandstone and shale. Structurally these rocks are in
the form of two truncated domes but have been extensively
broken up and displaced by complicated faulting. Vertical dikes

and horizontal sheets of a dark colored, holocrystalline variety of peridotite are found in the northern part of the area.

The chief economic mineral of the district is fluorite, but in places barite, galena, sphalerite and smithsonite have been mined. These minerals occur in one of three ways : (1) Fissure veins where the deposits fill fissures due to faulting ; (2) ores cementing breccias which have been caused by the shattering of the rock in a fault zone ; (3) metasomatic replacement of limestone by zinc minerals. The first of these types is the most productive. The source of the ore minerals is thought to have been one or another of the limestone formations, the mineral material having been transported and deposited in its present positions through the agency of underground waters.

The area is considered to form a minor division of the lead and zinc districts of the Mississippi Valley but differs from the others in these respects: (1) In the presence of basic igneous dikes ; (2) in the constant association of the lead and zinc ores with fluorite, the latter occurring in well-defined fissure veins ; (3) in the common occurrence of sphalerite in fine grains, largely as a metasomatic replacement of the limestone in or adjacent to the fissure veins. W. E. F.

5. *Die chemische Beschaffenheit von Eruptivgesteinen Finnlands und der Halbinsel Kola im Lichte des neuen amerikanischen Systemes ;* von V. HACKMAN, Bull. Com. géol. de Finland No. 15, 1905, 8°, pp. 143.—In this work the author has collected all the analyses of igneous rocks of Finland and the Kola peninsula which have been made, many of them heretofore unpublished. These are presented in tabulated form accompanied by their calculated norms and classification according to the new American quantitative system for the classification of igneous rocks. Collected into convenient shape these analyses will be a useful addition to the library of every working petrologist.

In his introductory chapter the author has much to say in praise of the new system ; he doubts, however, whether it can wholly replace the older one and suggests that the two should be used together, each supplementing the other, the older being modified to make it as quantitative as possible. L. V. P.

6. *Preliminary Announcement Concerning a New Mercury Mineral from Terlingua, Texas ;* by W. F. HILLEBRAND.—The mercury minerals of the Terlingua District, Texas, are noted for the unusual composition of several of their number. Besides cinnabar, calomel, and mercuric oxide, two oxychlorides, eglestonite and terlinguaite, have been described in detail by Prof. A. J. Moses (this Journal, xvi, 253, 1903), and a third, as yet unnamed, has been provisionally identified by him as likewise an oxychloride. This last, the No. 5 of Prof. Moses, seems to be the chief mineral on a number of specimens from the Terlingua District lately received for identification from Mr. H. W. Turner. Its examination reveals a composition most singular and apparently representative of a class of compounds hitherto unknown in na-

ture, viz: mercur-ammonium salts. So far as yet known, the qualitative composition is represented by the components Hg, N, Cl,SO$_4$, probably O and possibly H. The tests, both qualitative and quantitative, thus far made, seem to show, with little room for doubt, that the mercury and nitrogen form the mercur-ammonium radical. Dr. P. G. Nutting, of the Bureau of Standards, has kindly examined spectroscopically the products of progressive heating of the mineral under reduced pressure ; and besides nitrogen, mercury, chlorine and sulphur, obtained a small amount of helium. Singularly enough, this last seemed to come off wholly during the first warming of the mineral and before it underwent any visible breaking-up.

The complete examination of this novel mineral and its associated mercury compounds will probably consume much time. In order to reserve the field for the chemical examination by myself and the crystallographical (now in progress) by Mr. W. T. Schaller, this preliminary announcement is made.

U. S. Geological Survey, Washington, D. C.,
December 14, 1905.

7. *The Rodeo Meteorite.*—The Rodeo meteorite, described by O. C. FARRINGTON in the Publications of the Field Columbian Museum (Geol. Ser., iii, No. 2), is an iron mass found about 1852 near the hamlet of Rodeo, Durango, Mexico. With this specimen the State of Durango has now yielded six meteorites, all but one of them being masses of meteoric iron ; of these that known as the Bella Roca was found at a point about forty miles distant but though there are similarities in structure and in composition, they are not enough to make a common origin probable. The Rodeo meteorite is a medium octahedrite, with much schreibersite and some graphite but no troilite was noted. An analysis by H. W. Nichols gave the following results : Fe 89·84, Ni 8·79, Co 0·28, Cu 0·07, P 0·80, S 0·02, C 0·09 = 99·89. The high percentage of phosphorus corresponds to the large amount of schreibersite noted. For many years after the discovery of the iron, it was made to do duty as an anvil at a forge and its present appearance gives evidence of the use to which it was put. Its dimensions are $12 \times 9 \times 8$ inches.

8. *The Shelburne Meteorite.*—A detailed account of the meteorite which fell near Shelburne, Ontario, on August 13, 1904, is given by L. H. Borgström in the Transactions of the Royal Astronomical Society of Canada for 1904 (pp. 69–94). The phenomena connected with the fall were striking and were observed at a large number of places in the neighborhood of Shelburne ; the peculiar sound accompanying it, for example, was heard over an area having a radius of 35 miles. Two independent stones were found weighing respectively 13 lbs. and 28 lbs. ; they penetrated in their fall about two feet into the ground. These specimens conform to the general habit of such stones in the appearance of the crust and pittings. A microscopic examination of the crust showed that four zones could be distinguished : the outer black

crust; a second thin layer (0·02 to 0·03^{mm} thick) of brownish glass, slightly birefringent; a third layer, 0·02 to 0·10^{mm} in thickness, consisting of grains of the silicates, olivine and enstatite; a fourth layer, from 0·1 to 0·4^{mm} in thickness, consisting of the silicates but with an abundance of opaque matter among them; this is partly metallic, partly amorphous and glassy. As a whole the stones belong to the group of veined-gray chondrites, consisting largely of round chondrules mixed with others of angular or fragmentary form. The analyses of the soluble and insoluble portions made it possible to obtain an approximate determination of the mineralogical composition, as follows: Olivine 45·0 p. c., enstatite 27·8, aluminium silicate 13·0, nickel-iron 8·5, troilite 4·5, chromite 0·8, schreibersite 0·4 = 100. The olivine approaches fayalite with a ratio of Mg : Fe = 3 : 1. The nickel-iron gave the composition Fe 91·08 p. c., Ni 8·44, Co 0·48 = 100. The specific gravity of the entire stone was determined as 3·499.

9. *Bulletins of the New York State Museum.*—No. 83.—Pleistocene Geology of Mooers Quadrangle; by J. B. Woodworth. Pp. 60, pls. 25, and 1 map.

No. 84.—Ancient Water Levels of the Champlain and Hudson Valleys; by J. B. Woodworth. Pp. 265, pls. 28, and 1 map.

No. 85.—Hydrology of the State of New York; by G. W. Rafter. Pp. 902, pls. 45, maps 5, text-figs. 74.

No. 87.—Archeology to Perch Lake Mounds; by W. M. Beauchamp. Pp. 82, pls. 12.

No. 88.—Check List of the Mollusca of New York; by E. J. Letson. Pp. 112.

No. 89.—Aboriginal Use of Wood in New York; by W. M. Beauchamp. Pp. 87–272, pls. 35.

No. 91.—Higher Crustacea of New York City; by F. C. Paulmier. Pp. 117–189.

10. *Bibliographical Index of North American Fungi ;* by William G. Farlow; Vol. i, Part 1, *Abrothallus* to *Badhamia,* pp. xxxv + 312. Washington, 1905 (published by the Carnegie Institution).—The publication of this valuable Index, which has been in preparation for more than thirty years, is an event of much importance not only to the professional mycologist but also to the more general botanist. The purpose of the work is very comprehensive; it aims to include all the references to North American Fungi, except those which are wholly lacking in interest from the standpoint of systematic mycology. As originally planned the Index was to include only those species which occur north of Mexico. The limits were afterwards extended and now take in the West Indies and the whole of the North American continent north of the Isthmus of Panama. The magnitude of the work is at once apparent when it is considered that this first part scarcely goes beyond the first letter of the alphabet.

So far as possible the Sylloge Fungorum of Saccardo and the Pflanzenfamilien of Engler and Prantl have been followed in their limitations of genera and species and in their classification.

With regard to synonymy the author is conservative and introduces but few new names. The principle of adopting the oldest specific name is employed, although many old names which are indefinite or uncertain in their application are discarded. The consequence is that some of the new combinations which have recently been proposed by other writers are here reduced to synonyms.

One of the the most interesting features of the present part is the treatment given to the large genus *Aecidium* of Persoon, occupying nearly ninety pages of the text. In many of our species of this genus the life-history is incompletely known, but wherever the teleutosporic form of a species has been determined or is strongly suspected this fact is fully indicated by cross-references. It is noted, however, that our conception of species in the Rusts is being modified by infection experiments, so that the accepted nomenclature of some of the aecidial forms may be subject to change in the future. Another large genus treated is *Agaricus*, L., which has over sixty pages devoted to it. The genus is understood in its restricted sense with *A. campestris*, L. as the type. Most of the species, therefore, which are listed under this generic name, are referred to other genera by cross-references.

The Index is much more than a compilation. It is interspersed throughout with critical notes which deal more particularly with questions of nomenclature and with the determination of specimens distributed in exsiccati. The majority of these notes are by Professor Farlow himself. The others are by Mr. A. B. Seymour, to whom much of the work of indexing is also accredited. The succeeding parts of the Index will be awaited with interest. A. W. E.

11 *The Oyster, a Popular Summary of a Scientific Study;* by WILLIAM K. BROOKS. Second and revised edition. Pp. 225, with 15 plates. Baltimore, 1905 (Johns Hopkins Press).—This well known popular illustrated work on the anatomy, development, and cultivation of the oyster, of which the first edition appeared nearly fifteen years ago, is reprinted without essential change. The cause of the decline of the oyster industry in Chesapeake Bay and the remedies proposed are discussed in a most interesting and conclusive manner. W. R. C.

CONTENTS.

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Art. VI. — *On Wollastonite and Psuedo - Wollastonite, — Polymorphic Forms of Calcium Metasilicate;* by E. T. Allen and W. P. White, with optical study by Fred. Eugene Wright.

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

Introductory.†—Wollastonite is said to occur in massive rocks as an original constituent, but is perhaps confined to nepheline syenite such as is described from Alnö by Törnebohm, who found it as inclusions in feldspar, in nepheline and in ægirine. Similar rocks have been described by Mügge and others. It is also not uncommon in the crystalline schists. In some such cases, like that described by Cross from Brittany, the wollastonite is a secondary product and forms pseudomorphs after plagioclase. Among the crystalline limestones of the ancient schist series it is abundant, and it is found also in related rocks of the same series, such as garnetite and calcareous slates. Heinrich Wulf‡ has also described it as an original constituent of the crystalline schists in Hereroland in Southwest Africa, and one of his rocks consists of nearly equal parts of wollastonite and diopside.

Wollastonite is most abundant in and most characteristic of contact metamorphic limestones, either along the periphery of massives or in fragments included in a variety of eruptive rocks. It is thus usually classed as a contact mineral. It often forms well-shaped crystals of visible size, but no pseudo-wollastonite

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is known in nature nor any paramorph of wollastonite after pseudo-wollastonite. On the other hand, pseudo-wollastonite in crystals no less than a centimeter in width has been observed in artificial slags by Vogt and others.

Had the schists containing wollastonite crystallized at temperatures above 1180°, it would seem from the following investigation that the calcium silicate must have separated out as pseudo-wollastonite, and that even had it afterwards gone over by paramorphism into wollastonite, the original form must have left its traces. Such, too, must have been the case had the contact metamorphosis of limestones taken place at a higher temperature or had the fragments of limestones, often very small, which are included in effusive rocks, been heated above this critical temperature. Such included fragments are often sharply angular, and there is no probability that they were ever melted. Of course, the character of a melt is greatly modified by the constituents present, so that the admixture of other substances than calcium silicate must be taken into account; but it would appear that other substances, such as iron compounds, could only reduce the melting temperature of the mixture, making it safe to conclude that wollastonite can under no circumstances have formed above 1180°. The effect of pressure is probably without influence upon this conclusion in view of the very low vapor tension of the mineral at its inversion temperature. The present investigation therefore adds a very considerable amount of exactness to our knowledge of the temperatures at which the metamorphism of limestone has gone on. If the wollastonite of the nepheline syenite is primitive, at least one family of deep-seated intrusives has also been injected at temperatures lower than 1180°.

Messrs. Day and Shepherd have shown that wollastonite is very generally stable, and apt to make its appearance under a wide range of circumstances from melts of very different compositions. This, too, is in entire accord with the geological evidence afforded by contacts along which the chemical conditions vary greatly and rapidly, while wollastonite, through its frequency, exhibits, in nature as well as in the laboratory, a strong tendency to form under varying conditions.

Preparation of Wollastonite.—Attempts to synthesize the mineral wollastonite ($CaSiO_3$) generally result in the formation of a substance, apparently uniaxial, which has never been found in nature. Even when the natural wollastonite is fused and cooled again, it is almost invariably the uniaxial form which crystallizes. The genuine wollastonite has been observed as an accidental product of slow cooling in glasses, and crystals

of it, in a few instances,* have been obtained by intention from artifical magmas, usually without any clear insight into the causes of its formation. Hussak † obtained it as one of the products from a mixture of silicates and borates of calcium and sodium ; Doelter‡ from a magma made of lime and silica with fluorides of calcium and sodium. Methods of this kind will evidently yield mixtures more or less complex of which wollastonite is only one constituent and in which the experimenter is confined entirely to optical methods for the examination and identification of the mineral.

In connection with an extended study of the pyroxenes, it was our purpose to prepare wollastonite, determine its properties, and discover, if possible, its relation to the artificial form.

Suspecting that temperature was the determining factor,§ we first prepared a glass of the composition $CaSiO_3$, and by heating this at a temperature of 800° to 1000° succeeded in getting true wollastonite in pure condition and in portions of 50 grams at a time. The glass, to be sure, is a little difficult to prepare on account of the strong tendency of the liquid to crystallize. Although once we obtained 100 grams of it by simply cooling in the furnace where it was melted, it almost always crystallizes prematurely when thus treated. The safest way is to melt smaller portions and then chill suddenly in cold water.

For the preparation of the glass, we used the purest quartz and calcium carbonate obtainable. The latter contained only a few hundredths of a per cent of alkali and magnesium, the quartz, about two-tenths of one per cent of total impurities, chiefly oxide of iron. The ingredients were weighed in exact proportions and melted in a platinum crucible. It requires over 1500° to melt this mixture, a temperature readily reached by a Fletcher gas furnace.‖ When the contents of this crucible are quite fluid, the crucible is seized with tongs and plunged into cold water, care being taken not to agitate the liquid silicate. In this way, one obtains a brilliant colorless glass. Frequently a portion will crystallize in spite of the efforts of the operator, but if the quantity is small and not too much scattered, it can be separated mechanically from the glass with little trouble. The glass needs now only to be heated in a platinum crucible over the flame of a Bunsen burner, when it crystallizes directly and quite rapidly to wollastonite.

* Morozewicz, N. Jahrb. f. Min. 1894, ii, 223. Vogt, Die Silikatschmelzlösungen i, p. 45.
† Hussak, Zeitschr. für Kryst. und Min., xvii, 101.
‡ Doelter, Tschermak's Mitt. Petr. Mitth., x, 83, 1888.
§ Doelter has also expressed this view. N. Jahrb. f. Min. Referate, 1886, i, 123.
‖ 41a—Buffalo Dental Mfg. Co.

Properties.—The pure mineral is white in the mass and shows when prepared by the process just described the fibrous structure which is commonly characteristic of the natural mineral. A perfectly transparent variety in beautifully formed crystals of short prismatic habit was obtained later in an entirely different manner, which will be described subsequently. A detailed microscopic study of both varieties by Mr. Wright accompanies this paper.

The density of the fibrous material varies considerably, being dependent on the temperature of crystallization, and perhaps upon other conditions. The variation is satisfactorily accounted for by the presence of bubbles, or more probably vacuous spaces, which the microscope shows are generally present in the crystalline mass. They are probably the residual spaces which are left by the condensation of substance about the crystal nuclei. In one of the preparations, Prep. IV, which in crystallizing almost reached the inversion point, these bubbles were not found, and the crystalline fibers were much coarser. The following determinations were made by the method of Day and Allen:[*]

Specific Gravity of Fibrous Wollastonite, prepared by the devitrication of the glass. Determinations were made at 25° and compared with water at 25°.

Prep. I.	Heated about 3 days at a maximum temperature of 860°.	2·907 2·907
Prep. II.	Heated 17 hours at a maximum temperature of 950°.	2·876 2·876
Prep. III.	Heated 22 hours at a maximum temperature of 980°.	2·896 2·896
Prep. IV.	Formed from an under-cooled mass which began to crystallize at 1030° and rose in the process to a temperature of 1127°. The microscope showed a coarsely fibrous mass without the bubbles which appeared in I, II and III.	2·9145 2·9156 —— 2·915

The density of the glass from which the wollastonite is prepared is here given for purposes of comparison. The glass is perfectly free from bubbles and hence shows a practically constant density, which differs but little from that of wollastonite, being a trifle lighter than the densest preparation.

Specific Gravity of Glass of the Composition $CaSiO_3$, determined at 25°, compared with water at 25°.

Prep. *a*.	Prep. *b*.	Prep. *c*.
2·901	2·905	2·905
2·902	2·905	2·903

[*] Isomorphism and Thermal Properties of the Feldspars, this Journal, xix, 125, 1905. Publication No. 31, Carnegie Institution of Washington, p. 55.

The Inversion of Wollastonite to Pseudo-Wollastonite.—
It is sufficiently well known that the polymorphic forms of
solid crystalline bodies are divided into two well-marked classes,
the monotropic and the enantiotropic. Substances which,
like phosphorus, belong to the first class, possess one form
which is more stable than the other at all temperatures below
the melting point. The unstable form may therefore change
directly into the other over a considerable range of tempera-
ture, but the change in the opposite direction cannot be
brought about. In substances of the second class, the enantio-
tropic bodies, the transformation from one to the other takes
place at a characteristic temperature point, known as the
inversion point, and is reversible. Each form of a monotropic
substance possesses its own melting point, while in enantio-
tropic substances only one form melts in the region of its
stable existence, viz : that form which is stable at the higher
temperature.*

In calcium silicate we have unquestionably a case of enantio-
tropy, for one form changes to the other at a definite tempera-
ture, and the change is, under proper conditions, reversible.

When wollastonite, either natural or artificial, is heated to
about 1180°, it passes entirely into the hexagonal form. This
change of state occurs without melting, for, in every case, the
coarsely-powdered mineral which we employed in experiment
was found, after the inversion, to have shrunk away from the
walls of the crucible, forming a sintered cake, which, of course,
a liquid could never have done. Moreover, the separate grains
of the substance always preserved their sharp edges.

Brun† states that natural wollastonite from Auerbach melts
at about 1350° and then quickly solidifies. There is, of course,
the possibility that a rapidly heated charge might pass the
inversion point without change and melt in the metastable
region, as sulphur is known to do. A special effort was made
to test this possibility in the following manner: a 50 gram
charge of the purest natural wollastonite obtainable (from
Diana, N. Y.) was heated in the electric furnace past the
inversion point at the fastest rate consistent with the safety of
the heating coil, i. e., about 16° per minute. To hinder inver-
sion as much as possible, we selected rather large fragments of
the mineral with comparatively little surface. At 1260° a
perceptible absorption of heat was observed, immediately after
which the temperature was lowered and the charge examined.
Some fragments had undergone a slight local vitrification
which gave the effect of glazing, but the original form of each

* Roozeboom, Heterogene Gleichgewichte, vol. i, pp. 109, 110. Findlay,
The Phase Rule, 1904, p. 42.
† Archives des Sciences phys. et nat., série 4e, tome 18, p. 551.

was preserved down to the corners and edges, which remained as sharp as ever, and the microscope proved that all had been converted into pseudo-wollastonite. We were therefore unable to reproduce Brun's results or to explain them.

To locate the inversion point, we experimented in two different ways. On the one hand, we established a point below which inversion would not occur, by heating powdered wollastonite in contact with the hexagonal form at measured temperatures for more or less protracted intervals. At a temperature of 1100° there was no sign of inversion after a period of 60 hours. We relied upon microscopic evidence for our conclusion.*

A charge made up in the same way and held at 1170° for an hour likewise showed no indication of change, but the same charge returned to the furnace and kept at 1190° for another hour showed that the transformation had begun. The change revealed itself in the formation of small grains and patches of pseudo-wollastonite, embedded in the original wollastonite, which were plainly visible between crossed nicols. 1190° is therefore the lowest temperature at which we can certainly say that inversion takes place. Changes in the solid state are well known to be very sluggish, and this one, as will appear farther on, is a rather extreme case. It may therefore well be that if experiments were continued for very long periods, the true inversion temperature would be found to fall somewhat lower down.

By the use of Frankenheim's method,† in which the temperature is observed at regular intervals as heat is continually supplied to the mass, we were able to detect a small absorption of heat corresponding to the physical change revealed by the microscope.

A departure from previous practice was made in the use of a control element. The heating of a furnace can not be made perfectly regular even with storage batteries of large capacity, but the temperature rises with continual slight fluctuations, which, of course, are shared by the charge in the crucible, where they are indistinguishable in their effect on a thermo-element from slight evolutions or absorptions of heat in the charge itself. The control element, which gives the temperature of the furnace, enables a correction to be applied for the furnace fluctuations. It is read alternately with the element in the charge. In general, it is not easy to tell exactly what effect upon the charge is produced by a given fluctuation in

* For the examination of these mixtures the authors are indebted to Mr. W. Lindgren of the U. S. Geological Survey.
† Day and Allen, Isomorphism and Thermal Properties of the Feldspars, this Journal, xix, 93, 1905; Publication No. 31, Carnegie Institution of Washington.

the furnace, but the average difference of temperature between the two elements measures the rate at which heat is passing into the crucible, and any change in this difference shows an absorption or evolution of heat, provided that no great change in the average rate of heating has occurred.

INVERSION OF WOLLASTONITE.

Rate of heating in degrees per minute.	Inversion temperature.
8·8	1232
3·6	1225 (See curve 1, Table I.)
1·0	1198
1·1	1197 (See Table II.) Mixed with inverted form.
1·0	1211 Mixed with inverted form.

These results indicate, in harmony with the microscopic evidence, that the presence of the inverted form has, under the given conditions, little or no effect on the inversion. That the inversion temperature should seem to be higher as the rate of heating increases, was to be expected. The last sample was carried as far as 1245°, and on cooling was found to be inverted only in part.

The Reversion of Pseudo-Wollastonite.—When pure pseudo-wollastonite was cooled, even very slowly, it did not revert to wollastonite. Our first efforts to overcome this inertia were along the usual lines. We added to the mass a small quantity of the more stable phase (wollastonite) and allowed plenty of time for equilibrium to assert itself. The two forms, mixed in about equal proportions, were spread in a thin layer at the bottom of a platinum crucible, and on this was placed a deeper layer of the pseudo-wollastonite. Experiments lasting from 36 to nearly 60 hours at temperatures ranging from 900° to 1100° were without effect; the optical method of identification always showed both substances and indicated no change whatever. We next tried the effect of the solvent action of water. The two forms, mixed as we have described above, were heated for several days in a steel bomb with water above its critical temperature. The bomb held tight, but there was no indication of change in the crystals. We will not therefore describe the apparatus and the conditions of experiment in detail. Both crystalline forms were proved by the microscope to be practically unchanged by this treatment, and chemical tests showed little hydrolysis. This is somewhat surprising in view of the fact that these silicates impart an alkaline reaction to water on standing in the cold. It should be remarked that the quantity of water used was very small, only 3 to 4 cc. to 2 gr. of substance. On the glass

TABLE I.   TABLE II.

	Inversion.					Inversion. 20 per cent of the inverted form was mixed with the charge so as to start the action at the lowest possible temperature.			
		Curve I.							
Control.	Rise in 2 min.	Cruci-ble.	Rise in 2 min.	Diff.	Control.	Rise in 2 min.	Cruci-ble.	Rise in 2 min.	Diff.
11481					11795				
	92	11360		167		62	11662		133
573			92		857			62	
	93	452		167		59	724		133
666			93		916			58	
	94	545		168		57	782		134
760			94		944			54	
	90	639		166		56	836		134
850			91		12000			55	
	92	730		166		60	**891**		137
942			90		060			59	
	98	820		171		56	950		139
12040			92		116			56	
	96	912		176		54	12006		136
136			99		170			55	
	91	12011		170		54	061		137
227			90		224			53	
	89	101		170		51	114		136
316			82		275			50	
	90	175		188		49	164		134
406			59		324			52	
	96	**232**		222		51	216		132
502			79		375			54	
	98	311		240			270		128
600			124						
	95	435		213					
695			121						
	96	556		189					
791			114						
	97	670		170					
888			105						
	97	775		162					
985			101						
	84	876		151					
13079			98						
	92	974		151					
171			96						
	97	13070		150					
268									

CURVE I.—Inversion of Wollastonite.
Inversion Temperature, 1225°.
Rate of Heating, 3·6° per minute.
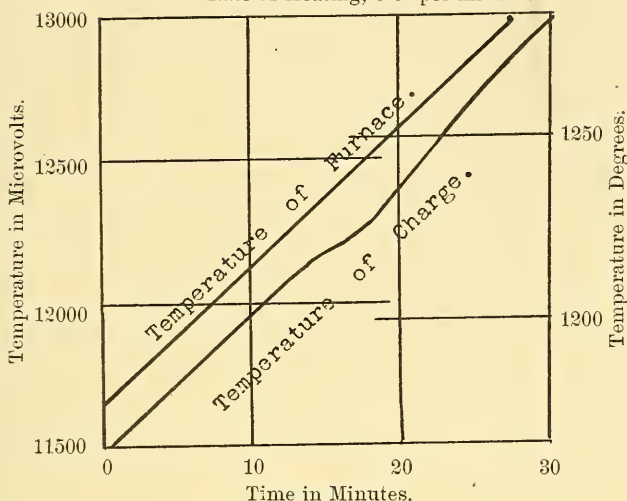
there were signs of some action. The grains were cemented tightly together, while the microscope disclosed what appeared to be an incipient crystallization.

From water we turned to the solvent action of a fused salt.* The necessary properties in a salt which should answer our purpose are evidently the possession of an ion common to calcium silicate, so that metathesis may not result; sufficient fusibility, and sufficient solubility, in order that the excess may be removed after the process is complete.

These requirements are fulfilled by calcium vanadate, $Ca(VO_3)_2$, which is prepared by heating calcium carbonate with the proper proportion of vanadic acid. In the first trial, we heated one gram of vanadate with several grams of pseudowollastonite at a temperature of 800° to 900° for a number of days. The solvent was then partially extracted by hot water, after which the residue, so far as possible, was removed by very dilute hydrochloric acid. The product was all changed into wollastonite. In later experiments, we tried larger quantities of vanadate and heated for different periods. One gram of vanadate readily transforms 5 grams of silicate and is removed when the change is accomplished with less trouble than a

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* Calcium chloride forms chloro-silicates, Gorgeu, Bull. Soc. Min., x, 271. In our experiments we did not get a pure product, though the majority of it, when a large excess of calcium chloride was used, crystallized in transparent lath-like crystals of orthorhombic (?) symmetry. The ratio of chlorine to silica in the product was in accord with the formula $2CaSiO_3.CaCl_2$.

larger quantity. The mass thus formed is scarcely pasty at the highest temperature of an ordinary Bunsen burner, yet the yellow color shows that the silicate is completely permeated by the vanadate. If one desires as large crystals as possible, it is well to take more vanadate and heat for a longer time. To get the silicate in pure condition, it is best to break up the fused mass in a mortar, with a little water, cover it with, say, 50 to 100 cc. cold water, and then add a few drops of dilute hydrochloric acid, stirring thoroughly. After a few minutes, pour off the water and repeat the treatment until the water is no longer colored yellow. In this way the calcium vanadate is decomposed and removed more readily than with water alone, while if one keeps the acid cold and very dilute, the silicate is not decomposed to any extent, and the microscope shows the product to be unmixed with foreign matter. It consists, as stated above, entirely of wollastonite in beautiful transparent crystals of short prismatic habit, with sharp edges and well developed faces. The largest were about 0·2 mm long.

This formation of wollastonite could hardly be anything else than a true reversion. It is well known that such transformations in solid bodies may be facilitated by the use of solvents which probably overcome resistance to molecular movement. In this case, at the temperature of 800 to 900°, wollastonite should be the more stable polymorph, possessing a lower vapor pressure and a lower solubility. Given a nucleus of this form, therefore, the other should pass into solution and continually precipitate in the form of wollastonite. That this is really what happens, we proved by stopping the transformation before it was complete (5 grams silicate to 1 gram vanadate heated three hours). Large grains of pseudo-wollastonite remained unchanged except for a rounding of corners and edges, and side by side with them appeared small well-formed crystals of wollastonite.

As these crystals, on account of their freedom from bubbles or pores, seemed especially adapted for the determination of density, two separate preparations were made for this purpose.

	PREP. I. Sp. gr. 2·914. Analysis.	PREP. II. Sp. gr. 2·912. Analysis.	Cal. for $CaSiO_3$
SiO_2	51·94	52·00	51·86
CaO	47·69	47·46	48·14
Fe_2O_3 etc.	·19	·18	----
V_2O_4 *	·38	·49	----

* Both preparations had a pale blue tint, which led us to suspect that the vanadium had been reduced in the process of heating over the gas flame to the blue oxide V_2O_4.

These numbers show very satisfactory agreement with the specific gravity 2·915 of the wollastonite which crystallized from an under-cooled melt, and may be regarded as the true specific gravity of pure wollastonite.

Some further light has been thrown on the formation of wollastonite by the unpublished work of Messrs. Day and Shepherd of this laboratory. They have examined the entire series of lime-silica mixtures and have obtained wollastonite easily in a variety of mixtures. There appears to be little difficulty in obtaining true wollastonite as soon as an excess of either component is present in the charge. The metasilicate first crystallizes in the hexagonal form, but the inversion to wollastonite occurs during cooling with little or none of the difficulty which we encountered in pure $CaSiO_3$ preparations. True wollastonite can, in fact, be obtained more readily out of concentrations with a slight excess of CaO than by the use of vanadic acid, but the crystals so formed are not large enough for convenient microscopic study, and cannot be readily separated.

In accord with nearly all of our laboratory experiments, both crystallization and inversion go on more slowly in the presence of an excess of silica, due probably to mechanical inertness or viscosity.

Pseudo-Wollastonite.—This form may be obtained by heating wollastonite above 1180°, or by crystallizing a melt above this temperature. It is only rarely that anything but pseudo-wollastonite is obtained on cooling a melt, but to insure its formation the melt needs only to be slightly agitated to overcome the instability. Pseudo-wollastonite has been described optically by Bourgeois.[*] It shows a basal cleavage, is optically positive, and very nearly uniaxial, though Bourgeois regards it as really monoclinic. Doelter[†] combats this view, but Mr. Wright in the microscopic part of this paper finds additional arguments in support of it. It crystallizes, under such conditions as have obtained in our experiments, in fibrous, fan-shaped aggregates. The density of the inverted but still unmelted crystals is variable, owing, no doubt, to the presence of bubbles, and not to be distinguished with certainty from the wollastonite, showing again that the volume change which accompanies the inversion is very small.

SPECIFIC GRAVITY OF WOLLASTONITE AT 25° COMPARED WITH WATER AT 25°.

1. Inverted but not melted.	2. Inverted but not melted.	3. Melted.
2·886	2·896	2·913
2·886	2·896	2·912

* Bull. Soc. Min., v, 14–15.
† N. Jahrb. f. Min., 1886, i, 120 and 122.

Melting Point of Pseudo-Wollastonite.

This was determined in practically the same way as the inversion, except that some of the readings were made every half minute. The rates of heating varied between 2·1 and 2·7° per minute.

FIRST SAMPLE. FOUR MELTINGS.

	Microvolts.	Degrees.*
El H	16058	1511·0
	16065	1511·5
	16062	1511·3
	16073	1512·1

SECOND SAMPLE. ONE MELTING.

	Microvolts.	Degrees.
El G	16053	1512·0 (curve 3.)
El L	16072	1512·1

THIRD SAMPLE. ONE MELTING.

	Microvolts.	Degrees.
El G	16060	1512·7

FOURTH SAMPLE. TWO MELTINGS.

	Microvolts.	Degrees.
El F	16104	1513·5
	16104	1513·5

Melting point, 1512.

Summary and Conclusions.

1. Wollastonite and pseudo-wollastonite are enantiotropic forms of calcium metasilicate, showing an inversion point at about 1180°. The change $W_n \longrightarrow W_p$† is easily effected by heating above this temperature, while the reverse change has not been accomplished without the addition of other substances, owing to the sluggish nature of the silicate. Cases of suspended transformation are common enough, but a reversion which fails altogether even after heating for days in contact with the stable form is remarkable. We may compare it to the case of the glasses of the alkaline feldspars, which resist all attempts to make them crystallize by heating and sowing with nuclei. The fact very well illustrates one of the difficulties which the experimenter constantly encounters in the study of

* Fractions of degrees are given in order to show the agreement obtainable in such determinations. The absolute value of the melting point is dependent upon the thermoelectric extrapolation of the gas scale, and is subject to correction whenever the latter shall be extended to this point.

† Let W_n represent the optically negative form, and W_p the positive.

Table III.*

Melting of Pseudo-Wollastonite. Curve 2.

Control.	Rise in 2 min.	Melt.	Rise in 2 min.	Rise in ½ min.	Control.	Rise in 2 min.	Melt.	Rise in 2 min.	Rise in ½ min.
15616					16109			33	8
							15993		8
	72	15604				66	16001		7
							008		7
688			70		175			27	6
							021		7
	72	674				70	028		6
							034		6
760			66		245			26	7
							047		7
	76	740				70	054		6
							060		7
836			66		315			28	7
							074		8
	77	806				65	082		10
							092		12
913			62		380			69	16
							126		25
	74	868				90	151		32
							183		
987			55		470			247	
	59	923				108	398		
			45		578				
16046	63	968		9					
		977		8					

the silicates.   Molten calcium vanadate brings about the reversion at temperatures below the inversion point by the formation of a solution from which the more stable wollastonite
crystallizes in well-formed prismatic crystals.   Excess of lime
or silica also facilitates the reversion.

Following the invariable rule, the change $W_n \longrightarrow W_p$ occurs
with an absorption of heat.   The volume change which
accompanies this transformation is so slight that it is uncertain
which form is the more dense.

The pseudo-wollastonite melts at 1512° to a comparatively
thin liquid, which almost always crystallizes above 1200° on
cooling down again.   This explains why true wollastonite cannot generally be formed from a liquid of its own com-

* All the numbers in this table are 7 microvolts too high, on account of a
slight, unavoidable leakage current through the insulation of the hot furnace.   Hence the true melting point is 16053 microvolts, as given in the
previous table.

CURVE II.—Melting of Pseudo-Wollastonite.
Melting Point, 1512°.
Rate of Heating, 2·7° per minute.
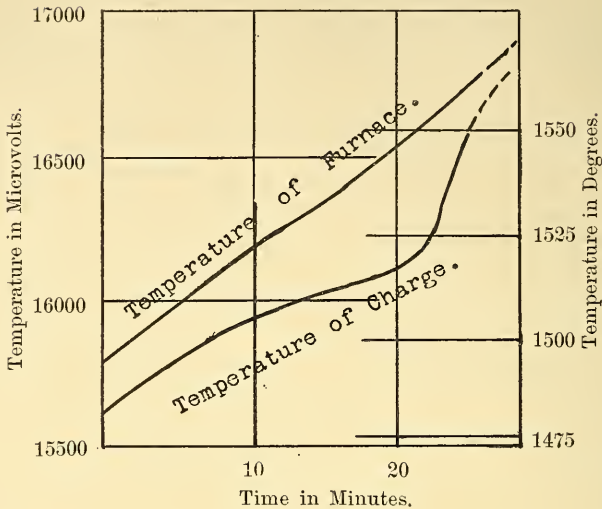
position.   We have already shown that the liquid can be undercooled to a glass ; it follows naturally that by a suitable disturbance a sufficiently undercooled melt should crystallize directly to wollastonite.   In fact, we have in one or two instances thus obtained well developed rosettes which the microscope showed were optically negative, and in one case the whole charge excepting a few surface grains yielded wollastonite.   That wollastonite rarely forms in this way is due, first, to the difficulty of undercooling the melt sufficiently, and second, to the release of the heat of fusion which tends to raise the temperature again beyond the inversion point.

The addition to calcium silicate of fluorides or borates in the proper proportion (to which some investigators have resorted), of course lowers the temperature of crystallization ; and it is to this influence rather than to any mysterious "mineralizing" action that the synthesis of natural wollastonite is to be ascribed.   It seems not impossible also that for a similar reason Gorgeu may have obtained it together with chlorosilicates, as he claims to have done, by the addition of calcium chloride.   So in the glasses of commerce which contain much sodium silicate, a slow cooling sometimes gives rise to crystals of wollastonite below the inversion point.

Although the *temperature at which wollastonite may crystallize from a magma* is conditioned by the composition of the

latter, it may be worth while to call attention to the fact that the value of the *inversion temperature* as a point of reference in geology is not impaired by the varying complexity in the composition of the magma, inasmuch as this temperature has to do with an equilibrium between two solid states of calcium metasilicate, and has no relation to the solution out of which either form crystallizes. It will of course be slightly affected by pressure in the usual way, and also to some extent by the impurities which, in small quantity, are found in the natural mineral, provided these are really dissolved in it.

IMPORTANT PROPERTIES OF THE TWO FORMS OF CALCIUM METASILICATE.

Symmetry.	Inversion Point.	Melting Point.	Specific Gravity at 25° compared with water at 25°.		
			Cryst. from an under-cooled melt.	Cryst. from $Ca(VO_3)_2$.	Molten.
Wollastonite { monoclinic / optically negative	1180°	....	2·915	*a.* 2·914 *b.* 2·912	- - - -
Pseudo-Wollastonite { probably monoclinic / pseudo-hexagonal / optically positive	"	1512°	....	....	2·912

Optical Study.

In the thin sections which were made from the various preparations of calcium metasilicate, both forms, wollastonite and pseudo-wollastonite, were recognized, and determined by their optical properties alone, their morphological features being too indefinite and inconstant to be of service. Fortunately several of the optical characteristics of the two minerals differ sufficiently to render the separation under the microscope relatively simple.

Textually the preparations show considerable variation, although in general the artificial wollastonite occurs in fibrous or long prismatic aggregates, while the pseudo-wollastonite is more coarsely crystalline and granular in appearance. Radial spherulites of wollastonite in which the crystals are elongated parallel to the axis of symmetry (*b*) were observed frequently, especially in the sections of wollastonite from crystallized glass.

In size the crystals range from the finest cryptocrystalline aggregates to individuals several millimeters in length. As

a rule the crystals formed out of a melt are larger than those produced by heating the silicate glass.

Wollastonite.—Under the microscope the artificial wollastonite resembles closely natural wollastonite and often presents its characteristic arrangement of divergent fibers. The colorless laths are usually transparent and show perfect cleavage cracks parallel to their long direction. Twinning after a face in the orthodiagonal zone was recognized on several of the crystals. Two of the crystals formed from the melt of calcium metasilicate and calcium vanadate were of sufficient size ($\cdot$1 x $\cdot$2 x $\cdot$5^{mm}) to permit goniometric measurement of their faces.[*] Both crystals were elongated in the direction of the axis of symmetry (b) and showed evidences of cleavage after u (001) and c (100). On the first crystal, the forms u (001),[†] v (101), t ($\bar{1}$01), a ($\bar{1}$02) and e (110) were observed ; on the second, which was less perfect, the forms c (100), u (001), t ($\bar{1}$01) and a ($\bar{1}$02) occurred, with two uncertain forms (302)? and (203)?. The forms (001) and ($\bar{1}$01) were the best developed and gave sharp reflexion signals. The faces of the other forms were smaller and less satisfactory in their measurement. The accordance of the observed interfacial angles with those of natural wollastonite, however, was sufficiently close to prove their identity. The following comparison of their polar angles shows differences which are not greater than had been anticipated from the inferior reflexion signals obtained.

Letter	Symbol.	Miller.	Artificial Wollastonite.		Natural Wollastonite.	
			ϕ	ρ	ϕ	ρ
u	0	001	90°00′	5°30′ ± 5′	90°00′	5°30′
c	$\infty 0$	100	"	90 27	"	90 00
e	∞	110	43 10	89 58	43 39	90 00
v	$+10$	101	90 00	45 06	90 00	45 33
a	$-\frac{1}{2}0$	$\bar{1}$02	"	19 54	"	20 03
t	-10	$\bar{1}$01	"	39 29	"	39 35

The greatest and least refractive indices were determined by Schrœder van der Kolk's[‡] method of refractive solutions to be about 1$\cdot$621 and 1$\cdot$636. Birefringence, about 0$\cdot$015. Optic axial plane, perpendicular to the cleavage lines. Optical character of principal zone, both positive and negative. Optical character of mineral negative with optic axial angle in air, $2 \mathrm{~E} = 69°30′ - 70°00′$, measured on several different prepara-

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[*] Goldschmidt's two-circled goniometer with reduction attachment was used.

[†] The crystallographic orientation of Goldschmidt's "Winkeltabelle," Berlin, 1897, pp. 286–287, has been followed in the notation.

[‡] Kurze Anleitung zur Mikroskopischen Krystallbestimmung, Wiesbaden, 1898.

tions after the Bertrand-Mallard method. In certain sections
the optic axial angle appeared to be smaller than in others, a
fact for which no explanation has been found. Optic axial
dispersion $\rho > \nu$. All of the above properties agree well with
those of natural wollastonite and substantiate the thermal and
chemical evidence of Messrs. Allen and White.

Several of the preparations of wollastonite were crypto-
crystalline and could be identified only by their low birefring-
ence and fibrous spherulitic character.

Pseudo-wollastonite appears either in the form of small
irregular grains often tabular in shape or in short prisms or
fibers arranged in parallel or divergent groups. The grains
are transparent and show occasionally well developed basal and
imperfect prismatic cleavage lines. Limiting refractive indices,
about 1·615 and 1·645, as measured by the method of refractive
liquids. Birefringence about 0·025–0·035, considerably higher
than in wollastonite. It is interesting to note in this connec-
tion how slightly the mean refractive index of wollastonite
differs from that of pseudo-wollastonite. Accurate optical
measurement would be required to ascertain satisfactorily
which mineral has the higher average index of refraction.
The same conditions prevail in their specific gravities, where
the differences observed might well be ascribed to experi-
mental error.

Optical character, positive, with very small optic axial angle
$2 E = 0° - 8°$. Plates cut parallel to the basal pinacoid show
in convergent polarized light an interference cross which can
often be seen to open slightly on turning the stage. The optic
axial angle thereby is so small that from it alone the mineral
might be regarded uniaxial, the mere opening of the interfer-
ence cross being an optical anomaly analogous to the irregu-
larities noted in many minerals. This is the view taken
by J. H. L. Vogt[*] in his studies on the formation of minerals in
slags. His opinion was strengthened by the hexagonal form
of the crystals and by the observed extinction parallel to the
basal pinacoidal cleavage cracks. Doelter[†], who also made an
extended microscopic study of this silicate, came to the conclu-
sion that the mineral was either hexagonal or orthorhombic in
crystal system, his observations agreeing otherwise with those
of Vogt. Bourgeois,[‡] on the other hand, pronounced the min-
eral monoclinic. His work was accomplished before that of
Doelter and Vogt and appears to have been less extensive in
scope. After a brief mention of the essential optical features
he describes the occurrence of twinning lamellæ in certain of the

[*] Mineralbildung in Schmelzmassen, Kristiania, 1892, 57–59.
[†] N. Jahrb. f. Min. 1886, i, 119–122.
[‡] Bull. Soc. Min., v, 14–15.

elongated crystals and interprets them as indicative of the monoclinic system. Doelter also mentions in passing the rare occurrence of twinning lamellæ in his preparations, but seems to have attached no significance to the fact. The present writer also observed in several of his sections sharp and occasionally polysynthetic, twinning lamellæ which were not unlike oligoclase feldspar twins in appearance. On a plate perpendicular to the optic normal the twinning lamellæ were normal to the plate and parallel to the basal pinacoid, their trace running parallel to the basal cleavage lines. The lamellæ showed an extinction angle $a : \mathfrak{a} = 2°$. Since the cleavage cracks are not perfect, the small extinction angle of 2° might easily be overlooked, under ordinary circumstances, and the extinction be considered parallel. In the hexagonal and orthorhombic crystal systems the basal pinacoid is a plane of symmetry and cannot act as a plane of twinning nor show an extinction angle, however small. The fact, then, that twinning after the basal pinacoid does occur in the pseudo-wollastonite crystals and does show an extinction angle, the double of which when taken between adjacent lamellæ is 4°, precludes the uniaxial and orthorhombic crystal systems. The writer considers the mineral with Bourgeois as probably monoclinic. The twinning law is analogous to that of Tschermak in the micas, where the basal pinacoid is also the plane of composition. Since its crystals frequently similate hexagonal forms, pseudo-wollastonite may well be treated as pseudo-hexagonal and probably monoclinic in form. It is not a modification of the natural monoclinic wollastonite, and differs from the latter profoundly in optical as well as crystallographical features.

Paramorphic changes.—The phenomenon of paramorphism, the change of crystal structure of a chemical substance in the solid state with consequent preservation of the crystal habit of the original form, is well illustrated in the inversion of wollastonite to pseudo-wollastonite. Since in certain paramorphic minerals it has been noted that a plane of symmetry or other direction may be common to both simulated and simulating mineral, several experiments were made to ascertain whether any crystallographic or other relations exist between the original wollastonite crystals and the pseudo-wollastonite which replaces them. Cleavage fragments of natural wollastonite from Diana, N. Y., were heated in an electric arc and then cooled rapidly by plunging them into mercury. Sections from this preparation showed that the wollastonite had thereby passed into the pseudo-form without any apparent regularity. The fibers of the original wollastonite were unaltered up to that portion which had touched the electric arc, from which point outwards irregular grains of pseudo-wollastonite occurred

without recognizable crystallographic grouping. The contact between the natural and pseudo form was sharp, indicating that the transition had taken place without any intermediate stage.

In a second experiment, natural wollastonite was heated in the electric furnace to 1260° and thus changed in the solid state to pseudo-wollastonite. The resulting mass consisted again of grains of the pseudo form, irregularly arranged, although indications of the original fibrous wollastonite texture are still indistinctly shown.

The conditions were altered in still another experiment by heating artificial wollastonite crystals, which had been obtained by crystallizing the silicate glass, to the inversion temperature (1190°) for about an hour. The resulting preparation was instructive in showing the paramorphic change in its incipient stage. The original larger crystals were filled with particles and clusters of the pseudo-form, arranged without apparent regard to the host. Had the preparation been allowed to remain at the inversion temperature for a longer period of time, the change would undoubtedly have progressed until all original wollastonite fragments had been completely replaced by innumerable pseudo-wollastonite grains.

As the above experiments were made with cleavage fragments of natural and artificial wollastonite which are not so well adapted to show paramorphism as crystals, artificial crystals of wollastonite obtained from the calcium vanadate flux were heated in the electric resistance furnace above the inversion temperature, and the product examined. The original crystals were elongated parallel to the axis of symmetry (b) and were bounded chiefly by forms of the orthodome zone with perhaps the unit prism and unit clinodome forms. After the alteration, each one of the original wollastonite crystals was found to have changed entirely to one pseudo-wollastonite individual alone, and rarely to two or more grains, as is usually the case, a remarkable fact which may be due perhaps to the minute size of the original crystals and to the equality of specific volumes of the two forms. In one instance a basal section of the pseudo-form was contained in the orthodiagonal zone of the original mineral, while in another plate cut perpendicular to the optic normal, sharp twinning lamellae were visible, the traces of which ran parallel to a unit prism or clinodome form terminating the crystal and making an angle of 29° with the direction of elongation of the simulated crystal. From these and other observations, it is evident that, generally speaking, in paramorphic change the planes of symmetry of the two forms do not coincide. Certain crystallographic directions,

however, may or may not retain their character during the change.

The paramorphic change of pseudo-wollastonite to wollastonite, which is the more imporant from the geologist's standpoint, could not be observed, since the conditions under which it was effected involved solution and precipitation, and did not occur in the solid state.

Summary.

The chief results attained by the optical study of the calcium metasilicate preparates were :

1. Identification of artificial wollastonite, whose properties agree precisely with those of natural wollastonite.

2. Determination of the pseudo-hexagonal, probably monoclinic, crystal system of the second form of $CaSiO_3$; in its crystals the occurrence of distinct and often repeated twinning lamellae parallel to the basal pinacoid and with an extinction angle $a : \mathfrak{a} = 2°$, was considered the decisive factor.

ART. VII.—*Studies on Early Stages in Paleozoic Corals;* [*]
by C. E. GORDON.

THE group of the Anthozoa has been the object of careful and detailed study for many years. The discovery that these organisms were really animals enlisted the attention of many investigators during the latter years of the eighteenth century. As first defined, the group included the Hydroid polyps, Bryozoa and Sponges ; forms now known to be quite distinct. In 1828 Milne-Edwards showed that the "Sea-mat" and allied forms possessed a definite mouth and anus. Later the Sponges were made a distinct class, and finally the Hydroid types were firmly established as a distinct division of the Cœlenterates. "The anatomy and classification of the group thus purged of intruders were placed on a firm basis by the classical works of Dana and of Milne-Edwards and Haime (1857)." Since then studies in the development, comparative anatomy, and histology of the Anthozoa have contributed to a further and more exact knowledge of the group, although much remains that is yet doubtful and obscure. Especially is this true of the extinct Anthozoa of Paleozoic time : the Rugosa of Milne-Edwards and Haime, the Tetracoralla of Hæckel.

Since with these extinct forms only the hard parts are preserved, the study of relationships and mode of development is exceedingly difficult, and all conclusions on these points are necessarily, to a greater or less degree, matters of conjecture and inference. Several investigators, however, have endeavored to show the relationship of these extinct types to modern forms. How far they have succeeded in doing this is still a matter of dispute.

In so far as the plan of structure, which should be understood to mean the plan of growth from the earliest stages, can be proved to be similar to that of modern forms, just so far can relationships be assumed. Here we recognize that an inference can be drawn from a study of the hard parts, for example, the arrangement of the septa in corals. This arrangement is such that a reasonable assumption may be made as to their order of appearance. The difficulty must lie in securing specimens well adapted to show primitive characters with respect to the plan of growth of these septa.

With modern corals the order of appearance of the mesenteries is made of prime importance, and since the septa follow the mesenteries, the endeavor to classify the fossil forms has

been on the order of appearance of the septa, so far as could be inferred by a careful study of early stages. It is by no means true, however, that the early stages of all fossil forms will give us the clue to the phylogeny of the group. It frequently happens that certain individuals represent a specialized condition and are, on that account, not suitable for working out their own life history, which could be interpreted only by a careful comparative study of many individuals. This specialized condition may result from an acceleration in development of certain ancestral characters resulting in a premature appearance of certain stages which normally belong somewhat later in the animal's life, and which obscure the early conditions by their premature development; again, certain characters are retained longer than usual and are prolonged to the obliteration of later stages, for the appearance of which the life of the animal is not long enough. In interpreting the structural characteristics of any species the possibility of specialization must not be overlooked. Among forms somewhat removed in geological time from the ancestral stock, one must look for types in which acceleration, or retardation, or both, have been important factors in altering early ancestral conditions, and have produced new species, or varieties, according to one's choice of designation.

It is not within the province of man to say where, or in what parts, these modifications are to take place when only natural conditions operate to produce them. They are to be looked for anywhere, and it is reasonable perhaps to expect them in parts which have taken on new physiological importance, or have ceased to have such importance, as responses to certain conditions. Instances are numerous which forcibly illustrate the principles of acceleration and retardation. The genera Cyathophyllum and Heliophyllum are distinguished by the presence in the latter of carinae. But sections of certain Heliophyllums (*Heliophyllum halli*) show the carinae appearing very late in the life of the individual.* Up to the time of their appearance they are not to be distinguished from Cyathophyllum. In other individuals the carinae appear so early as entirely to obliterate the Cyathophyllum stage. It is clear that here are two types originating from a common ancestor, which had both a Cyathophyllum and a Heliophyllum stage, the latter being a late ephebic character. One retained the Heliophyllum stage as an ephebic character, and is to be regarded as a retarded type. The other became accelerated until the carinae stage became established as a nepionic character. It is apparent that here are two distinct types, each

* "Hamilton Group of Thedford, Ontario," Shimer and Grabau ; Bull. Geol. Soc. Amer., vol. xiii, pp. 167–168.

having a Cyathophyllum ancestor, but that acceleration has produced in one case a distinct type in which the Cyathophyllum stage is either lost, or is of such short duration that it escapes notice.

In attempting to arrive at some definite conclusion as to the ancestral condition of any fossil group, or as to whether any particular plan of structure in fossil forms is a primitive one or not, one must not ignore these facts so obviously illustrated in many groups that have been carefully and successfully studied. In the absence of proof that the specimens in hand are primitive, or that they illustrate a primitive condition, of which one must always be in doubt, one must in order to meet the first requirements of a safe premise select a type most likely to be primitive, and this must be done on the basis of chronogenesis. A type occurring late in geological time, at least a considerable time subsequent to the earliest occurrence of a type at all similar, is likely to be far from primitive, in all respects at least, and at all events is not a safe type for study. But a specimen selected on the basis of its early appearance in geological time may be presumed to give the most primitive conditions which it is possible to obtain until an earlier form which is favorable for study can be secured.

Dr. J. E. Duerden has attempted to show by studies based on *Lophophyllum proliferum* that it is unnecessary to "account for a primitive tetramerism" in the Rugosa.[*] He would, on the basis of his studies, consider the quadripartite symmetry as a secondary development erected on a primitive hexameral arrangement of the primary septa; and by the development of the secondary septa, according to his interpretation of the primary condition, he finds the Rugosa, in so far as *L. proliferum* may be representative, most closely related to the modern Zoantheæ. In this paper I am not so much concerned with establishing the relationship of the Rugosa as with discussing the probable number of the primary septa in these forms. Certain studies which I have undertaken seem to indicate that there is still good ground for believing that the tetrameral plan is a primitive one.[†] Moreover, a careful study of the diagrams in Duerden's paper has raised the question if after all they may not illustrate a primitive tetrameral arrangement of the main septa.

It will be necessary in order to make as full a comment as seems desirable on Duerden's studies of Lophophyllum to reproduce a few of his figures.

[*] Johns Hopkins University Circular, January 1902; Annals and Magazine of Natural History, May 1902.

[†] For valuable suggestions and criticisms in carrying on these studies the writer is deeply indebted to Dr. Amadeus W. Grabau.

In figure 1 we have a

"transverse section, through the tip of the corallum. The dark median lines of only six primary septa are present, but the outlines of the septa as a whole are not clearly determinable, their surfaces being fused throughout. The two median septa are represented by a continuous line, while the other four septa are arranged as an upper bilateral pair and a lower bilateral pair. Of the six primary interseptal spaces the two upper are slightly smaller than the others. By interseptal spaces may be here understood the interval between the dark lines of two contiguous septa ; the septa are so broad as to occupy the whole of the calicinal cavity, leaving no interseptal loculi."

The author explains that the terms "upper" and "lower" are used merely for convenience and have no morphological significance. I wish here to call attention to Duerden's observation that the two upper "primary" (of Duerden's figures) interseptal spaces are smaller than the others, as this fact lends some support to a different interpretation of the figures from that which Duerden had given and which I presently wish to discuss.

FIGURE 1. *Lopho-phyllum proliferum.* Transverse section through the tip of the corallum. After Duerden.

"In all the figures the upper border corresponds with the convex side of the coral, and the lower with the concave border ; the primary septa are indicated by the Roman numeral I, and the later septa by the letters A-D, according to their order of appearance within the four primary interspaces."

The reader's attention is again called to the exact language of the author, as great stress is laid by him upon the development of these septa in four primary interseptal spaces, which according to him do not represent the whole number, but only four out of six such spaces. I think another interpretation may be given to this early arrangement as exhibited in the apical section studied by Duerden.

In figure 2, which is a transverse section through the tip of another corallum taken comparatively a little higher than in the case of figure 1, two new septa are making their appearance, apparently as a unilateral pair. This is probably to be explained as a case of slightly unequal growth, as Duerden remarks. The dark tadpole-shaped spaces represent the interseptal loculi and partly indicate the boundaries of the septa. The dotted line in all the figures marks the outline of the actual section.

Figure 3 represents a transverse section of a third corallum taken a little higher than in the previous sections. Duerden remarks that the six primary septa are recognizable by their greater size. The outlines of the septa are indicated in the figure by the thin marginal lines and the oval interseptal loculi. The two median septa are now distinct from one another and the upper is larger than the lower. Duerden indicates that the former is

"thereby already recognizable as the main or chief septum."

FIGURE 2. *L. proliferum.* Section through the tip of a second corallum ; a little higher than in figure 1. After Duerden.
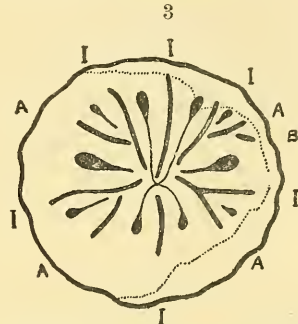
FIGURE 3. *L. proliferum.* Section of a third corallum from a still higher level. After Duerden.

He also makes the important observation that the

"upper primary interseptal spaces are much narrower than the middle and lower interspaces. Within each of the latter an additional septum (A) has appeared, and within the middle, right interspace the rudiment of a second additional septum (B) occurs. No new septa are ever developed within the two upper interseptal spaces."

Figures 4 and 5 are easily interpreted with respect to what has already been explained concerning the structural features of previous figures. Figures 6 and 7 will be referred to again.

The reader's attention is now directed to figures 8, 9, 10 and 11, which are Duerden's diagrams reproduced again, but this time inverted. This has been done for the sake of easier comparison. In figure 8 it will be noticed that what are now the upper lateral septa are, as indicated by the dark lines, more nearly at right angles with the median than are the lower ones, while the median dark lines of the lower ones in this figure (upper in Duerden's) have a proximity to the median dark line which is at this stage very noticeable and suggestive.

Before entering upon a further discussion of the diagrams obtained by inverting Duerden's figures, I wish to call atten-

tion to the possibility, which I have suggested above, of a specialized condition in *Lophophyllum proliferum.* Lophophyllum is a Carbonic type. It occurs comparatively late in the geological history of the Rugosa. It may, therefore—I should say rather, it must, therefore—have been somewhat
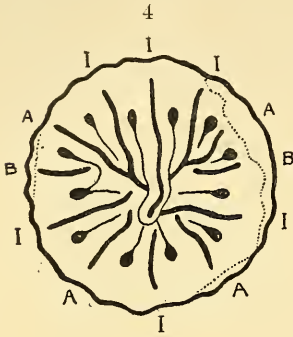
FIGURE 4. *L. proliferum.* Section from same specimen as in case of figure 3, but a little further from the apex. After Duerden.

FIGURE 5. *L. proliferum.* Section of same corallum as before from about the middle of its length. After Duerden.

modified from an earlier condition. Whether this modification took place in the arrangement or order of appearance of the septa there is no absolute means of ascertaining, while one cannot gainsay the possibility that either acceleration, or retard-

FIGURE 6. *L. proliferum.* Section from upper part of the same corallum as before. After Duerden.

FIGURE 7. Section towards the upper region of a fourth individual. After Duerden.

ation, or both, have operated to produce an apparent anomaly in Lophophyllum in these respects.

The arrangement and order of appearance of the septa in the Zaphrentoid coral, as generally accepted, is illustrated in figure 15 ; (*h*) is the " cardinal" septum ; (*g*) the " counter" septum ; (*s*) the "alar" septa. The radiating lines indicate septal margins as they appear on the surface of the corallum when viewed from below. By the figure it will be seen that in the cardinal quadrant the septa first to appear take a position next the alar septa. In the counter quadrants the first to
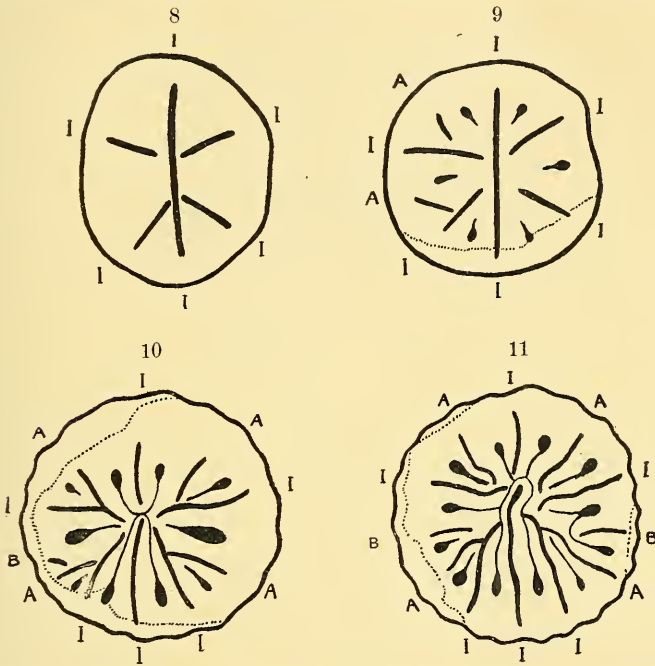
FIGURES 8, 9, 10 and 11. Figures 1, 2, 3 and 4 of Duerden, inverted.

appear take a position next the counter septum. Let us carefully examine Duerden's figures to see if in any way they may reveal traces of a tetrameral arrangement of the septa according to the law apparent in the development of the septa in the Zaphrentoid coral as above explained.

By referring to figure 9, which it will be remembered is Duerden's diagram (figure 2) inverted, we observe the appearance of two secondary septa, each marked A, apparently as a unilateral pair. I have already remarked that this appearance as a unilateral pair may be explained on the principle of unequal growth. Since we are concerned only with their relation to the septa, marked in the figure by the Roman numeral

I, this unilateral order of appearance is of no significance, particularly as later figures almost conclusively show that it is simply a matter of unequal growth. It will be observed in figure 9 that the septum marked (A) bears a relation to the septum marked I in the lower left hand quadrant very similar to the relation which septum number 2 in the counter quad-
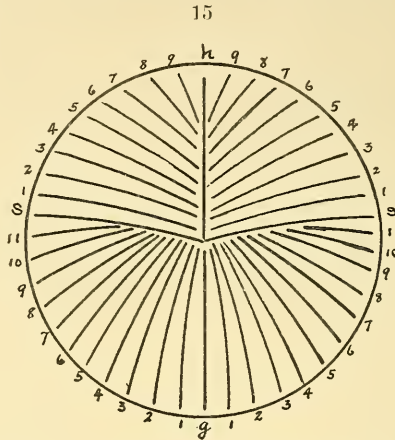

FIGURE 15.   Plan of the septa in a Zaphrentoid coral.

rant of figure 15 bears to septum number 1. Likewise the septum marked (A) in the upper left hand quadrant of figure 9 holds a relation with reference to the adjacent primary septum similar to that which number 1 in the left hand cardinal quadrant of figure 15 bears to the adjacent transverse septum. It will be remembered, also, that in the above explanation of Duerden's figure 1, the comparative thinness of the upper pair of septa marked I was pointed out and that this was considered to be suggestive.

In figure 10 (figure 3 of Duerden, inverted) we observe a further increase in the number of secondary septa. Here the comparative thinness of the lower pair of septa marked I is again noticeable. In the upper quadrants are two secondary septa marked (A), each lying adjacent to the upper lateral "primary" septum on the side in which it appears. In the lower quadrants are two new septa marked (A) and in the left the beginning of a third, marked (B), which bears the relation to (A) that the latter holds with respect to the adjacent septum marked I. In this figure we also notice the division of the median septum into an upper and lower portion, the upper part of which, in Duerden's figures, is marked the "cardinal," the lower the "counter"; i. e., in Duerden's diagram 3, the upper

(the lower here) is called the " cardinal," and the lower (the upper in figure 10) is called the " counter." Figures 4 and 11 mark an increase in the number of secondary septa, and a noticeable increase in the length of the " cardinal " septum, and a shortening of the " counter " septum. In figure 11 it will be observed how similar the general arrangement of the septa is to that given in figure 15. The lower portion of the median corresponds to (*g*) in figure 15, the upper to (*h*). In the upper quadrants the secondary septa (A) in their relations to the upper pair marked I, follow the plan exhibited in the cardinal quadrants of figure 15. In the lower quadrants the secondary septa marked (A) and (B), as also do the " primary " septa (Duerden) marked I, have an arrangement that strongly suggests the condition in the counter quadrant of figure 15. Figures 5 and 12 show this arrangement even better, and bear a striking similarity to figure 15. There is now evi-

FIGURE 12. Figure 5 inverted.

dent a striking bilateral arrangement of the septa, which according to Duerden and Pourtalès proceeds from an unsymmetrical development of the secondary septa in only four of six primary interspaces—proceeding as they do on the assumption that there are six primary septa.

An examination of figures 13 and 14 shows the position of the fossula in Lophophyllum to be in the same position as in the Zaphrentoid coral. To designate the cardinal septum always as the primary septum on the convex side of the corallum (after Nicholson) introduces some difficulty in making comparisons. The cardinal septum is to be regarded as that which, with the secondary septa in the same quadrant, exhibits a pinnate arrangement. That this may occur on the concave or convex side of the corallum is well known. According to Jakowlew the one fossula which can be determined is always developed on the cardinal septum.* Both the pinnate arrangement of the septa, which marks the position of the cardinal septum, and the fossula are by this author regarded as the product of the mode of growth of the corallum. However that may be, we have examples of the fossula and the cardinal
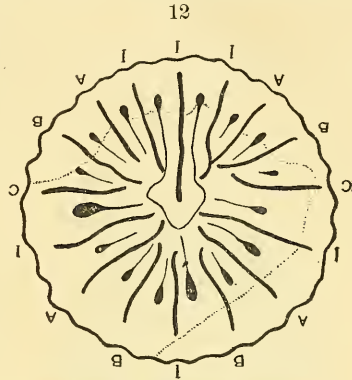
* " Ueber die Morphologie und Morphogenie der Rugosa," Verhandlungen der Russisch-Kaiserlichen Mineralogischen Gesellschaft zu St. Petersburg. Bd. XLI, Lief 2, 1904.

septum occurring on the concave side.   Since we find not only
the fossula, but also the pinnate arrangement of the septa,
occupying the position of the lower portion of the median sep-
tum in Duerden's figures, this portion must be the cardinal,
which in this specimen is on the concave side ; and the upper
portion is the counter instead of the cardinal, as Duerden has
designated it.   That this interpretation is correct is clearly
shown by the figures.   We have now simply to invert the
diagrams to get a well organized Zaphrentoid type, in so far as
the adult arrangement of septa and fossula are concerned.

It remains yet to consider the two upper " primary " septa
of Duerden's figures in more careful detail.   Certain studies
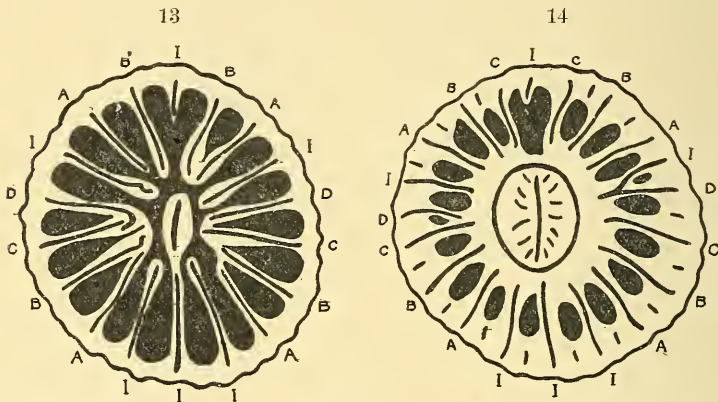
FIGURES 13 and 14.   Figures 6 and 7 inverted.

which I have made on *Streptelasma profundum* from the
Black River limestone seem to indicate most strongly a tetra-
meral plan of growth in the primary septa of the Rugosa; to
use a borrowed phrase, " in so far as this type may be taken as
representative."   These studies will be given in greater detail
presently.   Their significance here, however, is to indicate
that the tetrameral arrangement is not a secondary develop-
ment on a hexameral basis, but on the contrary, that the hex-
ameral arrangement in the tip of Lophophyllum is really only
apparent and that *L. proliferum* from the beginning exhibits
a quadripartite plan of the septa.   To one who examines
Duerden's figures the hexameral plan at first sight seems to be
the only way of interpreting this very early condition.   And I
am well aware that by some it is likely to continue as the only
interpretation.

Jakowlew came to the important conclusion that the prim-
ary spaces in which the secondary septa did not develop

appeared adjacent to the counter septum without regard to whether the latter appeared on the convex or concave side of the polyp.* In so far as Jakowlew's careful comparative studies are conclusive this would again indicate that what Duerden has designated as the cardinal septum is really the counter septum, as I, by comparison with a typical Zaphrentoid arrangement above, have pointed out to be the case.

By an examination of the diagram of the adult we are further impressed with the fact that the so-called primary spaces in which secondary septa do not develop are at the time of maturity not to be distinguished in any respect from the spaces which separate the secondary septa in the same quadrants. We note also that the lateral septa marked I in the upper quadrants of Duerden's figures have a position and an order of appearance which, if they were to be regarded as secondary septa, would correspond to the septa marked by the Arabic numeral 1 in the counter quadrants of figure 15, which illustrates the usually accepted order of appearance in the Zaphrentoid coral. We are furthermore impressed by the fact that the later sections of the corallum (figures 7 and 14) show the appearance of the tertiary septa, in the two *Kammern* next the "cardinal" (Duerden) at the top of figure 7, having precisely the same relations to adjacent septa as do the tertiary septa in all *secondäre Kammern*. The tertiary septa may have no sequence value, but the fact that they appear at all in the "primary" interspaces next the "cardinal" septum is suggestive that these spaces do not differ essentially from the secondary interspaces.

I am aware that in support of the interpretation which I shall presently present as an explanation of the presence of this pair of so-called primary septa next the "cardinal" septum, I have no absolute proof. I have called the reader's attention to the striking resemblance which Duerden's diagrams have to the usually accepted arrangement and order of appearance of the septa in the Zaphrentoid coral when the diagrams are inverted and their structural features interpreted in the terms of Zaphrentis. In Streptelasma (figure 16) it will be seen that the tertiary septa are present also in all interspaces. As to any sequence in their order of appearance, it was not possible to determine in the specimen, as their lower ends were very thin, and the extent to which they went down into the calyx could not be traced. The lines representing the tertiary septa in figure 16 do not indicate their indistinctness at their lower ends.

With regard to the "ultimate fate of the two bilateral pairs of primary septa" Duerden expresses himself as follows:

* Ueber die Morphologie und Morphogenie der Rugosa," Seite 412.

"One pair forms the 'alar' or lateral septa of the paleontologist, while the two moities of the remaining pair, recognized by Ludwig and Pourtalès, but not accepted by Kunth, are disposed one on each side of the axial septum on the convex side of the calice."

By the several figures reproduced here, e. g., figure 5 or figure 12, we observe how accurately this statement disposes of the septa, so far as their position is concerned, according to the Zaphrentoid plan. We see the "two moities" occupying exactly the position which the first two secondary septa to appear in the counter quadrant should occupy and we see them appearing before those of the cardinal quadrant as the greater number of septa in the counter quadrant of the adult
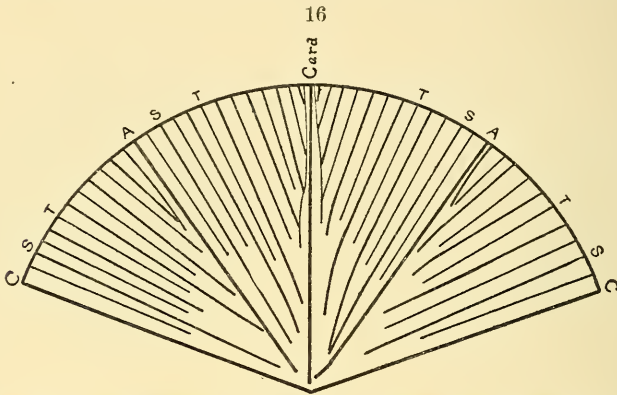
FIGURE 16.—*Streptelasma profundum.* Diagrammatic drawing somewhat enlarged.

would indicate to be the natural and logical order. The fact that the counter quadrant has the greater number of secondary septa supports the idea of acceleration in this quadrant. It is also to be noted that the number in the upper quadrant of Duerden's figures exceeds that in the lower quadrant by more than one, if we include the so-called "primary" septa.

How are we to account for this close resemblance of *L. proliferum* to a typical Zaphrentoid? Are we to regard these "primary" septa, which "are disposed one on each side of the axial septum on the convex side of the calice," as primary or secondary? If primary, what evidence is there that they are primary? If secondary, what evidence can be brought forward in support of their secondary nature, or what explanation can be offered of their appearance so early in the life history of the individual? The strongest evidence of their primary nature, of course, is their presence in the extreme tip of the

corallum. There they are, and if they do not show by their presence a primary hexameral arrangement some very strong evidence must be brought forward to show why they do not.

I am aware of the difficulty of explaining away their very apparent primary character, especially as any perfect series of fossil forms is not at hand to give us the absolute proof that *L. proliferum* may be at the extreme end of an accelerated series in which the pair of "primary" septa under discussion appear at progressively earlier and earlier stages in the life history of the individual until at last in *L. proliferum* we have them established so early that they simulate the nature of primary septa. In my criticism of Duerden's paper I wish to accord the author the credit due his careful investigations and to acknowledge his wide acquaintance with the Anthozoa. I would be understood in offering any other interpretation of his figures than that which he gives as being conservative, and far from committing myself as to having settled the matter. At the same time I believe that such an acceleration, difficult as it might be to account for, is far from being impossible, if it is not quite probable. In the absence of definite proof we have to rely upon analogy to a large extent, and call to our service in interpreting the structures in *L. proliferum* the knowledge furnished by studies upon other forms.

The idea of acceleration is by no means a new one. The principle undoubtedly has been an all important factor in bringing about those mutations which are the true species in certain evolutional series. In fact, it seems to be in many cases the only means of interpreting certain aberrant individuals which are so often grouped together in a heterogeneous way. We may be unable to explain why certain structures appear earlier in the life of certain individuals than they did in ancestral forms; but it is undoubtedly to be explained in many cases as a reaction towards its environment on the part of the individual, the response being a new anatomical structure, or a different plan of development because of a new importance of old structures, such as the assumption of a greater physiological importance of certain ones. On this wise it would not be difficult to imagine that for some reason or other, obscure as that may be, the mesenteries next the "cardinal" septum in Duerden's figures are really secondary septa called into being so early as to appear to be primary septa. The striking resemblance of Duerden's figures, if I may again call attention to this fact, to the usually accepted Zaphrentoid type of arrangement and the fact that the so-called primary septa follow the well recognized law of Kunth, are offered in

support of this interpretation; the possibility of acceleration makes the inference logical.*

If these two septa were called into being at a relatively early period, that is, before they normally would appear in a non-accelerated type, it is easy to conceive how, once established, this acceleration, as the name implies, would cause these septa to appear at an earlier and earlier stage until in a later geological type they would appear in the early nepionic stages so fully developed as to present the character of primary septa. Their true nature then, in the absence of a series showing this progressive acceleration, could be explained by noting the subsequent development of secondary septa that were not accelerated, and, in this connection, noting the final
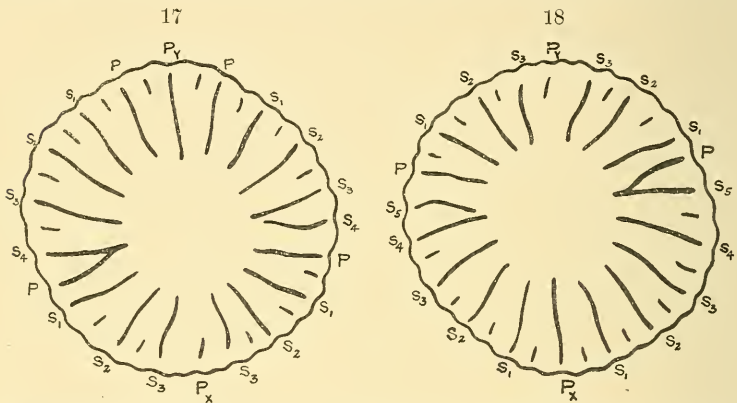
FIGURES 17 and 18.   A portion, in each case of figures 7 and 14, with new lettering.

position of the septa that were accelerated, as I have done. Duerden's figures, to my mind, lend themselves in every respect to this interpretation.

At the risk of repetition I have at this place introduced a portion, in each case, of figures 7 and 14 with new lettering, which may serve to recapitulate and make a little clearer the foregoing discussion.

Figure 17 shows in a diagrammatic way the value of the septa as interpreted by Duerden in figure 7.   (P_y), " cardinal septum " (Duerden); (P_x) " counter septum " (Duerden); (P)

* The suggestion of Boveri that the anomalous number of the septa of the first cycle in *Tealia crassicornis* may be explained as due to the precocious development of four septa belonging to the second cycle, is a recognition of the fact that acceleration in development may operate to conceal a primitive condition. Boveri's suggestion is supported by his own observations on the peculiar mesenterial arrangement in an undetermined larval form. (This suggestion was not seen until this article was written.)

other "primary septa," (Duerden); (S) secondary septa. The subscripts indicate the order of appearance.

Figure 18 is a portion of figure 14 and is figure 17 inverted. The lettering in this case indicates the author's interpretation of the value of the septa. (P_y) "cardinal septum" (author); (P_x) "counter septum" (author); (P) "alar septa" (author); (S) secondary septa. The subscripts indicate the order of appearance. Note that the cardinal and counter septum are reversed and that the number of primary septa are reduced by two.

Duerden, from his wide acquaintance with modern corals, makes the statement that no living coral presents such a mesenterial (septal) sequence as *L. proliferum*, yet it bears the closest resemblance to what is found to be characteristic of Zoanthoid polyps, except that the mesenterial increase takes place in only two exocoelic chambers in these forms, while, as Duerden would have it, in *L. proliferum* it is carried on in four such chambers. Of whatever value the fact may be, it yet remains that no modern coral has precisely the same septal sequence as is described for *L. proliferum*, which suggests that here we have merely a specialized type of the Zaphrentoid coral. Starting with the hypothesis that the primary septal plan of *L. proliferum* is hexameral, we have yet to investigate other corals, selected with the purpose of getting a primitive species as well as one which is favorable for study, to find out how far they lend support to the hexameral primary septal plan or tend to disprove it.

The difficulty involved in getting sections of coral tips that really show anything one way or the other is appreciated only after one has made the attempt. The tips either break at an inopportune moment, or after sectioning show nothing conclusive. Turning from sections which revealed little or nothing, I was more fortunate in securing some specimens of *Streptelasma profundum* from the Black River limestone. The specimens were silicified and had been removed from their matrix by acid. Though small, they showed the well-preserved septa on the inside of the corallum. These specimens were carefully examined. Two were found which revealed the arrangement of the septa at the base of the calyx on the inside of the coral so satisfactorily that they were set aside for detailed study. During the attempt to sketch the relations of the septa in one of these specimens the corallum was unfortunately broken into several pieces so that it was impossible to make a satisfactory drawing. A drawing of the other is given in figure 16, which in all essentials is like the one which was broken.

The corallum of *Streptelasma profundum* in figure 16 is represented as split on the counter septum and rolled out; the point toward which the heaviest lines converge is the apex; the curved line is the circumference of the calyx; (C) is the counter septum; (S), the secondary septa; (T), the tertiary septa; (Card), the cardinal septum. The corallum was so small and fragile that it was impracticable to attempt drawing to an exact scale, as the measurements could not be made in the corallum without the risk of breaking it. Care was exercised not to exaggerate the relations of the septa, so that in the drawing, though necessarily more or less diagrammatic, one sees a very close approximation to the actual appearance. In this figure it is obviously impossible to represent anything but lengths. In doing this I have tried to be true to facts. At the base of the corallum (and in describing the corallum from now on it must be remembered that we are looking down into the vase of the corallum) the septa are not so deep (by depth I mean extension from the wall inward) as a little way up, as though they had undergone resorption or ceased to grow. In modern corals a resorption of the mesenteries takes place at the base, as the animal grows upward.* It is not unlikely that this is the explanation of the tapering off that was observable in all the septa which extended deepest into the calyx. Of the four primary septa represented in the drawing, the counter extended farthest down, the cardinal next, and the alar septa next. The bending represented in the alar septum on the right is meant to represent the slight deflection of the inner edge of the septum upward, as though the mesentery has been crowded by the counter septum at the base. Attention is directed to the fact that only four septa appear in the early stage of the corallum. The alar septum on the left is appreciably longer than the secondary septum adjacent to the counter represented in the left hand portion of the figure by S. The latter showed greater depth near the base than the corresponding one on the right, as though it had been resorbed to a less extent, or as though it had grown faster. The second secondary septum in the left hand counter quadrant exhibits a condition of unequal growth. The order of development of the secondary septa is plainly seen to correspond exactly to that in the Zaphrentoid coral in figure 15. With respect to the tertiary septa, although examined with the aid of a powerful binocular in artificial light, it was impossible in all cases to tell to what length they extended down into the coral. In the cardinal quadrants near the main septum they merged with a ridge

* "Morphology of Coral Polyps," J. E. Duerden, Smithsonian Miscellaneous Collection, Quart. Issue, vol. ii, No. 1, 1904, p. 98.

represented by the curved line, which ridge was small and of about the same size as the tertiary septa.

As was stated above, the specimen was examined by the aid of a binocular in electric light. No doubt was left in my mind that the four septa indicated by the heaviest lines in the figure extended farthest down into the base of the calyx. Not content, however, with my observations, I submitted the specimen to two others, whose results tallied with mine. The results, therefore, seemed to indicate that *Streptelasma profundum* showed a primary tetrameral arrangement and that the further addition of the secondary septa proceeded in accordance with the law that the Zaphrentoid type has been shown to illustrate.

In the criticism offered above of Duerden's figures I have, I think, offered another possible interpretation of the occurrence of one of the pairs of so-called primary septa in the tip of *Lophophyllum proliferum.* Whether this interpretation is accepted or not, I think it is by no means established that the hexameral arrangement is a primitive one. In the first place, as I have pointed out above, *L. proliferum* is in some respects, notably because of its occurrence in Carbonic time, not a suitable specimen upon which to establish a primitive arrangement of the septa. *S. profundum* from the Ordovicic was selected for study mainly because of its early geological occurrence. The fact that it shows a primary tetrameral arrangement suggests that such was the primitive condition. To my mind it suggests this because it is a comparatively old type and, because, so far as the septal sequence is concerned, it shows absence of acceleration.

It is evident, I think, that the primitive condition of these septa in the Rugosa is not yet settled. The tetrameral arrangement, if primary, will so long as this is made the basis of classification, place those corals which possess it in a group by themselves. No modern corals exhibit the peculiar septal plan as revealed in *Streptelasma profundum ;* nor, in fact, as revealed in *Lophophyllum proliferum.* The fact that Lophophyllum is quite distinct from anything that is modern perhaps gives some support to the view that it is merely an accelerated type of a Zaphrentoid coral, occurring as it does among an extinct group.

Whether the hexameral plan is derived from a tetrameral one is still an unsolved mystery. Developmental studies among modern forms may yet throw some light on this question.

From the wide prevalence of the tetrameral arrangement among the extinct Rugosa it is probable that it is something inherent rather than acquired by mode of growth, especially

as it is characteristic not only of bent forms but also of simple, straight cones. At all events, one may take exception to the statement that " studies on the septal development of extinct Paleozoic corals reveal that in these early forms the primary septal plan was hexameral like that of modern forms."

Further studies upon well-preserved specimens of early Rugosa are much to be desired.

Postscript.

Since writing this article I have received and carefully read an excellent paper by Dr. Duerden on " The Fossula in Rugose Corals." In this article I find a full recognition of the principle of retardation in development. The author shows beyond question that the alar fossulae and the cardinal groups of shortened fused septa in Hadrophyllum are developmental stages when compared with the ephebic condition of a form like Streptelasma. Since retardation in development means the retention in the adult stage of characters which belong to earlier stages, nepionic or neanic, Hadrophyllum must be a retarded type when compared with a form like Streptelasma, which passes through a Hadrophyllum stage. Both forms are probably to be regarded as derived from a protostreptelasmic stock.

The author of the paper makes the point that,

" Whenever alar fossulæ are present they represent an incompletion in the establishment of the newer septa of the alar region as compared with species in which no alar fossulæ are represented ; they have only a developmental significance and would not correspond with any structural peculiarity of the fully developed polyp."*

This is the point which I have insisted upon with reference to the pair of so-called " primary septa " in *L. proliferum ;* namely, that they do not have the structural importance which Duerden gives to them, but that they have a developmental significance only.

Duerden further remarks :

" As would naturally be expected from such an explanation even individuals of the same species may vary much with regard to the presence or absence of alar fossulæ." †

This is evidently true. The only exception one might take to such a statement is the propriety of calling the variations

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* " The Morphology of the Madreporaria, VI, The Fossula in Rugose Corals," p. 33.
† Ibid., p. 33.

members of the same species. For example, Hadrophyllums in which no alar fossulæ were present in the adult stage would be accelerated types and properly should be made a distinct genus.

Literature.

Manual of Paleontology, Nicholson and Lydekker, Vol. I.

Treatise on Zoology, edited by E. Ray Lankaster, Part II, Porifera and Cœlenterata.

" Relationships of the Rugosa (Tetracorolla) to the Living Zoäntheæ," J. E. Duerden, Johns Hopkins University Circular, January 1902.

" Report on the Actinians of Porto Rico," J. E. Duerden, U. S. Fish Commission for 1900, Vol. III.

" Morphology of Coral Polyps," J. E. Duerden, Smithsonian Misc. Collections, Vol. XLVII, Quart. Issue, Vol. II, No. 1, 1904.

" Hamilton Group of Thedford, Ontario," Hervey W. Shimer and Amadeus W. Grabau. Bull. Geol. Soc. Amer., Vol. XIII, pp. 149–186.

" Ueber die Morphologie und Morphogenie der Rugosa," von N. Jakowlew. Verhandlungen der Russisch-Kaiserlichen Mineralogischen Geselschaft," Bd. XLI, Lief 2, 1904.

Text-Book of Paleontology, Zittel.

" Deep Sea Corals," L. F. de Pourtalès. Illust. Catalog Mus. Comp. Zool., Harvard College, IV.

" Actinozœn und Bryozœn aus dem Carbonkalkstein im Government Perm," R. Ludwig, Palæontographica X.

" Korallen aus Paläolithischen Formationen," R. Ludwig, Palæontographica XIV, 1865–66.

" Beiträge zur Kenntniss fossiler Korallen," A. Kunth, Zeit. der Deutsch. Geol. Geselsch., xxi, 1869 ; xxii, 1870.

" The Morphology of the Madreporaria, VI ; The Fossula in Rugose Corals," J. E. Duerden. Biol. Bull., Vol. IX, No. I, June, 1905.

Art. VIII.—*The Behavior of Ferric Chloride in the Zinc Reductor ;* by D. L. Randall.

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

The column of amalgamated zinc as applied in the earlier form of the Jones reductor[*] or the simpler form now generally employed[†] has proved very effective in the reduction of ferric sulphate preparatory to the estimation of the ferrous salt by potassium permanganate. The impression has prevailed, however, that the salt of iron acted upon by the amalgamated zinc must be the sulphate and that chlorides and nitrates must not be present even in small amounts.

The following work was undertaken to see whether ferric chloride might not be treated effectively in the reductor and the reduced solution successfully titrated with standard permanganate. For this work a solution of ferric chloride was made up and standardized by evaporating known amounts with 10^{cm^3} of sulphuric acid to the fuming point of the acid, passing the solution thus freed from chlorides through the reductor, and titrating with standardized permanganate. In general the procedure was to first run 100^{cm^3} of warm dilute 2·5 per cent sulphuric acid through the reductor, next to pass in the iron solution diluted with 100^{cm^3} of the warm 2·5 per cent acid and then to wash down with 200^{cm^3} of the warm dilute acid followed by 100^{cm^3} of hot water. The receiving flask of the reductor was kept in a vessel containing running tap water, so that the solution was cooled as fast as it was reduced ; and in some of the early experiments carbon dioxide was passed in at the beginning of the reduction to drive out the air and at the end of the reduction before titration, a practice which was found to be unnecessary and so was discontinued. In this work a column of amalgamated 20-mesh zinc was used in the reductor.

In the preliminary experiments there was some evidence in the high results that chlorine was evolved, even in dilute solutions, but this tendency was overcome by adding 1 gram of manganous sulphate in solution to the receiving flask before starting the reduction, according to the suggestion of Keissler[‡] and Zimmermann[§] to apply to titrations of ferrous salts by permanganate in the presence of chlorides.

Table I shows the results obtained under the varying conditions detailed.

* The Chemical Analysis of Iron, Blair, 2d edition, p. 203.
† Ibid., 4th edition, p. 94.
‡ Ann. Phys., cxviii, 41 ; cxix, 225–226.
§ Ber. Dtsch. Chem. Ges., xiv, p. 779.

TABLE I.

Exp.	FeCl$_3$ taken. cm³.	Fe. grm.	H$_2$SO$_4$ 2·5 %. cm³.	HCl. cm³.	Volume at titration. cm³.	MnSO$_4$. grm.	KMnO$_4$. cm³.	Fe found. grms.	Error. grms.
1*	20	·0349	100	0	600	0	19·50	·0354	+ ·0005
2*	20	·0349	100	0	600	0	19·53	·0354	+ ·0005
3*	20	·0349	100	0	600	0	19·45	·0353	+ ·0004
4*	20	·0349	100	0	600	0	19·49	·0354	+ ·0005
5*	20	·0349	100	0	600	1·00	19·30	·0350	+ ·0001
6*	20	·0349	100	0	600	1·00	19·30	·0350	+ ·0001
7*	20	·0349	100	0	600	1·00	19·20	·0348	— ·0001
8*	20	·0349	100	0	600	1·25	19·28	·9349	± ·0000
9	20	·0349	100	0	600	1·25	19·35	·0351	+ ·0002
10	20	·0349	100	0	600	1·25	19·20	·0348	— ·0001
11	20	·0349	100	0	600	1·25	19·30	·0350	+ ·0001
12	20	·0349	100	0	600	1·25	19·21	·0348	— ·0001
13	20	·0349	100	5	600	1·25	19·29	·0350	+ ·0001
14	20	·0349	100	10	600	1·25	19·30	·0350	+ ·0001
15	20	·0349	100	20	600	1·25	19·50	·0354	+ ·0005
16	20	·0349	100	20	600	1·25	19·50	·0354	+ ·0005
17	20	·0349	100	15	600	1·25	19·22	·0348	— ·0001
18	20	·0349	100	20	1000	2·50	19·32	·0350	+ ·0001
19	20	·0349	100	20	1000	2·50	19·30	·0350	+ ·0001
20	20	·0349	100	30	1000	2·50	19·31	·0350	+ ·0001
21	20	·0349	100	30	1000	2·50	19·37	·0351	+ ·0002
22	20	·0349	100	35	1000	2·50	19·45	·0353	+ ·0003
23	20	·0349	100	40	1000	2·50	19·50	·0354	+ ·0005
24	20	·0349	100	50	1000	2·50	19·50	·0354	+ ·0005

In the last seven experiments by diluting abundantly it was possible to work with a greater amount of free acid. Having found the work to go successfully with small amounts of iron and dilute permanganate solutions the experiment was continued with the use of more ferric chloride and a stronger permanganate solution.

TABLE II.

Exp.	FeCl$_3$. cm³.	Fe taken. grms.	H$_2$SO$_4$ 2·5 %. cm³.	HCl. cm³.	Volume at titration. cm³.	MnSO$_4$. grms.	KMnO$_4$. cm³.	Fe found. grms.	Error. grms.
1	25	·0437	100	0	600	1·	7·70	·0434	— ·0003
2	25	·0437	100	0	600	1·	7·73	·0435	— ·0002
3	25	·0437	100	0	600	1·	7·76	·0438	+ ·0001
4	25	·0437	100	0	600	1·	7·74	·0436	— ·0001
5	25	·0437	100	0	600	1·	7·75	·0437	± ·0000
6	50	·0874	100	0	600	1·	15·50	·0874	± ·0000
7	50	·0874	100	0	600	1·	15·49	·0873	— ·0001

* CO$_2$ was used in receiving flask.

TABLE II (continued).

Exp.	FeCl₃. cm³.	Fe taken. grms.	H₂SO₄ 2·5%. cm³.	HCl. cm³.	Volume at titration. cm³.	MnSO₄. grms.	KMnO₄. cm³.	Fe found. grms.	Error. grms.
8	100	·1748	100	0	600	1·	30·90	·1742	—·0006
9	100	·1748	100	0	600	1·	30·92	·1743	—·0005
10*	50	·2532	100	0	600	1·	44·95	·2533	+·0001
11	50	·2532	100	0	600	1·	45·00	·2536	+·0004
12	50	·2532	100	0	600	1··	45·01	·2537	+·0005
13	50	·2532	100	0	600	1·	44·95	·2533	+·0001
14	50	·2532	100	0	600	1·	44·97	·2534	+·0002
15	100	·5064	250	0	800	1·	89·94	·5069	+·0005
16	100	·5064	250	0	800	1·	89·94	·5069	+·0005
17*	75	·4872	100	0	750	1·	70·81	·4871	—·0001
18	75	·4872	100	0	750	1·	70·75	·4867	—·0005
19	75	·4872	100	0	750	1·	70·83	·4873	+·0001
20	75	·4872	100	0	750	1·	70·82	·4872	±·0000
21	75	·4872	100	0	750	1·	70·83	·4873	+·0001
22	100	·6497	100	0	750	1·	94·43	·6497	±·0000
23	100	·6497	100	0	750	1·	94·44	·6498	+·0001
24	100	·6497	100	10	750	1·	94·44	·6498	+·0001
25	100	·6497	100	20	1000	5·	94·53	·6503	+·0006
26	100	·6497	100	25	1000	5·	94·53	·6503	+·0006
27	100	·6497	100	25	1000	1·25	94·53	·6503	+·0006
28	100	·6497	100	25	1000	1·25	94·48	·6500	+·0003
29	100	·6497	100	25	1000	5·00	94·49	·6501	+·0004

For purposes of comparison Table III gives some results obtained by the direct evaporation of the ferric chloride solution with sulphuric acid.

TABLE III.

FeCl₃ = cm³.	Fe taken. grms.	H₂SO₄ 1:1. cm³.	Volume at titration. cm³.	KMnO₄. cm³.	Fe found. grms.	Error. grms.
75	·4872	25	750	70·75	·4867	—·0005
75	·4872	25	750	70·83	·4873	+·0001
75	·4872	25	750	70·83	·4873	+·0001
75	·4872	25	750	70·88	·4876	+·0004

These experiments show that it is possible to reduce ferric chloride in the zinc reductor and to determine the iron with success by potassium permanganate, provided the titration is carried on in the presence of manganous sulphate and in solutions sufficiently dilute. A small excess of hydrochloric acid has no influence on the result in dilute solutions, and by diluting to one liter the excess may amount to as much as 25$^{cm^3}$ of the strongest acid.

In closing the writer expresses his thanks to Prof. F. A. Gooch for advice and assistance given during the progress of the work.

* Changed standard of solutions.

Art. IX.—*Dipnoan Affinities of Arthrodires;* by C. R. Eastman.

In the modern fauna, *Neoceratodus* stands out as an isolated landmark which has preserved faithful indications of the course evolution has taken amongst Dipnoan fishes. Compared with its nearest surviving relatives, *Protopterus* and *Lepidosiren,* it represents a relatively early larval stage of development ; and its generalized organization bears witness to an extremely ancient origin. Regarding the Ceratodont type as decidedly more primitive in structure than that of *Dipterus* and its allies, and this view is supported by weighty evidence, two conclusions are possible with respect to their genetic relations. Either the more primitive type was in existence as early as the Devonian, and has survived practically unchanged ever since ; or else modern Lung-fishes are to be looked upon as degenerate descendants of the *Dipterus* stock.

Objections stand in the way of either theory. Opposed to the first is the failure of Palæontology to realize our conception of a '*Palæoceratodus*'—that is to say, of fossil organisms standing in ancestral relations to both Ctenodipterines and Ceratodonts ; and added to this is the difficulty of supposing any primitive type to have come down to us from remote ages without undergoing extensive modifications. The newer interpretation, proposed some years ago by Dollo,[*] is attended with still graver difficulties. For if we make *Dipterus* the initial term of a series leading through various Palæozoic genera and culminating in modern Lung-fishes, it will be necessary, as Professor Bridge has observed,[†] "to assume the possibility of an ossified skull so far degenerating as to lose almost all trace of endochondrial ossification, and secondarily revert to the condition of a skull so completely cartilaginous, and so primitive in other respects, as that exhibited by the living *Ceratodus.* So far as I am aware, there is no evidence to justify belief in such a possibility."

Comparison of other structural features besides the skull leads to altogether similar conclusions. Thus, the argument that the heterocercal tail of *Dipterus* must be antecedent to the diphycercal (or gephyrocercal) of *Neoceratodus* is met by Fürbringer[‡] in following wise : "Nachdem in jeder Beziehung

[*] Dollo, L., Sur la phylogénie des Dipneustes, Bull. Soc. Belge Géol., vol. ix (1895), pp. 79–128.

[†] Bridge, T. W., Morphology of the Skull in Lepidosiren, etc., Trans. Zool. London, vol. xiv (1898), p. 370.

[‡] Fürbringer, K., Beiträge zur Morphologie des Skeletes der Dipnoer. (Semon's Zool. Forschungsreisen in Australien, etc.), Jena Denkschr., vol. iv (1904), p. 500.

Ceratodus als der primitivere erkannt ist, muss auch die
Annahme Dollo's, dass die Heterocerkie bei *Dipterus* etwas
Primitives bedeute, fallen.   Der Schwanz von *Ceratodus*
zeigt zwar gewisse Rückbildungen ; fur eine ehemahlige
Heterocerkie bei ihm ist aber kein Beweis erbracht.   Ich kann
nach alledem, falls überhaupt eine Verwandtschaft zwischen
Dipterus und den recenten Dipnoern besteht, diese im Gegen-
satz zu Dollo nur im Sinne von Woodward und Bridge auffassen."
    Elsewhere the same author expresses himself unreservedly
as to the relative specialization of the two types : "So wäre
eines doch sicher, dass *Ctenodus* und namentlich *Dipterus*
weit höher differenzirt sind als Ceratodus."   Smith Wood-
ward's opinion is that *Dipterus* and its allies are more special-
ized than any existing Dipnoan, and that the more generalized
types have alone survived to represent the group at the present
day.*   Though he does not distinctly say so, his remarks
would imply that the archetype of *Ceratodus* was ancestral to
Ctenodipterines, the latter becoming finally extinct.
    So much for a statement of the problem.   Remains to
inquire whether Palæontology can point the way toward a solu-
tion, even if indirectly.   It has been said that no generalized
form standing in the relation of ancestor to both *Dipterus* and
Ceratodonts—the latter alone having persisted,—is known
from the Devonian.   Were such a form to be brought to light,
or should its existence become a necessary postulate from
other facts, it is evident that the question as to descent of mod-
ern Dipnoans would be stripped of much perplexity.   In that
event, also, there would be no necessity for an appeal to the
imperfection of the palæontological record, such as has hereto-
fore existed.
    Now we confidently believe that the relations between
recent and fossil Dipnoans will appear in much clearer light
through comparison of *Neoceratodus* with Arthrodires, taking
Mylostoma and *Dinichthys* as typical examples of the latter.
There is no novelty in the idea that Arthrodires are related to
Dipneusti, Newberry's original suggestion to that effect hav-
ing found several warm supporters, notably Cope and Smith
Woodward.   It must be said, however, that the question has
remained eminently controversial, first one and then another of
rival interpretations gaining headway.   That a singular lack of
unanimity prevails as to the sytematic position of Arthrodires
must be apparent to anyone having a casual acquaintance with
the literature.   The reason for such diversity of opinion evi-
dently lies in non-recognition of homologies between the struc-
tural type of Arthrodires on the one hand, and those of fossil and

* Woodward, A. S., Catalogue Fossil Fishes British Museum, Part II
(1891), introduc. p. xx.

recent Dipnoans on the other. It is even denied by writers of authority that such homologies exist. Dean, for instance, affirms that there is as much propriety in referring Arthrodires to the sharks as to Dipnoans, and in his latest contribution proposes to exclude them from fishes altogether.* Their nature is conceded to be highly problematical by President Jordan, who dismisses all thought of a connection between them and Lung-fishes. Thus, in the recent standard treatise of this author we read as follows : †

These monstrous creatures have been considered by Woodward and others as mailed Dipnoans, but their singular jaws are quite unlike those of the *Dipneusti*, and very remote from any structures seen in the ordinary fish. The turtle-like mandibles seem to be formed of dermal elements, in which there lies little homology to the jaws of a fish and not much more with the jaws of Dipnoan or shark.

The relations with the Ostracophores are certainly remote, though nothing else seems to be any nearer. They have no affinity with the true Ganoids, to which vaguely limited group many writers have attached them. Nor is there any sure foundation to the view adopted by Woodward, that they are to be considered as armored offshoots of the Dipnoans.

Again, at page 445 of the same work, occurs this passage :

These creatures have been often called ganoids, but with the true ganoids like the garpike they have seemingly nothing in common. They are also different from the Ostracophores. To regard them with Woodward as derived from ancestral Dipnoans is to give a possible guess as to their origin, and a very unsatisfactory guess at that.
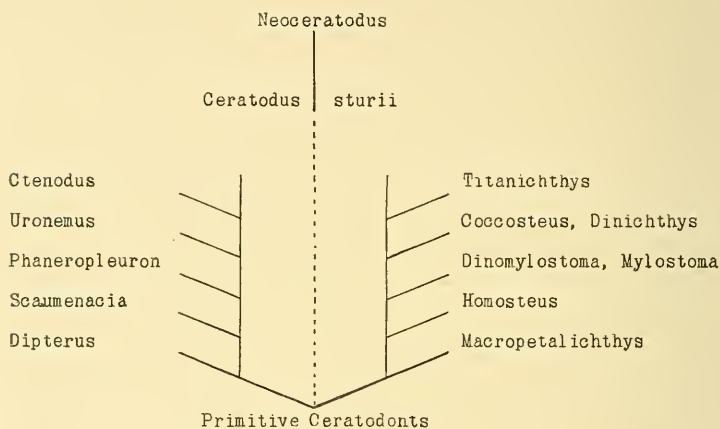
What is meant by the charge that Woodward's view rests upon insecure foundation is simply this: Arthrodires are provisionally classed amongst Dipnoans by Woodward on the assumption that they were autostylic ; however probable the assumption, its truth remains to be demonstrated. And we must admit that, according to the usual interpretation of jaw-parts in Arthrodires, it would be very difficult to prove that autostyly existed. Granting all this, yet in the light of a novel interpretation, and of cumulative evidence drawn from various parts of the skeleton, the problem may be simplified, perhaps even placed in fair way of solution.

Our object will now be to suggest a new interpretation of the dental elements of Arthrodires, and to point out certain homo-

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*Dean, B., Palæontological Notes, Mem. New York Acad. Sci., vol. ii (1901), p. 111.
†Jordan, D. S., Guide to the Study of Fishes, vol. i, p. 582 (New York, 1905).

logies between them and *Neoceratodus.* Provided a case be
made out, the structural resemblances between the two types
can hardly be explained except on the hypothesis of a common
origin. It therefore becomes necessary to suppose that a
generalized archetype of modern Dipnoans, probably derived
directly from the Elasmobranch stem, was present during the
lowermost Devonian, giving rise to two specialized groups,
but manifesting itself, like *Limulus, Cestracion,* Scorpions and
other archaic survivals, extraordinary persistence and conserva-
tism ever since. The relations between the three recognized
orders of Dipnoans would then appear after some such scheme
as this :

Neoceratodus

Ceratodus | sturii

Ctenodus   Titanichthys
Uronemus   Coccosteus, Dinichthys
Phaneropleuron   Dinomylostoma, Mylostoma
Scaumenacia   Homosteus
Dipterus   Macropetalichthys

Primitive Ceratodonts

    In what follows we shall endeavor to show (1), that the
dentition of Arthrodires is distinctly of the Dipnoan type, aris-
ing in the same manner and representing the same elements ;
(2) the relations of the Meckelian cartilage are identical in
both types ; (3) the dermal plates forming the cranial roof have
undergone corresponding reduction and are arranged after
essentially the same pattern, both in Arthrodires and Cerato-
donts ; and (4), *Neoceratodus* recalls throughout its entire
organization, save for the absence of dermal armoring, the
principal features of Arthrodires. Such intimate structural
resemblances cannot be explained by parallelism, but point
plainly to common descent.
    Dentition of Dinichthys and Neoceratodus compared.—So
long ago as 1875, Newberry* was struck with the close par-
allelism between the jaws of *Dinichthys* and those of *Pro-*

*Newberry, J. S., Rept. Geol. Surv. Ohio, Palæont. vol. ii (1875), p. 15.

topterus, even imagining the latter to be a lineal descendant of " Placoderms." Now the trenchant dental plates of *Protopterus* and *Lepidosiren* are clearly but a variant of the Ceratodont type, and we have to take only a step further to see that the Dinichthyid dentition has been similarly derived. No difficulty is offered by the so-called " premaxillary " teeth of *Dinichthys,* which are the precise equivalents of the vomerine pair in modern Dipnoans. As for the characteristic crushing plates in upper and lower jaws of Ceratodonts, these occur normally in *Mylostoma,* but in *Dinichthys* have become rotated so as to stand upright in the jaws, their outer denticulated margins functioning against one another like the blades of a pair of shears. An inkling as to how this variation was brought about is afforded by the Triassic *Ceratodus sturii,*[*] which may be taken to represent an incipient stage of metamorphosis. The dental plates of this form are seen to be turned more or less on edge, the corrugations interlocking in opposite jaws when the mouth is closed, and a rudimentary beak being developed in front which recalls the well-known projection in Dinichthyid mandibles.

As for the so-called " maxillary " or " shear-tooth " of *Dinichthys,* this corresponds plainly to the triturating upper (palato-pterygoid) dental plate of Ceratodonts, turned rather more upright than in *C. sturii:* and its anterior process or " shoulder " is represented by the forwardly placed ascending process of modern forms.[†] In Arthrodires, as in other Dipnoans and higher forms, the functional lower jaw is formed by membrane plates which have ossified around the Meckelian cartilage. Distinct angular and articular elements appear to be wanting in *Dinichthys,* but the splenial is strongly developed, supporting the dental plate properly speaking in front, and being articulated posteriorly with the cranium by cartilage, as in *Neoceratodus.* But one interpretation can be given of the conspicuous groove which extends forward along the inferior border of the splenial, passing underneath and to the inner side of the dental plate proper, and terminating at the symphysis. In it were lodged remnants of the Meckelian cartilage, precisely as in the living *Protopterus.*[‡] Intermandibular teeth have not been definitely proved to occur, although their presence would be in strict accord with embryological evidence, and the appearance of certain specimens has created a

[*] Teller, F., Ueber den Schädel eines fossilen Dipnoërs, Abhandl. k. k. Reichsanstalt Wien, vol. xv (1891), pt. 3, pl. iv.

[†] This process is well shown in Plate 1*a*, fig. 4, of Miall's " Monograph of the Sirenoid and Crossopterygian Ganoids." Palæont. Soc., 1878.

[‡] Wiedersheim, R., Morpholog. Studien, Heft 1, p. 55, pl. ii, figs. 3, 8. Fürbringer, K., *op. cit.,* p. 481, pl. xxxix, fig. 28.

surmise that such were developed;[*] moreover, in *Coccosteus* we are confronted with a denticulated symphysial margin the significance of which has not been explained. Finally, it should be noted that an approach to the Dinichthyid form of mandible is made even amongst Ctenodipterines,[†] and some of these also developed cutting surfaces, as in *Sagenodus pertenuis*, for instance.

Dentition of Mylostoma and Neoceratodus compared.—Our knowledge of *Mylostoma* received important additions a few years ago, as the result of Dr. Bashford Dean's investigation of the type species, *M. variabile.*[‡]   In the light, however, of

Fig. 1.—Upper dentition of *Mylostoma variabile* Newb., from the Cleveland shale of Sheffield, Ohio.   x ½.

freshly discovered material, it is clear that this author was not entirely successful in determining the relations of the palatopterygoid plates in the unique specimen studied by him. That their true arrangement is depicted in the accompanying text-figure 1, can be proved in several ways, as follows : First, in no other position is there such accurate fit between upper and lower dental plates when the jaws are closed.   Secondly, this reconstruction is in harmony with embryological evidence. And thirdly, it is identical with the arrangement recently

* Dean, B., Fishes, Living and Fossil, p. 133.   (New York, 1895.)

† Atthey, T., On Ctenodus obliquus, etc., Ann. Mag. Nat. Hist. ser. 4, vol. xv (1875), p. 309, pl. xix, fig. 2.   By Smith Woodward this species is considered identical with *Sagenodus inæqualis* Owen.

‡ Dean, B., Palæontological Notes : On the Characters of *Mylostoma* Newberry, Mem. N. Y. Acad. Sci., vol. ii (1901), pp. 101–109.

worked out for a new genus, intermediate between *Mylostoma*
and *Dinichthys*—as the name *Dinomylostoma* implies—from
the Portage beds of Mt. Morris, New York. For the privi-
lege of studying the important specimen referred to, the writer
is indebted to his friend Professor Schuchert, of Yale, in
whose custody it is, and at whose suggestion the specific title
is inscribed to the memory of the late Professor Beecher.

It is beside our purpose to present here a detailed account
of the new form ; suffice it to note that it permits accurate

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Fig. 2.—External aspect of (*a*) right, and (*b*) left mandibles of *Dinomylo-
stoma beecheri* (MS.), from the Portage of western New York. x ½.

reconstruction of the entire dental apparatus, and acquaints us
for the first time with the articular union between the lower
jaw and cranium of Arthrodires. In this latter respect the
conditions are exactly as we should anticipate from analogy
with *Neoceratodus ;* the articular cartilage is attached to the
outer surface of the splenial at its posterior extremity, and
forms a hinge with the suspensorial cartilage of the cranium.
Whether this latter was in direct connection with the head-
shield, or supported by a squamosal element, we are as yet with-
out information. The articular cartilage of the left mandible
is somewhat indistinctly shown in text-figure 2 ; that belong-
ing to the right mandible is removable, and has been omitted
in the uppermost figure.

On referring to the diagram in fig. 1, it will be seen that the vomerine teeth in *Mylostoma* are succeeded behind by two pairs of palato-pterygoid plates, instead of one only, as in Ceratodonts. Embryology teaches, however, that the discrepancy is apparent, not real; for as shown by Semon,[*] the dental plates of *Neoceratodus* arise through concrescence of conical denticles, which are at first disposed so as to form two pairs of palato-pterygoid plates, arranged as in *Mylostoma*, these afterwards fusing into one. Clearly, therefore, the upper dentition of *Neoceratodus* passes through an early *Mylostoma*-stage. Further, it will be noted that the peculiar posterior contour of the hindermost pair of plates in *Mylostoma* (the same holds true also for *Dinomylostoma*) is conformable to, and therefore to be associated with, the usual pattern of palato-pterygoid cartilage found in all Dipnoans. Amongst Ctenodipterines this element is ossified, and passes under the name of " upper dentigerous bone "; the fact that it is unossified in Arthrodires agrees with other evidence pointing to their lesser specialization.

The mandibles of *Mylostoma* betray unmistakable indications of a Ceratodont origin, for the functional dental plate is even more sharply demarcated from the supporting splenial than in *Dinichthys* or *Dinomylostoma*. It even bears prominent ridges radiating from the inner margin, which may possibly be a survival of primitive Dipnoan conditions. The presence of intermandibular teeth would be in complete harmony with embryological evidence, and as a matter of fact, certain detached teeth have been somewhat doubtfully interpreted as such by Newberry.[†] The pair figured by him, however, have every appearance of being vomerine; interpreting them as such, we must confess ignorance of a pair opposed to them in the lower jaw. Amongst Ctenodipterines, *Synthetodus* is the only genus in which symphysial teeth are permanently retained, thus paralleling an evanescent stage of *Neoceratodus*.

Cranial Characters of Arthrodires and Neoceratodus compared.—The most notable peculiarity of the skull in *Neoceratodus*, as compared with Ctenodipterines, is its retention throughout life of a completely closed and almost entirely unossified chondrocranium. The contrast presented by *Dipterus* in this respect is very striking, Traquair's claim being amply supported that this genus attained a higher grade of

[*] Semon, R., Die Zahnentwickelung des Ceratodus forsteri. Zool. Forschungsreisen in Australien. Jena Denkschr., vol. iv (1901), pp. 115-133.

[†] Newberry, J. S., Palæozoic Fishes of North America, Monogr. U. S. Geol. Surv., vol. xvi (1889), p. 165, pl. xvi, fig. 4.

specialization than any existing Dipnoid.* But in Arthrodires, on the other hand, all available evidence goes to show that the skull was constructed upon essentially the same model as in *Neoceratodus;* consequently the latter serves as a most valuable criterion for interpreting various structural details which have heretofore been misunderstood. So far as can be determined from the interior of the headshield in *Macropetalichthys*,† *Chelyophorus*,‡ *Homosteus*§ and a few other genera, the chrondrocranium of Arthrodires was even less ossified than in *Neoceratodus*. It is certain that the parasphenoid was largely cartilaginous, and for all that appears to the contrary, the palato-pterygoid elements must have remained entirely so. The presence of a pineal gland, sometimes but not always communicating with the external surface, is clearly indicated in the Arthrodiran skull, its position being as in *Neoceratodus*. There are also conspicuous ridges on the under side of the cranial shield, both in Arthrodires and in *Neoceratodus*, which extend forwards and inwards from the posterolateral angles, and give off descending processes in front. These are seen in the recent form to furnish support for the palato-pterygoid dental plates. Herein we have an explanation for the great solidity of these ridges in *Dinichthys*, for it can scarcely be doubted that they served a corresponding function as regards the powerful shear-teeth of that form.

We have next to speak of the dermal bones forming the cranial roof. Their origin is admitted to have been through fusion of numerous small dermal plates; but that which is truly remarkable, and claims our closest attention, is that the primordial *Dipterus*-like plates should have become reduced practically to the same extent, and rearranged almost exactly in the same fashion, both in Arthrodires and *Neoceratodus*. When was this simplification brought about? Amongst Ctenodipterines, despite their specialization in other respects, we know that the mosaic pattern of cranial roofing bones persisted as late as the Carboniferous. Amongst Arthrodires, reduction had already taken place in the lower Devonian, after which a fairly uniform pattern was adhered to. Amongst Ceratodonts, we have yet to learn how their cranial plates were arranged anterior to the Trias. Manifestly modern Dipnoans cannot be derived from *both* Ctenodipterines and Arthrodires; and if descendants of the former, how are we to explain the extraor-

* Traquair, R. H., On the genera Dipterus, Palædaphus, Holodus, etc., Ann. Mag. Nat. Hist., ser. 5, vol. ii (1878), p. 5.
† Cope, E. D., On the Characters of some Palæozoic Fishes, Proc. U. S. Nat. Mus., vol. xiv (1891), p. 453, pl. xxix.
‡ Eichwald, E. von, Lethæa Rossica, vol. i (1860), p. 1529, pl. lvii, figs. 1, 2.
§ Woodward, A. S., Note on some Dermal Plates of Homosteus, Proc. Zool. Soc., 1891, pp. 198–201.

dinary resemblance between them and Arthrodires as regards cranial osteology, to say nothing of other skeletal features? But if modern forms are not directly descended from either
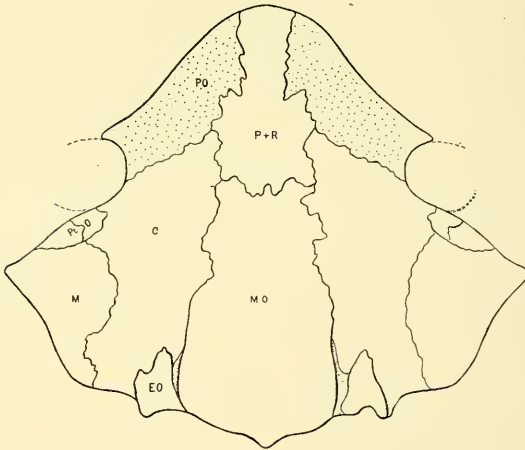
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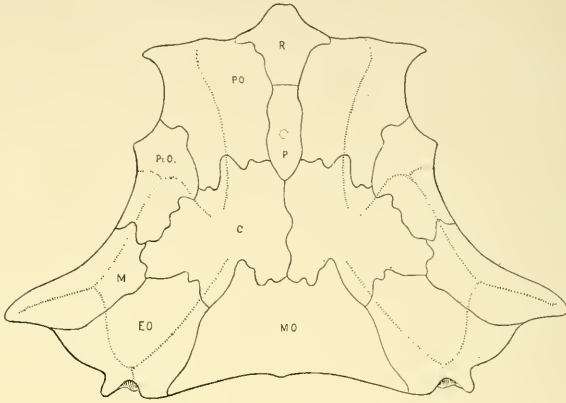
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Fig. 3.—*Dinichthys pustulosus* Eastm. Middle Devonian ; Iowa. Restoration of the headshield, dorsal aspect.   x ¼.

Fig. 4.—*Neoceratodus forsteri* Krefft.   Dorsal aspect of cranial roof, drawn as if flattened out.   Cartilaginous portions dotted.   x ½.

of these groups, if their ancestry can be projected backward in imagination to the starting-point from which both of them diverged, then these difficulties become reconciled, real homologies are established between all three groups, and two of them are seen to have elaborated similar cranial patterns.

Space is wanting to enter into detailed comparisons of the cranial roofing plates as they occur in Arthrodires and modern Dipnoans, but it will be evident from the annexed figures that there is marked agreement between them. Allowance must of course be made for the fact that some of the elements, such as the pre- and sub-orbitals, remain more or less cartilaginous in the modern form. The centrals, also, have become enlarged, much more so than in the Triassic *C. sturii*, and excluded from contact with each other in the median line though elongation of the median occipital. Yet the latter element is relatively less elongated than in *Homosteus*, and *Macropetalichthys* affords a parallel example of fusion between the pineal and rostral. Turning to *Protopterus*, we find that the bones corresponding to the centrals are actually in contact for a certain distance anteriorly, and those of *C. sturii* have practically the some conformation as in *Dinichthys*. In all known Dipnoans, recent and fossil, two opercular bones are present, but these remain for a time fused together in the young *Neoceratodus*. *Coccosteus*, and *Dinichthys* as well, is commonly understood as having one opercular element; Jaekel, however, affirms the existence of two in the former genus.* The significance of this observation, if confirmed, is apparent.

Axis and Body-armoring.—Both in living Dipnoans and amongst all Arthrodires where the vertebral column is known, the latter remains notochoral, and the neural and haemal arches, together with the dorsal fin-supports, have expanded extremities. The resemblance between *Coccosteus* and *Neoceratodus* in this respect is very great. The encasement of the anterior portion of the trunk in dermal armor is to be looked upon as a specialized feature peculiar to Arthrodires, yet comparable, in a general way, to the extensive ossification observed amongst Ctenodipterines, and to the ganoine investment of their squamation. The question of body-armoring is of purely secondary importance in determining affinities, inasmuch as wide variation prevails amongst closely related forms. So far as we may rely on negative evidence, *Macropetalichthys* and *Asterosteus* were unprotected by abdominal armor, and within a single family of Ostracophores, *Pterichthys* is scaled, *Bothriolepis* naked. The fact that two of the dermal covering plates are articulated with the headshield should occasion no surprise, when it is remembered that the so-called "cranial ribs"—which may represent morphologically a pair of costal elements—articulate with the skull in modern Dipnoans.

Fins.—Many writers have taken it for granted that the tail of *Coccosteus* was heterocercal. Not a particle of evidence

* Jaekel, O., Ueber Coccosteus und die Beurtheilung der Placodermen, Sitzungsber. Gesellsch. Naturf. Freunde, Jahrg. 1902, p. 109.

exists in favor of this supposition ; on the contrary, authorities like Traquair and Smith Woodward agree that it may as well have been diphycercal. Now it still remains to be proved that the diphycercy of *Neoceratodus* is not a primitive feature, that does not faithfully reproduce ancestral characteristics. One is, indeed, at perfect liberty to believe that the tail of Ceratodonts and Arthrodires never advanced beyond the diphycercal condition, *Dipterus* and its allies alone becoming heterocercal. Inasmuch as the median fins of *Coccosteus* are well separated, their continuity in *Neoceratodus* would seem to be a secondarily acquired character; but the burden of proof surely rests on those who hold that original heterocercy has become suppressed through abortion of the extreme end of the axis, and coalescence of the dorsal and anal fins.

No enlightenment could be more welcome than that which would acquaint us with the structure of the paired fins in Arthrodires, as to whether they were biserial or uniserial, Crossopterygian-like or Pleuracanthus-like. Of the pectoral pair no trace whatever has been preserved, nor do we even know that a girdle was present. Failure of the latter to be preserved might be attributable to a cartilaginous condition resembling that of *Neoceratodus*, but we should expect to find at least some traces of fin rays, were these structures developed. Complete atrophy of the pectoral pair would indicate, of course, high specialization. Obscure traces of a pelvic pair have been detected in some specimens of *Coccosteus*, but nothing is known of their configuration or structure. There seems to be no doubt as to the occurrence of a pelvic arch, and all that different writers have affirmed of it is consistent with the view that it was constructed essentially as in modern Dipnoans. In the latter it has remained cartilaginous; in *Coccosteus* and *Dinichthys* it was ossified.

Conclusions.—The aggregate of facts brought together through comparison of Arthrodires with modern Dipnoans seems to uphold the following general propositions :

1. *Neoceratodus* bears intimate resemblances to Arthrodires on the one hand, and to Ctenodipterines on the other, but represents a more primitive structural type than either.

2. It is impossible to regard *Neoceratodus* as the degenerate descendant of *both* the earlier, more specialized groups, nor of either of them to the exclusion of the other; since, however, it partakes of the characters of both, community of origin is necessarily presupposed for all three orders, Sirenoids, Ctenodipterines and Arthrodires.

3. Arthrodires and Ctenodipterines may be regarded as specialized offshoots which diverged in different directions from primitive Dipnoan ancestors; and the more generalized

descendants of these latter have alone survived until the present day.

4. The primitive stock must have been autostylic, diphycercal, without a secondary upper jaw and dentigerous dentary elements, and with *Uronemus-* or *Dipterus*-like type of dentition; characters which do not permit us to ascribe the ultimate origin of Dipnoans to the Crossopterygii, but suggest rather a descent from *Pleuracanthus*-like sharks.

5. The recognition of Arthrodires as an order of Dipneusti precludes their association with Ostracophores in any sense whatever. The "Placodermata," as originally understood by M'Coy and Pander, is therefore an unnatural assemblage, and should be abandoned.

EXPLANATION OF FIGURES.

Fig. 1. Reconstruction of the upper dentition of *Mylostoma variabile* Newb., from the Cleveland shale of Ohio. The small obtuse vomerine teeth are succeeded behind by two pairs of palato-pterygoid dental plates, as in the young of *Neoceratodus*. The dotted lines are intended to indicate the position of the supporting palato-pterygoid cartilage.   x ½.

Fig. 2. Mandibles of *Dinomylostoma beecheri* (MS.), from the Portage beds of Mt. Morris, N. Y. Both the right (*a*) and left (*b*) mandibles are shown from the lateral, external aspect. The posterior portion of the splenial in *b* is seen to have the compressed articular cartilage attached to its outer side.   x ½.

Fig. 3. Restoration of the cranial shield in *Dinichthys pustulosus* Eastm. from the Middle Devonian of Iowa. *C*, central ; *EO*, external occipital : *M*, marginal ; *MO*, median occipital ; *P*, pineal ; *PO*, preorbital ; *PtO*, postorbital ; *R*, rostral or mesethmoid. Sensory canals represented by double dotted lines.   x ¼.

Fig. 4. Cranial roof of the recent *Neoceratodus forsteri* Krefft, drawn as if flattened out, and dermal plates lettered to correspond with those of *Dinichthys*. The anterior median plate is commonly termed mesethmoid.   x ½.

Harvard University,
        Cambridge, Mass.

Art. X.—*A New Name for the Dinosaurian Genus Ceratops ;* by Richard S. Lull.

In a recent letter to Professor Osborn, Mr. T. D. A. Cockerell calls attention to the fact that the name *Ceratops*, used by Professor Marsh in 1888, for a genus of horned dinosaurs, was preoccupied by Rafinesque in 1815, who thus designated a genus of birds.

The dinosaurian genus is a well-defined one from the Judith River beds of Montana and their equivalent, the Belly River of Canada ; the chief generic characters as set forth by J. B. Hatcher * being as follows : " Parietals reduced to a narrow median bar and slender postero-lateral processes, enclosing on either side large elongated parietal fontanelles. External branches of parietals overlapped by the elongated and triangular squamosals. Supraorbital horn cores well developed, circular in cross section except near the base, and curving backward and outward. Nasal horn core strong and curved forward instead of backward as in *Monoclonius.*"

The type species is *Ceratops montanus* Marsh, and Hatcher also included in the genus *Monoclonius recurvicornis* Cope, *M. canadensis* Lambe, and *M. belli* Lambe. *Ceratops paucidens* Marsh, Hatcher abandoned owing to the nature of the type material, which was such as to preclude precise definition.

This genus is quite distinct from *Monoclonius* and *Centrosaurus*, its contemporaries, and from the Laramie genera *Agathaumas*, *Triceratops*, *Diceratops* and *Torosaurus*.

The name *Proceratops* is offered as a substitute for *Ceratops* as suggestive of the latter name and as indicating the forerunner of the great horned dinosaurs of the Laramie. This necessary change would seem to invalidate Marsh's family name of Ceratopsidæ given in 1888 and necessitate the use of Cope's term Agathaumidæ (1889) for the group.

Amherst, Mass.

* Bulletin of the U. S. Geological Survey, No. 257, p. 93.

ART. XI.—*On the Interlocking of Emarginate Primary Feathers in Flight ;* by C. C. TROWBRIDGE.

THIS paper contains the results of observations showing that certain birds interlock the emarginate primary feathers of their wings in flight. Some of these observations were made a number of years ago, but were withheld from publication until sufficient evidence could be collected to demonstrate conclusively the existence of this principle of animal mechanics. The additional evidence has been obtained and the complete paper is now presented.

A paper published in 1887, entitled "Something New About the Flight of Birds,"* contained a short account of an observation which I made during the autumn of 1885 ; namely, that on several occasions some of the primary or long end feathers of wings of hawks were found interlocked when these birds were killed while in flight. The primaries found interlocked were those which were emarginate, that is, having their webs narrowed half way to the tips (as shown in fig. 1), the feathers being interlocked in the emarginations.

The essential facts of the observation were also presented by my father, the late Professor W. P. Trowbridge, before the National Academy of Sciences and the New York Academy of Sciences, and shortly afterwards a controversy on the subject took place in *Science* between the late Dr. Elliot Coues, who opposed the hypothesis that the primaries were interlocked in flight,† and the late Professor J. S. Newberry and Professor Trowbridge, who took a strong stand in its favor.‡ Investigation of the subject has been continued by me with the purpose of obtaining further facts.

In September, 1891, at New Haven, Conn., during the migrations,§ a large number of hawks were killed and examined as soon as they fell to the ground. The observations on one occasion were assisted by my father and on another by Mr. Henry Townsend of New Haven. These and later observations have been presented before the New York Academy of Sciences but have not been published heretofore.

The alleged interlocking or overlapping of the primaries has been repeatedly disputed by prominent ornithologists, a fact which has caused me to defer the publication of a paper on the subject until I could decide the question positively.

* C. C. Trowbridge, O. & O., vol. xii, No. 12, p. 202.
† Sci., vol. x, No. 256, p. 321. ‡ Ibid., vol. xi, No. 257, p. 9.
§ C. C. Trowbridge, Hawk Flights in Connecticut. The Auk, xii, No. 3, July 1895.

This paper contains the following sections :

1

I. Emarginate Primaries, their Form and Inter-relation.

The number of primary feathers of the wing that are emarginate in different species is often used as one of the means of identification in standard works on ornithology. The emarginate shape of these feathers is natural and not produced by wear, as is well known. It is very marked in eagles and hawks and other birds of prey. In some species, six out of ten primaries are deeply emarginate on the posterior web.

A complete set of emarginate primaries of a common hawk (*Buteo lineatus*) are shown in fig. 1. In this species the first

primary (1) is emarginate only on the posterior web, and the
fifth primary (5) emarginate only on the anterior web, while
the three other primaries (2, 3 and 4) are emarginate on both
webs.   The sixth primary (6) is not emarginate and is shown
for comparison.   The emarginate contour of the anterior web
is sometimes called "sinuate."* When the primaries are in
their natural places in the wing the emargination of the ante-
rior web in every case exactly corresponds to the emargination
of the posterior web of the preceding feather, and permits
the feathers to be easily and firmly interlocked at the points on
the webs where the emarginations begin.   (See *a* and *b*, fig. 1.)
This correspondence is characteristic and demonstrates the
inter-relation of emarginate primaries.

To illustrate the way in which primaries are interlocked,
the five outer primaries of a Red-shouldered hawk are shown
as they appear when they are not interlocked, as seen from
beneath the wing, in fig. 2, and then as they are when inter-
locked in fig. 3.   The same set of primaries as seen from above
the wing are shown in figs. 4 and 5.

The primaries may be more widely separated than they
appear in these figures and yet be firmly interlocked, espe-
cially in the case of large birds where the feathers are long in
proportion to their rigidity.   Under these circumstances the
emarginate portions of the primaries are usually curved slightly
upward by the pressure of the air.   This upward curve has
often been observed.

II. Observations made at New Haven, Conn., showing the Interlocking of Primaries in Certain Species.

In September, 1891, during the hawk migrations of that
year, about thirty hawks were killed, examined as soon as
they had fallen to the ground, and the number of primary
feathers interlocked recorded.   These observations are given in
Tables I and II, in which the columns marked A and B refer
to the wings of the bird, because the wings were not designated
by "right" and "left" when the observations were made.   The
hawks were shot as they were passing over a high hill south-
east of New Haven, Conn.

Large migratory flights of hawks have occurred along the
coast of Connecticut nearly every autumn, the greatest flights
having taken place in September.   On numerous occasions
many thousands hawks have passed during a day, when flocks
of upwards of one hundred of certain species have been
observed.   In the opinion of the writer, the time of these
extensive migratory movements is directly dependent upon the
direction and velocity of the wind.   If the wind starts to blow

* E. Coues, Key to N. Amer. Birds.

2, 3, 4, 5

FIG. 2.   Primaries not interlocked. viewed from beneath the wing.
FIG. 3.   Primaries interlocked, viewed from beneath the wing.
FIG. 4.   Primaries not interlocked, viewed from above the wing.
FIG. 5.   Primaries interlocked, viewed from above the wing.

from the north, northeast or northwest, hawks immediately appear in large numbers. Records seem to show that these birds utilize the wind as a means of migration, and that they begin their migration movements independently of changes of temperature that occur.[*] The hawks that were shot had been migrating for hours, alternately soaring and coasting, and were killed as they passed over one of the high hills near the coast. During the migration, where a portion of the journey is against the wind, if hawks approach a hill in line of their flight, they usually coast with set wings and descending pass rapidly over the crest of the hill close to the ground. Having passed the crest of the hill they almost invariably soar until they have ascended many hundred feet, apparently using the upward air currents that exist on the windward slope. They then again coast towards the next hill that lies in the direction in which they are migrating.

In a few places the coast line is at right angles to the direction of migration. At these points in the migratory route the hawks often fly almost against the wind. Where the wind is favorable the hawks migrate at an altitude of a thousand feet or more.

The observations at Paterson, N. J., in the spring (Table III, etc.) have been made when hawks are moving northward, migrating in the manner just described.

This brief description of the way in which the Falconidæ make their migrations has been given to show the conditions under which the observations recorded in this paper have been made. All the hawks obtained were killed during the migrations.

An examination of Table I shows the following significant facts : —

Number of perfect wings of 23 specimens of one species examined 40
Number of wings found with some primaries interlocked 40
Number of wings with five (all) primaries interlocked 10
Number of wings with four primaries interlocked 8
Number of wings with three primaries interlocked 11

Thus 29 out of 40 wings were found to have an average of 76 per cent of their emarginate primaries interlocked.

Total number of emarginate primaries of perfect wings 200
Total number of emarginate primaries of perfect wings interlocked 134
Percentage of primaries found interlocked 67.0%

[*] C. C. Trowbridge : Relation of Wind to Bird Migration, Amer. Nat., xxxvi, 429, Sept., 1902.

TABLE I.

Sharp-shinned hawk (*Accipiter velox*) (5 outer primaries emarginate). Number of primaries interlocked in columns A and B.

No.	Date.	A wing.	B wing.	Both wings.	Remarks.
1	Sept. 8, 1891	2	2	4	
2	" " "	3	3	6	
3	" " "	4	_ _	4	Wing B badly shot
4	" " "	5	3	8	
5	" " "	_ _	_ _	_ _	Both wings badly shot, some primaries interlocked
6	" " "	5	5	10	
7	" " "	3	4	7	
8	" " "	5	5	10	
9	Sept. 9, 1891	4	5	9	♀
10	" " "	3	2	5	
11	Sept. 14, 1891	1	_ _	1	Wing B moulting
12	" " "	2	3	5	♀
13	" " "	2	3	5	♀
14	" " "	4	4	8	♂
15	" " "	4	5	9	
16	" " "	5	1	6	
17	" " "	0	0	0	Hawk wounded, record not possible
18	" " "	4	3	7	
19	" " "	1	2	3	
20	" " "	5	3	8	
21	" " "	4	2	6	♀
22	" " "	5	2	7	♀
23	" " "	3	3	6	♀
	Total	74	60	134	

TABLE II.

Osprey, (*Pandion haliætus carolinensis*) 4 outer primaries emarginate.
Marsh hawk, (*Circus hudsonius*) 4 outer primaries emarginate.
Broadwinged hawk, (*Buteo latissimus*) 3 outer primaries emarginate.

Species.	Date.	Number of primaries interlocked.			Remarks.
		A wing.	B wing.	Both wings.	
Osprey	Sept. 8, 1891	0	0		Bird wounded, no record
Osprey	" 9, "	3	_ _	3	Wing B broken at tip
Marsh hawk	" 14, "	4	3	7	Young of year
Broadwinged hawk	" 14, "	2	2	4	Young of year

In Table II both wings of the first Osprey were discarded because the bird was wounded, and also one wing injured by shot in the case of the second Osprey, leaving five perfect wings with a total of eighteen emarginate primaries; fifteen, or 83 per cent, of these were interlocked.

III. Observations made at New Haven, Conn., and at Paterson, N. J., in 1904–5.

Since the data of Tables I and II were obtained, many hawks have been shot and at once examined, and the ratio of the number of primaries found interlocked to the number of primaries that are emarginate has been found to be about the same as in the above tables.

The observations given in Table III were made during the past year, and were obtained incidentally while I was engaged in a study of certain notches made in the primaries by the interlocking of these feathers. The observations made on October 27th recorded in this table were on adult birds, all flying low, scudding with half-closed wings against a strong northwest wind. Two of the three fell dead when shot.

The observations in these tables is conclusive evidence that a very large percentage of the emarginate primaries are found interlocked when hawks are killed while in flight.

TABLE III.

Sharp-shinned hawk, *Accipiter velox*, 5 outer primaries emarginate.

	Date.	Number of primaries interlocked.			Remarks.
		Right wing.	Left wing.	Both wings.	
(1)	Sept. 21, 1904	1	5	6	Young
(2)	" 22, "	5	1	6	Young: deep notches in primaries
(3)	Oct. 27, "	5	4	9	Adult: bird fell dead
(4)	" 27, "	2	2	4	Adult : bird fell dead.
(5)	" 27, "	2	3	5	Adult
(6)	May 1, 1905	3	3	6	Notches in primaries 3^{mm} deep
(7)	" 1, "	(1*)	5	5	Adult: notches 2–5^{mm} deep
	Total	18	23	41	

In this table 41 out of 65 emarginate primaries were interlocked, or 63 per cent. For explanation of notches see next section of the paper.

Specimens 1 to 5 were shot at New Haven, Conn., 6 and 7 at Paterson, N. J.

* Right wing torn by shot and discarded.

IV. Measurement of Notches in the Primary Webs showing how long these Feathers were interlocked.

It has been suggested that the interlocking of the feathers in the many instances which have been recorded was accidental and took place while the birds were falling to the ground. Perhaps a few primaries were thus accidentally interlocked after the birds were shot; on the other hand, it is probable that as many or more of the emarginate primaries if interlocked while the birds were flying became unlocked when the birds were struck by shot and fell. This matter has been carefully investigated and the fact demonstrated that the feathers interlocked were in that condition either intermittently or continually for several hours previous to the death
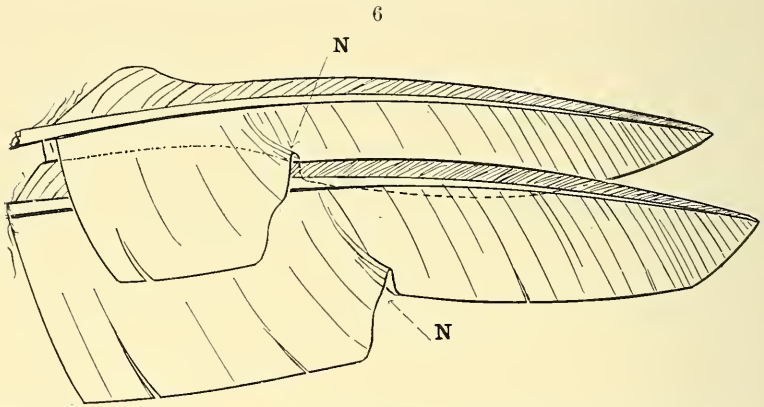
of the birds. Considerable difficulty has been experienced in obtaining the necessary observations. During the past few years not less than thirty trips have been made to a hill five miles from New Haven, Conn., in the autumn, and ten trips to the Watchung Mountain range near Paterson, N. J., in the spring. Many times large numbers of hawks were observed but none could be obtained, owing to the fact that they were migrating with a fair wind at an altitude that was beyond gun range. The observations were finally collected and are given herewith.

When hawks are shot while they are flying, deep notches are found in the edges of the posterior webs of the emarginate feathers that are interlocked. In unlocking the feathers it is necessary to lift them free of these notches. (See N, fig. 6.) The notches are due to the pressure of the feathers which have been in contact. It occurred to me that the immediate disappearance of the notches on unlocking the primaries would

indicate that the feathers had been interlocked a very short time. If, however, the notches remained for a period of minutes or more it would show that the feathers had been interlocked for a longer time. This proved to be the case in experiments which consisted of artificially interlocking the emarginate primaries for different lengths of time. The recovery of the semi-elastic webs of the primary feathers notched by the pressure of the interlocked feathers has therefore been the subject of investigation.

Measurements have been made which consisted in determining the widths of a notch at different intervals of time immediately after the death of a hawk. For the purpose of explanation, in fig. 7 the initial width of the notch is indicated

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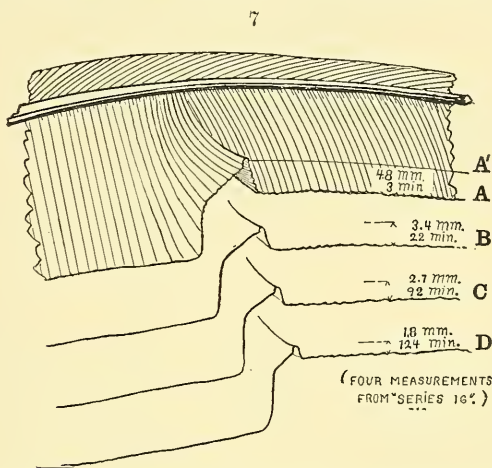
by the distance apart of the lines A and A′, and the gradual diminution in its width is indicated by the notches on the lines A, B, C, and D, which represent the edge of the web of a primary at different intervals of time after the feathers were unlocked.

Method of Measurement.

The method of measurement was as follows : the points of a pair of fine dividers were adjusted to correspond with the width of a notch in a primary as soon as possible after a hawk had been killed. Impressions of the points were then made in a notebook and their distance apart afterwards determined by means of a fine scale. Measurements were made every few minutes in this way until the notch disappeared or ceased to diminish in width.

In the case of Series 4 and 8 a photographic method was employed and the width of the notches measured by means of a Repsold star plate measuring machine loaned for the purpose by the Department of Astronomy, Columbia University. The caliper method was used in subsequent measurements because it was found to be sufficiently accurate.

The method of photographing the primaries consisted in constructing a standard S, as shown in fig. 8, to support both camera C and the primaries P. The latter were held in position by thumb-tacks T. An auxiliary lens, L, was used by which a life-sized image was formed on the film when the object was held on the standard, 15 centimeters from the lens.

Photographs of the notches in the first primary feathers are shown in figs. 9 and 10. The former is one of the photographs of Series 4, a Sharp-shinned hawk. The latter is one of Series

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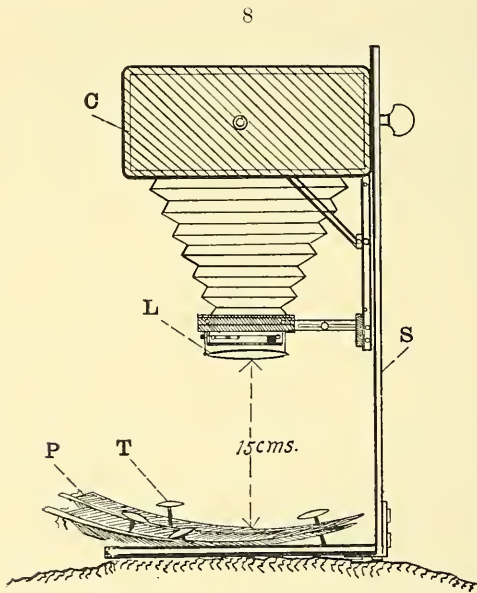
8, an Osprey, which was moulting and the primary had not completed its growth ; therefore, the notch is not at the point where the emargination begins, which is the usual case. The photographs given were selected from among those in Series 4 and 8 as giving the best definition for reproduction.

Curves have been drawn from the measurements showing the recovery of the web of the feathers after the pressure caused by the interlocking of the feathers was relieved. Sim-

ilar curves have been obtained by artificially interlocking the primaries for several hours and then measuring the recovery of the web of the feathers with a micrometer microscope. It

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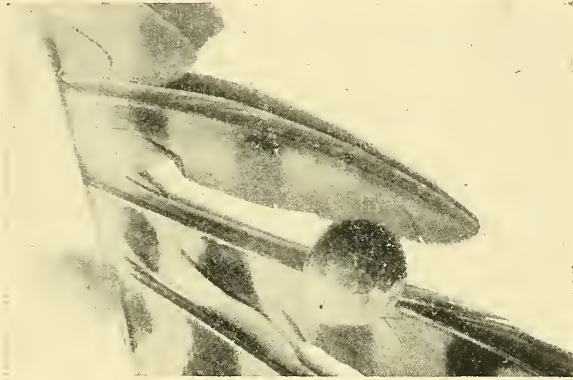
Fig. 9. Notch in the first primary feather of a Sharp-shinned hawk formed by the interlocking of the feathers. Photograph taken 18 minutes after the bird was killed. (Round object is a large thumb tack holding feathers in place.)

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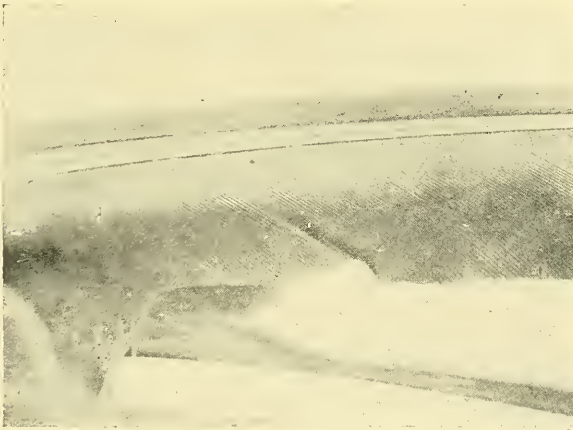
Fig. 10. Notch in the first primary feather of an Osprey formed by the interlocking of the feathers. Photograph taken 60 minutes after bird was killed.

was found that artificial interlocking of the feathers for fifteen minutes produced either no notches or those that were small and rapidly disappearing, while interlocking them for several

hours formed notches only about one-half as deep as those found when the hawks were killed.

As previously stated, the records of the widths of the notches were made by the impression of the points of a pair of dividers, the actual measuring being done in the laboratory afterwards. In this way each measurement was little influenced by the preceding. This naturally resulted in experimental variations, but it seemed to be the best method to employ and the measurements give approximate curves of the rate of recovery of the web of the feathers in each case, which was all that was desired. If the measurement had been mostly confined to the second, third, etc., primaries instead of the less elastic first primaries, more nearly perfect curves would have been obtained, as shown by curves 14, 15 and 16.

TABLE IV.

Recovery of the webs of three primary feathers of a Broad-winged hawk (*Buteo latissimus*) shot at 10.30 A.M., April 13th, 1904, at Paterson, N. J.

Series 1.

Notches found in the primaries of the right wing a few minutes after the bird was shot.

Time after fall of bird. Minutes.	First primary width of notch. mm.	Second primary width of notch. mm.	Third primary width of notch. mm.
0	- -	- -	- -
10 (approx.)	1·1	2·0	1·7
20	0·8	- -	1·7
30	0·3	1·0	1·3
40	0·3	0·2	0·8
60	0·3	0·0	0·0

Series 2.

Primaries of left wing artificially interlocked for 30 minutes with strong pressure within one-half hour after death of bird.

Time after unlocking. Minutes.	First primary width of notch. mm.	Second primary width of notch. mm.	Third primary width of notch. mm.
0	2·1	0·4	0
5	1·0	0·0	0

The reason for making sixteen series of measurements was to include every possible condition and to obliterate the effect of experimental errors in the conclusions drawn. The results all point to the fact that wherever notches were found the primaries must have been interlocked for two or more hours. Deep notches are almost always present in primaries that are found interlocked, and, moreover, in almost all of the primaries that are emarginate that are not found interlocked, showing that the latter were unlocked when the birds were shot and fell to the ground.

The results of the measurements are shown by the accompanying tables and curves.

Explanation of Table I V.

Table IV shows the result of observations on the primaries of a Broad-winged hawk. They were the first made, and while the few measurements must be regarded as only approximate they demonstrate the fact that the feathers were interlocked for some hours previous to the death of this bird, as seen from

TABLE V.

Recovery of the web of a first primary feather notched by natural interlocking, specimen : Sharp-shinned hawk (*Accipiter velox*), adult ♂ , shot at 2.38 P. M., April 21st, 1904, Paterson, N. J.

Series 3. By calipers.			Series 4. By photography		
Time. h. m.	Time after fall of bird. Minutes.	Width of notch. mm.	Time. h. m.	Time after fall of bird. Minutes.	Width of notch. mm.
2·51	*13	1·85	2·48	10	1·92
2·57	19	1·70	2·56	18	1·80
3·02	24	1·55	3·45	67	1·53
3·10	32	1·50	4·40	122	1·39
3·19	41	1·40	4·50	132	1·16
4·07	89	1·30	5·15	157	1·07
4·30	112	1·0	5·25	167	·98
4·38	120	1·05	10·45	487	·66
4·42	124	1·10			
5·00	142	1·10			
5·20	162	1·1			
9·00	382	·60			
10·40	522	·50			

a comparison of the two series of measurements. The time required for the webs of the feathers artificially interlocked to recover (see Series 2) was very short and the notch was not even formed in one-half hour in the case of the third primary. Before the measurements of Series 2 were made the primaries of the left wing were interlocked for five minutes, but as no notches were formed, the interlocking period was increased to thirty minutes. This bird was shot by a person near me and was handled before I reached it. The primaries were then not interlocked but the notches were very prominent, so their recovery was measured. It was not possible to obtain another specimen of this species of hawk for measurement.

* Time was lost preparing camera for Series 4.

Explanation of Table V and Curves in Fig. 11.

The measurements in Table V were made on one of the first primary feathers of a Sharp-shinned hawk; Series 3 by calipers and Series 4 by photography and a measuring machine.

The primaries of the wing of the same bird as that from which Series 3 and 4 were taken were later artificially interlocked and pressed together with constant pressure; then, after having been interlocked for several hours (see fig. 11,
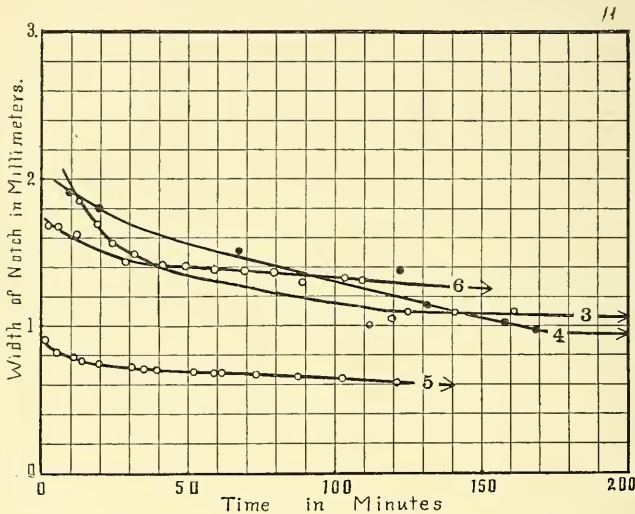
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Fig. 11.   Series 3 and 4: Recovery of a web of a first primary feather notched by natural interlocking.   Sharp-shinned hawk, *Accipiter velox*, Series 3 by calipers, Series 4 by photography, see Table V, primary found interlocked.

Series 5 and 6: Recovery of the webs of first primary feathers of the same bird when the feathers were interlocked by artificial interlocking.   Series 5 interlocked for 2 hours 40 minutes, Series 6 interlocked for 4 hours 10 minutes, measurement by micrometer microscope.

Series 5 and 6) the feathers were unlocked and the gradual recovery of the web as shown by the decrease in the width of the notch was measured by means of a micrometer microscope. Series 5 was taken seven days after the hawk was killed and Series 6 was taken about one week later.   The notches in the webs of the feathers thus artificially made are seen to be less in width than the notches found in the webs of the feathers which were naturally interlocked (Series 3 and 4).   The rate of recovery is approximately the same as is also the form of the curves, as in Series 3 and 4.

Explanation of Table VI and Curves in Fig. 12.

In Table VI, Series 7, first primary of an osprey was made by calipers and Series 8 by photography and a measuring machine. These series are shown by curves in fig. 12. It should be kept in mind that the purpose of the measurements was to determine the rate of diminution of the width of the notches rather than their exact width. The width of the notches in Series 7 and 8 are not equal, because it was not possible to take the photographs exactly life size. The rates of decrease of 7 and 8 are seen to be the same.

TABLE VI.

Recovery of the web of a first primary feather notched by natural interlocking. Osprey (*Pandion haliaetus carolinensis*), shot at 3.45 P. M., April 21, 1904, at Paterson, N. J. First primaries of each wing found deeply notched.

Series 7. By calipers.			Series 8. By photography		
Time. h. m.	Time after fall of bird. Minutes.	Width of notch. mm.	Time. h. m.	Time after fall of bird. Minutes.	Width of notch. mm.
3·49	4	3·3	4·00	15	3·22
4·00	15	2·5	4·08	23	2·85
4·08	23	2·4	4·45	60	2·84
4·30	51	2·4	5·05	80	2·76
4·45	60	2·1	5·20	95	2·72
5·00	75	2·2	10·45	420	1·67
5·20	95	2·1			
9·00	315	1·6			
11·45	480	1·2			

The primaries of the same bird were then artificially interlocked. The measurements of the resulting notches are also shown in fig. 12. Series 9 was made two days after the bird was killed, and Series 10 several days after that.

Explanation of Table VII and Curves in Fig. 13.

In fig. 13, Series 12, is merely a verification of previous observations, the species being a Sharp-shinned hawk; and likewise Series 13.

Series 14 and 15, Table VII, are important since they show the rate of change in the depth of the notch found in the second and fifth primaries of a Sharp-shinned hawk. The webs of these feathers are seen to be more elastic than those of the first primaries and the recovery is more rapid and complete. The feather structure of the first primary is very rigid and therefore its web not only requires a long time to recover

from the pressure of the adjacent primary but usually a small permanent notch remains, 10 or 15 per cent of the initial width.

Series 12, 13, 14 and 15 are shown by curves in fig. 13.

On September 21st, 1905, a specimen of the Marsh hawk, *Circus hudsonius*, was killed at New Haven, Conn. The bird was shot after it had been coasting for several hundred yards
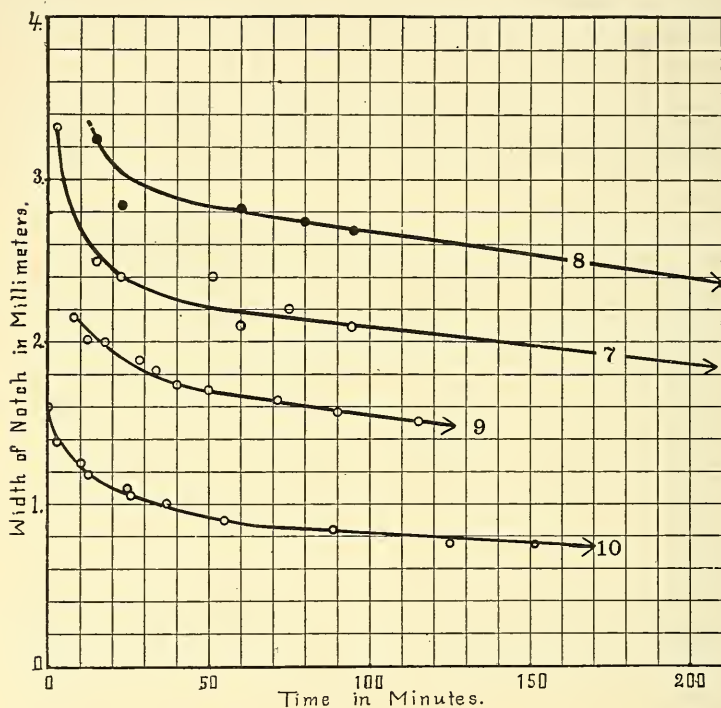

FIG. 12. Series 7 and 8 : Recovery of the web of a first primary feather notched by natural interlocking. Osprey, *Pandion haliaetus carolinensis.* Series 7 by calipers, Series 8 by photography, see Table VI.

Series 9 and 10 : Recovery of the webs of the first primaries of the same bird when the feathers were notched by artificial interlocking. Series 7 for 1 hour strong pressure, Series 10 for 3 hours light pressure.

toward the hill on which the writer was stationed. The left wing was broken near the shoulder; the four (all) emarginate primaries of this wing were interlocked. The right wing primaries were partly interlocked, but shot had cut the feathers, and all the emarginate primaries of both wings had notches in them from four to six millimeters in width.

<div align="center">Table VII.</div>

Recovery of the webs of the 2d and 5th primaries, notched by natural interlocking, specimen: Sharp-shinned hawk (*Accipiter velox*), adult ♂. Shot at 11.49 A. M., Oct. 27, 1904, New Haven, Conn.

	Series 14. 2d primary r. wing.			Series 15. 5th primary r. wing.	
Time. h. m.	Time after fall of bird. Minutes.	Width of notch. mm.	Time. h. m.	Time after fall of bird. Minutes.	Width of notch. mm.
11·52 A. M.	3	1·1	11·55 A. M.	6	2·1
11·55	6	0·9	11·56	7	1·7
11·58	9	0·8	11·58	9	1·4
12·01 P. M.	12	0·7	12·02 P. M.	13	1.1
12·02	14	0·8	12·04	15	1·0
12·07	18	0·7	12·09	20	0·9
12·14	25	0·6	12·18	29	0·8
12·26	37	0·6	12·27	38	0·7
12·40	51	0·7	12·40	51	0·5
1·16	87	0·4	1·16	87	0·4

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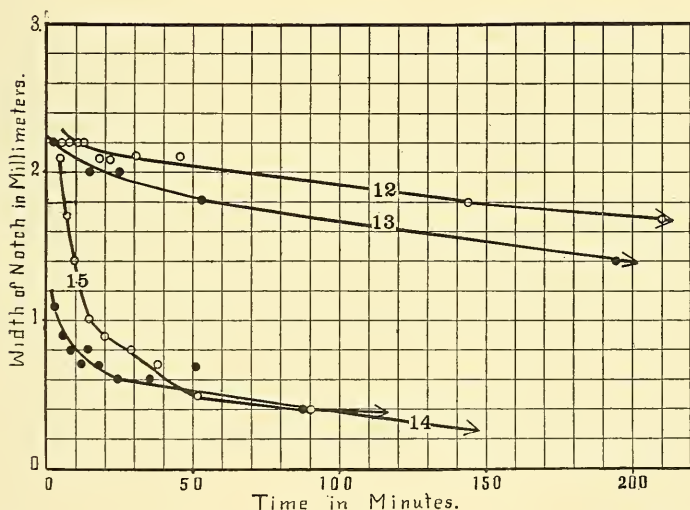
Fig. 13. Series 12 : Recovery of the web of the first primary feather, right wing, of a Sharp-shinned hawk, *Accipiter velox.* Shot Sept. 21, 1904, 10.58 A. M., New Haven, Conn. Feather found interlocked.

Series 13 : Recovery of the web of a first primary feather of a specimen of the same species, shot Sept. 22, 1904, 9.24 A. M., New Haven, Conn. Feather found interlocked.

Series 14 and 15 : Recovery of the webs of primaries of a specimen of the same species, shot Oct. 27, 1904, 11.49 A. M., New Haven, Conn. Series 14, second primary right wing ; Series 15, fifth primary, right wing. Feathers found interlocked. See Table VII.

The primaries of the left wing were lifted out of the notches and the third primary subjected to measurement. The recovery of this feather from the pressure caused by the interlocking is shown in Series 16, fig. 14. The notches in the other feathers were as wide as the feather measured and disappeared gradually approximately at the same rate. It is seen that the notch decreased in width from 4·8 to 1·8 millimeters in about two hours. In the case of this hawk a little over two minutes were lost before the feather was unlocked and subjected to measurement, but it has already been shown that it requires

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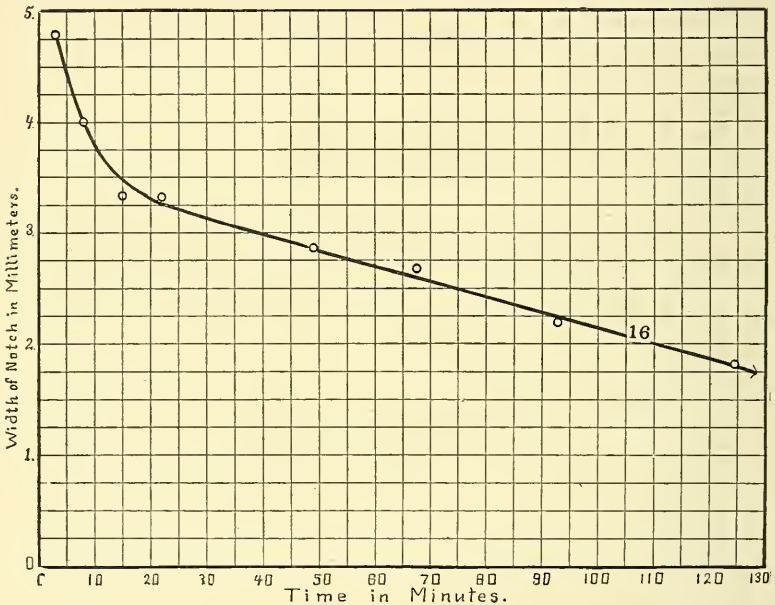
Fig. 14. Series 16. Recovery of the web of the 3d primary of the left wing of a Marsh hawk, *Circus hudsonius*, shot Sept. 21st, 1905. 9.26 A. M., at New Haven, Conn. 1st–4th primaries of left wing found interlocked.

ten to twenty minutes to form the smallest notch. So that this time (2 minutes) was a small factor in the time of forming the notch.

V. Species which have Emarginate Primary Feathers.

The emarginate formation of the primaries is more pronounced in the *Raptores* than in any other birds, especially in the case of the sub-order of *Accipitres*, or diurnal birds of prey, eagles, hawks, etc. Some of the family of *Cathartidae* or American vultures have a number of their primaries emar-

ginate, a few of the family *Ardredae* or herons, birds that frequently both soar and coast, and other large-winged waterfowl. In case of a few small birds, notably some of the family *Tyrannidae*, or flycatchers, one or two of the primaries are emarginate. These birds are "insect hawks" and dive and sail with set wings for their prey, and the formation may be more than rudimentary in this case.

In almost, if not in every instance where emarginations are present, the species is one which frequently coasts with set wings or dives through the air. In many species the emarginate formation of the primaries is present but in far less degree than in those above mentioned. In a large number it is rudimentary or wanting.

Important examples of North American species having emarginate primaries are as follows:

The Bald Eagle, *H. leucocephalus*, and Golden Eagle, *A. chrysaetus*, each have six primaries deeply emarginate, the Osprey, *P. haliaetus carolinensis*, having four. The *Buteos*, or buzzard hawks, have three to five primaries emarginate. In early editions of Coues' Key of North American Birds this sub-family was classified as follows: "Heavy weights five outer primaries cut," containing one example, now *Parabuteo unicinctus harrisi:* Harris's Buzzard, "Heavy weights, four outer primaries cut," *B. albocaudatus sennetti*, *B. borealis*, the latter the familiar large Red-tailed hawk, and several varieties of this species.

Light weights; "four outer primaries cut," *B. lineatus*, *B. abbreviatus*, etc.

Light weights: "three outer primaries cut," comprising *B. swainsoni* and *B. latissimus*, the second being the Broad-winged hawk mentioned frequently in the present paper.

In the sub-genus *Archibuteo* the species have from two to five outer primaries emarginate, and in *Asturina* or hawk-like buzzards, four.

In the sub-family *Accipitrinae*, or the true hawks, the number of emarginate primaries are *A. atricapillus* 4, *A. cooperi* 4, *A. velox* 5.

In the sub-family of *Falconinae*, or falcons, the first one or two outer primaries are emarginate. In the sub-family of *Milvinae*, or kites, *R. sociabilis*, or the Eveglade kite, has five outer primaries emarginate, the other species in this sub-family having but two primaries emarginate.

In the case of the sub-order *Striges*, or owls, the number of emarginate primaries varies from one to six; some examples are as follows; *S. cinerea* (Great grey owl of Canada) has five outer primaries emarginate, *S. nebulosa* 4, *N. nyctea* (Snowy owl) 4, *M. asio* 4, *B. viginianus* 3, *A. wilsonianus* 1, *A. accipitrinus* 1.

VI. THREE WELL-DEFINED TYPES OF FLIGHT IN RAPTORES.

Three distinct types of flight employed by birds of prey,
herons and various other large birds, are as follows:

(1) Periodic wing beats; in which for a part of the stroke
at least the primaries are fully extended.

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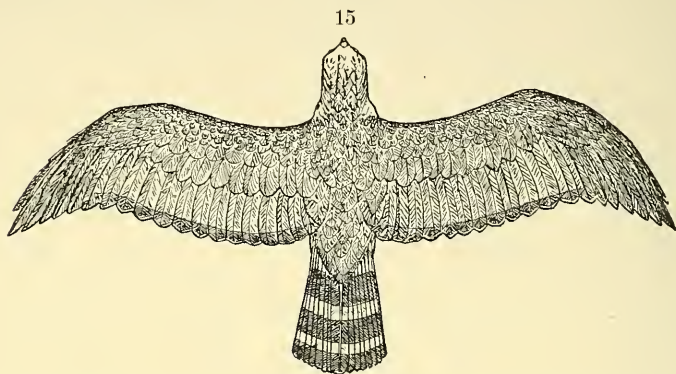
(2) Soaring (in circles): in which the wing is widely extended
and the primaries may or may not be extended, depending on
conditions of wind, etc.

(3) Coasting with set wings. In this case the primaries are
partly extended only, as shown in fig. 15. Diving through
the air differs only in degree from coasting but in this case
the wing is partly closed, the primaries nearly flexed and the

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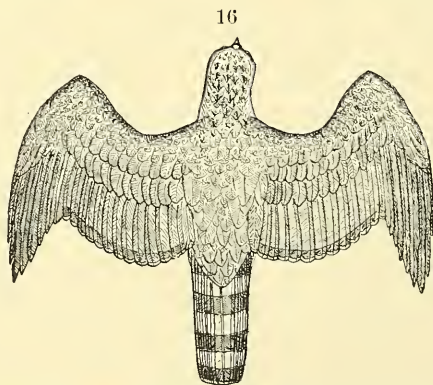
tail often closed, steering being aided by the wings, as in fig.
16. Of course birds often combine these types, i. e., alternat-
ing periodically (1) and (2), or (1) and (3). Coasting flight is
one that is employed by Raptores, herons, gulls, etc., continu-
ally, both during their migrations and in their daily evolutions.

During the autumn I have often watched flocks of from twenty-five to seventy-five Broadwinged hawks coasting together for a distance of upwards of half a mile without beating their wings; this maneuver, characteristic of their manner of migration, was periodically repeated after a short interval of soaring.

VII. The Function of Interlocked Primaries in Flight.

In coasting flight : The primary feathers, the most important feathers of the wing, are subjected to great strain and pressure. The backward pressure on these feathers is particularly great under the following conditions : (1) When a bird is sailing or coasting through the air with set wings, fig. 15. (2) When it is diving or twisting in pursuit of its quarry as in birds of prey, fig. 16. In both cases some means of producing rigidity in the end of the wing seems necessary.

In these types of flight the interlocking of the primaries would make the end of the wing very rigid, thereby not only forming a strong surface to withstand the pressure of the air, but when the primaries are interlocked no muscular force is required to keep them partially extended. In addition, the shape of the wing is curved by the process of interlocking, figs. 18 and 19, in such a way that the lower rather than the upper surface of the feathers bears the pressure of the air when the bird is coasting or diving ; the effect of the interlocking of the primaries appears to make a much more efficient aeroplane of the wing than when the primary feathers are not interlocked.

No special set of muscles is required for interlocking the primaries. In coasting flight, if these feathers are extended and then allowed to fall back, the pressure of the air forces the end of each primary above the plane of the succeeding primary and those that are emarginate become interlocked. These feathers can usually be interlocked artificially by holding an open wing in the hand and striking the air with it as in a downward wing beat.

In soaring flight (circling): Whether the emarginate primaries are interlocked in soaring flight or not is an undecided question.

Photographs and visual observation of Turkey buzzards and other large birds show the primaries considerably separated when these birds are soaring, but this is by no means evidence that the feathers are not sufficiently overlapped to keep them in place without muscular effort.

When a bird is soaring in a light wind the air pressure acts on the primaries almost entirely from beneath. The outer primaries of large birds while soaring have been observed to

be bent upwards by the air pressure. They are then not only extended in a horizontal plane but also separated to some extent in a vertical plane. Under these circumstances while the primaries would appear widely apart, they might readily
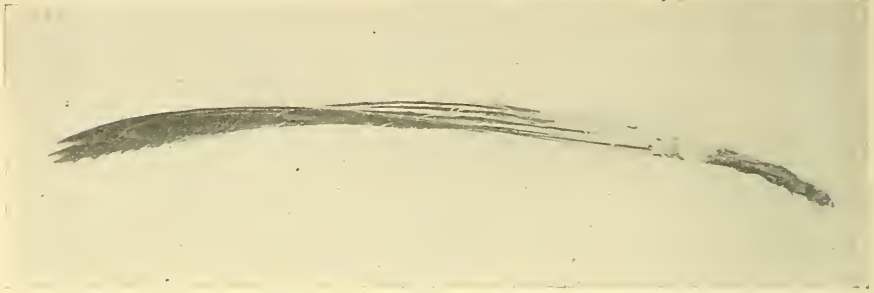
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FIG. 17.   Primaries not interlocked, viewed from in front of the wing.

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FIG. 18.   Primaries interlocked, viewed from in front of the wing.
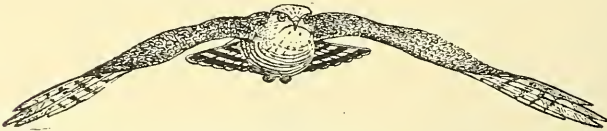
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FIG. 19.   The bowed effect of the wings is seen in many species in swift coasting flight.   The twist of the wing is shown as given by Pettigrew.*

be held in an extended position, or in other words interlocked, by the emarginations, thus forming a firm stepped aeroplane at the end of the wing.

* Pettigrew, Animal Locomotion, p. 186 and 198.

VIII. The Wear of the Primaries as seen by the Microscope.

The primaries of a number of hawks killed when their plumage was at various stages of wear, were subjected to, microscopic examination. In this way it was hoped to determine if the primaries had become worn by habitual interlocking, or by the absence of any wear to find an argument against any such interlocking,

It was found that the wear of the extreme edge of the posterior webs of the emarginate primaries began very shortly after they had completed their growth, that is, after the moult. Also that a general breaking of the feather structure all along the edge of the webs in most cases obscured any special wear at any particular place. In a number of cases, however, the webs of the feathers, where the webs touched when interlocked, were completely broken down, apparently showing wear from constant contact or pressure. Owing to the uncertainty of this evidence, no further observations were made.

IX. Final Summary and Conclusions.

The most salient facts established in this paper are as follows :

(1) Of over thirty hawks killed while in coasting flight, which were examined immediately after they fell, in every case some emarginate primaries were interlocked (several slightly wounded birds not included). In the case of 27 specimens of one species, 175 out of all emarginate primaries (270) were found to be interlocked, or about 65 per cent. Other observations agree approximately with this ratio. Many hawks, including seven species not recorded in this paper, have been shot and found with their primaries interlocked by the writer and others. There is, therefore, conclusive evidence that when hawks are killed while in flight, of certain types, a large percentage of the emarginate primaries are found firmly interlocked.

(2) The webs of emarginate primaries of hawks that have just been killed show well-defined " notches " where the edges of the interlocked webs have rested against one another. The facts determined by a long continued study of the formation of the notches are these :

(3) The notches formed by artificially interlocking the primaries are identical with those found after birds are killed and which are always present when the primaries are found interlocked.

(4) It requires from ten to twenty minutes to form even very slight notches artificially in the primaries of a freshly killed bird.

(5) When the notches are formed artificially by a strong pressure for several hours they are not as deep as those made by the natural interlocking of the primaries.

(6) The notches found in the primaries of freshly killed birds could not have been formed accidentally during the time between when the birds were shot and when they were examined (often less than 30 seconds), but were the results of a pressure due to the interlocking of the primaries acting either constantly or intermittently for two or three or more hours directly previous to the time when the birds were killed.

(7) The interlocking of the primaries as an auxiliary mechanism of flight appears to be advantageous for three reasons:

(a) To make the end of the wing, or that part formed by the primaries, more rigid when the wing is employed as an aeroplane in coasting flight.

(b) To produce a curvature of the wing which gives to the bird better control in the air.

(c) To keep the primaries partly extended without muscular exertion on the part of the bird; otherwise the air pressure produced by the motion of the bird acting against the primaries would tend to close them, unless the bird was continually exerting muscular force to keep them extended.

Confirmatory Observation in Japan.

After this paper had been submitted for publication, a letter on the subject appeared in *Science*,[*] written by Professor Bashford Dean describing an observation recently made by him in Japan. The facts of the observation were stated with careful detail, but only a small portion of the letter is here quoted.

" It so happened that we were coming up the narrow canal from Sakai to Matsue in the face of a strong wind, so strong, indeed, that our small steamer labored to make headway against it. At one point we disturbed a kite, *Milvus melanotus*—a very common bird, by the way, along Japanese waterways—which rose slowly in the face of the wind and after making several circles followed the margin of the canal, flying and soaring, almost opposite the boat and making about equal headway." . . . . . . " For several minutes the hawk thus flew alongside of the boat, with quite regular periods of flapping and soaring; then, suddenly shifting its course, it circled out, soaring, passing over my head at a distance of about twenty feet. I could then see plainly that the primaries

* Sci. xxii, No. 564, Oct. 20th, 1905.

of one wing (right) were interlocked—the condition of the other wing I had not time to observe."

" My conclusion, therefore, is that the interlocking of the primaries of the hawks takes place, as Mr Trowbridge has shown, under the conditions of soaring in the face of a strong wind." Written from Rinkai Jikenjo, Misaki-Miura, Japan, September 3, 1905.

This confirmatory observation of Professor Dean's was apparently made under the most favorable conditions. The observer and the hawk were both moving for a part of the time at nearly the same velocity; therefore they were approximately stationary with respect to each other, and hence the bird must have appeared almost like a still object and the observation made with certainty.

The observations presented in this paper have shown that when hawks are killed in certain types of flight a large percentage of the emarginate primaries of their wings are found interlocked, and it has been proven that these feathers were interlocked for several hours previous to the moment when the hawks were killed; therefore the principle of the interlocking of the emarginate primaries in flight has been conclusively demonstrated.

Phoenix Physical Laboratory, Columbia University.
New York, September, 1905.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The Determination of Nitrous and Nitric Acids.*—Weisen-heimer and Heim describe a convenient method for the gaso-metric determination of either or both of these acids. The operation is carried out with a flask of 50^{cc} capacity, in which the slightly alkaline solution of the substance (containing ·1 to ·2 g. of nitrite) is placed. Carbon dioxide is led in from a Kipp's gener-ator through a tube reaching below the liquid in the flask, and a delivery tube is attached which ends in a turned-up point in a trough containing 12 per cent sodium hydroxide, in such a man-ner that an eudiometer filled with the sodium hydroxide solution may be placed over the outlet. A funnel tube provided with a pinch-cock is placed in the third hole of the rubber stopper of the flask. The stem of this funnel tube is narrowed at the end and it is filled with water up to the funnel at the beginning of the operation. The apparatus is first freed from air by passing car-bon dioxide through it, then 10 or 15^{cc} of a five per cent solution of potassium iodide are introduced, and then, slowly, the same amount of dilute hydrochloric acid. All the nitrous acid is thus converted into nitric oxide according to the equation

$$HNO_2 + HI = NO + I + H_2O.$$
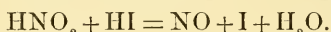
The liquid is slowly raised to the boiling-point and the gas is swept over into the eudiometer by the stream of carbon dioxide, and is measured. When nitric acid is to be determined, a newly filled eudiometer is placed over the delivery tube, 10 or 20^{cc} of a concentrated solution of ferrous chloride in strong hydrochloric acid are introduced, and the gas formed according to the equation

$$HNO_3 + 3FeCl_2 + 3HCl = NO + 3FeCl_3 + 2H_2O$$
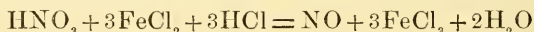
is collected and measured as before. Test analyses with nitrites and nitrates alone, and with mixtures of both, gave very satisfac-tory results. The method has the advantages of being rapid and in furnishing direct determinations of both acids in a single sam-ple of substance.—*Berichte,* xxxviii, 3834. H. L. W.

2. *The Modifications of Antimony*—Stock and Siebert have found that, like arsenic, antimony exists in a yellow, a black, and a metallic gray modification. The last is the most stable form, and the only one heretofore mentioned in chemical literature. The black modification may be obtained by heating the yellow form to temperatures above $-90°$, by the action of oxygen upon liquid antimony hydride above $-90°$, and also by the sudden cooling of the vapor of ordinary antimony. Its specific gravity is 5·3, while that of the ordinary metal is 6·7. It is chemically active, often igniting when exposed to the air. It is changed into metallic antimony by heating, the change being instanta-neous at $400°$. The authors consider the black precipitates pro-

duced by the action of certain reducing metals upon antimony solutions as mixtures of black and metallic antimony. The preparation of yellow antimony is difficult, since it rapidly blackens at temperatnres above $-90°$. It is formed in small quantities by the action of oxygen upon SbH_3 at $-90°$ or $-91°$, just above its freezing point. It is formed also by the reaction of chlorine and antimony hydride when dissolved in liquid ethane at $-100°$. The authors call attention to the interesting fact that while antimony, arsenic, and phosphorus have similar allotropic modifications, the stable form at ordinary temperatures is the metallic one with antimony, the black one with arsenic, and the yellow one (in absence of light) with phosphorus.—*Berichte*, xxxviii, 3837.

<div align="right">н. l. w.</div>

3. *Quantitative Determination of Bismuth.*—Two articles have been recently published in which the determination of bismuth as the phosphate, $BiPO_4$, is recommended. STAEHLER and SCHAFFENBERG find that the metal may be completely precipitated by adding tribasic sodium phosphate to the nitric acid or hydrochloric acid solution until the stronger acid has been replaced by phosphoric acid, since in the latter the precipitate is entirely insoluble. The precipitation is made at a boiling temperature by the addition of boiling ten per cent sodium phosphate solution. If the liquid becomes alkaline, it should be acidified with a little nitric acid. After boiling a short time the precipitate settles well, and then, while the liquid is hot, the substance is collected on a Gooch filter, and washed with a one per cent solution of nitric acid to which a trace of ammonium nitrate is added. After drying, the precipitate is ignited for ten minutes over a large Bunsen burner, and is then weighed. Test analyses gave excellent results, and it was shown that bismuth can thus be separated from copper, cadmium, mercury, and silver, but not from lead, since lead phosphate is but slightly soluble in phosphoric acid.

H. SALKOWSKI, for determining bismuth as phosphate, recommends operating in a weak nitric acid solution, in which case the separation from Cu, Cd, Hg, Ag, Pb, Fe, Mn, Co, Ni, Zn, Cr, and Al may be effected with good, or in some cases with only satisfactory results. In this case, where a strong acid is present, hydrochloric acid and other chlorides must be absent. Attention is called to the fact that the almost complete insolubility of bismuth phosphate in weak nitric acid affords a very satisfactory method for the qualitative detection of bismuth. — *Berichte*, xxxviii, 3862 and 3943. н. l. w.

4. *The Distillation of Gold.*—MOISSAN finds that gold can be readily distilled in the electric furnace, that its boiling-point is higher than that of copper, but lower than that of calcium oxide. When the vapor is condensed on a cold surface, the metal is found in the filiform condition, or in very small microscopic crystals. When alloys of gold and copper, or of gold and tin, are distilled, the copper and the tin distill more rapidly than the gold.

Moreover, in distilling an alloy of gold and tin, when the mixed vapors come in contact with air the tin is oxidized and the gold condenses in the finely divided condition corresponding to the "purple of Cassius." Similar purple products are formed also with other oxides, such as silica, zirconia, lime, magnesia, and alumina.— *Comptes Rendus*, cxli, 977.   H. L. W.

5. *Fluoride of Bromine.*—Although Moissan had noticed that fluorine reacts with bromine very vigorously, the product of the reaction was not isolated by him. LEBEAU has now prepared the compound and has found that it is a colorless, fuming liquid corresponding to the formula BrF_3. Its vapor is very irritating, attacking the skin violently. It solidifies at about 4° to a colorless, crystalline solid. The compound possesses great chemical activity, reacting violently with water, and attacking many other substances similarly to free fluorine.— *Comptes Rendus*, cxli, 1018.   H. L. W.

6. *On some Properties of the α-Rays from Radium.*—Prof. E. RUTHERFURD thus summarizes his recent investigation of this subject.

(1) The rays from radium in radio-active equilibrium are complex, and consist of α particles projected with different velocities.

(2) The α particles decrease in velocity in passing through air and through aluminium.

(3) The absence of increased deflection of the rays from a thick layer of radium, after passing through aluminium, observed by M. Becquerel, is a necessary consequence of the complexity of the rays.

(4) The decreasing path of the rays in air, observed by Becquerel, is also a necessary consequence of the complexity of the rays.

(5) There is evidence of a distinct scattering of the rays from radium C in their passage through air.— *Phil. Mag.*, Jan. 1906, pp. 166–176.   J. T.

7. *Emission Spectrum of the Auer burner.*—H. RUBENS has measured the amount of energy given out by the so-called Degeas mantle which is composed of 99·2 per cent thorium oxide (ThO_2) and 0·8 per cent cerium oxide (Ce_2O_3). The method of measurement was substantially that described in Wied. Ann., lx, p. 737, 1897. The measurements were taken between wave lengths $\lambda = 0, 45\mu$ and $\lambda \pm 18\mu$. Curves of energy are given for the Auer burner in question, for the ordinary Bunsen burner and with a mantle covered with a thin layer of iron oxide. One obtains the latter by dipping the Auer burner in ink and then raising to a glow in the Bunsen burner. The mantel shows then in the flame mantel of the burner a red glow. The curves show that the mantel of the Auer burner is transparent for the rays of the Bunsen burner. They also show that the Auer burner radiations depart largely from the maxima of the Bunsen burner. Rubens believes that the cerium oxide plays a role in the burner similar to that of a sensitizer on the photographic plate in that it brings

forth an absorption region at a desired place without influencing the remaining spectral region. If another coloring substance could be found which added to the thorium mantel could blacken not only the short waves of the visible spectrum but also the yellow and red without disturbing greatly the ultra-red, the light working of the burner would be increased three times.—*Ann. der Physik*, No. 14, 1905, pp. 725–738. J. T.

8. *Afterglow produced by Lightning Discharges.*—E. Touchet (Compt. Rend., cxl, p. 1031, 1905) accounts for this by the supposition of an after-heating of the air. K. E. F. Schmidt (Elektrotechn. Zeitschrift, xxvi, p. 903, 1905) believes that it is a phosphorescent effect. B. WALTER gives his reasons for supposing that it is due to an after-discharge of electricity along the first path of the original discharge.—*Ann. der Physik*, No. 14, 1905, pp. 863–866. J. T.

9. *Specific Heat of Superheated Steam.* — Regnault in his investigation on this subject used a water calorimeter at the temperature of the room. This method had the disadvantage that the steam condensed in the calorimeter. To avoid the resulting errors Regnault let steam at 128° and afterwards at 217° stream through the apparatus. L. RUBENS and F. HENNING use paraffin oil instead of water above 100° and thus avoid the condensation of the steam, and proceed as with non-condensing gases.

They obtain the result $C_\theta = 0,4410 \, (1 + 0,00014_5 \theta)$.—*Ann. der Physik*, No. 14, 1905, pp. 739–756. J. T.

10. *Use of the Microphone Contact for Telegraphic Relays, and for Detection of Weak Currents.*—It has occurred to many inventors that a relay might result from simply placing a microphone contact against the vibrating disc of a telephone. It was soon realized that the excursions of such a disc were too small to actuate efficiently such a microphonic contact ; moreover the pressure of the contact on the disc interfered with the vibration of such a disc. CHR. JENSEN and H. SIEVEKING have taken up the general subject of microphonic contacts with the view of using them in some form of telephonic relay. In order to shun disturbing vibrations the microphonic contact was placed on a Julius suspension consisting of a heavy board or table hung from the ceiling with the usual arrangement of supporting wires. They found this suspension very useful. No mention, however, is made of the singing of microphonic contacts ; a trouble which is very difficult to overcome in the practical use of any microphonic contact. Possibly the currents employed by these investigators were too feeble to cause this singing. The paper contains a great many measurements of microphonic resistances and concludes with the following questions which were suggested by the investigation.

(1) What sensitiveness must one desire in order to obtain a practical working telegraphic relay ?

(2) In avoiding shaking or other disturbances within what limits is it safe to work without the necessity of too delicate adjustments ?

(3) What pressure is it best to select?

(4) What electromotive force at the contact should one employ?

The authors did not succeed in supplanting the galvanometer by a microphonic contact for the detection of very feeble currents.—*Ann. der Physik*, No. 14, 1905, pp. 695–724.   J. T.

11. *Mathematical and Physical Papers ;* by Sir GEORGE GABRIEL STOKES, Bart.   Vol. V, pp. xxv + 370 (Cambridge University Press).—This is the final volume of the collection and covers the period from 1876 to 1903.   It is well known that, during these years and, in fact, for some time prior to 1876, Stokes spent much labor upon his duties as secretary of the Royal Society and as a member of its publication committee.   These duties were so conscientiously performed that (in the opinion of those who knew him) they interfered greatly with his own work. But the service to science which he thus indirectly rendered by aiding, criticizing, and suggesting extensions of the work of others, must have been very great.   Some idea of this service may be obtained from the present volume, which is largely made up of notes and explanations appended to papers by other authors in the publications of the Royal Society.   One hitherto unpublished paper upon Water Waves (written in 1880) is included, as is also the Wilde Lecture on the nature of Röntgen rays, in which the accepted theory of these rays was first proposed.   A very interesting feature of the volume is the series of examination papers which Stokes prepared, from time to time, for the Mathematical Tripos and for the Smith's Prize Examination at Cambridge.

In the preface, Prof. Larmor promises a further volume " of biographical character, to be occupied in part by a selection from Sir George Stokes' voluminous scientific correspondence, including some unpublished manuscript material "; this will be looked for with much interest and it is to be hoped that nothing will interfere with its early publication.   H. A. B.

12. *Lehrbuch der Physik ;* von O. D. CHWOLSON.   Band III. Deutsch von E. Berg.   Pp. xi + 988.   Braunschweig (F. Vieweg und Sohn).—The first two volumes of this German translation of the Russian text-book of Prof. Chwolson have been noticed in previous numbers of this Journal.   The present volume deals with the theory of heat and has the same admirable qualities of clearness, completeness and perspective which are so noticeable in the earlier volumes.   H. A. B.

13. *The Polariscope in the Chemical Laboratory.   An Introduction to Polarimetry and Related Methods ;* by GEO. WM. ROLFE, A.M., Instructor in Sugar Analysis in the Mass. Institute of Technology, pp. 320, 8vo.   New York, 1905. (Macmillan Co.)—It has happened not infrequently in the past that American men of science, when impelled by one or another motive to prepare elementary text-books, have produced works decidedly superior to any analogous publications that had appeared previ-

ously in Europe. This result may perhaps depend primarily on the national virtue vaunted by Matthew Arnold, that " in matters within their range most Americans see straight and see clear," but is doubtless influenced also by an altruistic sentiment acting to help forward the cause of education and of national well-being such as was illustrated very remarkably long ago by the career of Noah Webster as set forth by Horace Scudder in his biography. The fact that such books are usually written without any hope of pecuniary gain throws them in a sense into the category of scientific memoirs and imparts a note of eclecticism, open-mindedness and fair-mindedness not to be looked for in the ordinary productions of Grub St. The book of Mr. Rolfe is noteworthy as a successful effort to elucidate and explain to beginners and even to the intelligent workman a form of scientific apparatus which is not infrequently held to be innately complex and difficult of comprehension. He has done this simply and clearly, and his descriptions cannot fail to be understood by all persons occupied with the business of testing and manufacturing sugars. The book will be appreciated also by those chemists and students of chemistry who wish to keep in touch with the progress of knowledge in the great field of saccharine matters and the related carbohydrates.   F. H. S.

II.   Geology and Mineralogy.

1. *Status of the Mesozoic Floras of the United States* (Second Paper) ; by Lester F. Ward, with the collaboration of William M. Fontaine, Arthur Bibbins, and G. R. Wieland. Part I, Text, 616 pp. ; Part II, Plates I–CXIX. Monograph XLVIII, U. S. Geol. Survey. (Washington, 1905.)—The extensive and sumptuously illustrated work before us forms the seventh paleobotanic monograph published by the United States Geological Survey. It, however, more immediately follows Part II of the 19th annual report, On the Cretaceous Formations of the Black Hills as indicated by the Fossil Plants, and Part II of the 20th annual report, On the Status of the Mesozoic Floras of the United States,—both of which are of monographic proportions. The monographs of the survey solely on fossil plants are therefore now virtually ten in number.

The subjects of Monograph XLVIII, being mostly in continuation of previous work, occupy a wide range, chiefly as follows : The older Mesozoic of Arizona ; the Jurassic of Oregon with the description of numerous ferns and many handsome cycad and ginkgo leaves with other conifers ; various minor Jurassic-Cretaceous floræ from Cape Lisburne, Alaska, from Montana, and from California ; the description of many additional cycadean trunks from the Freezout Hills of Carbon County, Wyoming, to the illustration of which 18 handsome plates are devoted ; the flora of the Shasta formation of California and Oregon ; further plants from the Kootanie of Montana, and the Lakota of South

Dakota ; an exhaustive description of the occurrence and macro-
scopic characters of the cycadeoidean trunks from the lower
members of the Potomac group of Maryland, illustrated by many
plates ; the description of various additional plants or specimens
from the Potomac group of both Virginia and Maryland with
various correlations and a discussion of the age of the beds.

The study of the Maryland and Wyoming cycadean trunks is
by Professor Ward. The most of the descriptions of floræ are
by Professor Fontaine. Mr. Bibbins contributes a paper on the
Potomac group and the occurrence of the cycadean trunks
therein, together with a splendid triple-plate map (Plate LXXX),
showing the areal distribution of the formations of the Potomac
group in Maryland, on which are indicated all of the known
plant and cycadean trunk localities. Mr. Wieland's contribu-
tions to the volume include the discovery of the leaves of the
Wyoming cycad trunks, with some account of their structure,
and two papers on the stratigraphy and paleontology of the
Black Hills rim, including a description of the leaves of the
Lakotan quasi-cycad *Nilssonia nigricollensis*, strikingly like some
of the forms of the Oregon Jurassic described by Fontaine.

Most interesting is the beautiful cycadean trunk from the
Grapevine Valley of Colusa County, California, described by
Professor Ward. This fossil is from the lower Chico or Horse-
town beds, the strata in which it occurs doubtless being of much
the same age as those yielding the numerous cycadean trunks in
Maryland and South Dakota. The most interesting feature dis-
played by the trunk is the presence of a peduncle in the axil of
every leaf-base of the lateral trunk surface. This extraordinarily
prolific growth of axillary fruits likewise characterizes the fine
type *Cycadeoidea nigra* from Boulder, Colorado, but is not found
in equal degree in any other cycadean specimens.

For the first time the Cycad trunks from Maryland are
adequately illustrated by numerous and beautiful plates, and Pro-
fessor Ward also adds many views of additional trunks and
finely conserved fragments from the Freezout Hills of Wyo-
ming. While holding the illustration and descriptions given by
Professor Ward as in the main most effective, necessary and
admirable, the reviewer nevertheless feels called upon to say that
he does not find from his own anatomical and structural studies
that there is any such great specific variation as is ascribed to
these cycads. Macroscopic leaf-base and armor characters may
serve to distinguish certain occasional and unique specimens
within specific limits; but as soon as one comes to deal with a
large number of trunks, so many transitions in preservation and
structure appear that the method fails of accuracy.

The study of the additional materials from the Potomac series
of Virginia and Maryland shows a similarity of floral change in
these beds of both states. It also appears that while impor-
tant floral changes of the Potomac group are evident in the
Raritan, little change in vegetation occurred during the Patuxent

and Arundel, doubtfully referred by Bibbins to Upper Jurassic and ascribed to the Lower Cretaceous by Professors Ward and Fontaine. Neither of the latter now hesitate to regard the flora of the Potomac as essentially Wealden and Lower Cretaceous, on the basis that the Wealden is the non-marine equivalent of the Neocomian, this being of course the most interesting geologic question dealt with by the volume. As Marsh held the Potomac to be Jurassic on the basis of its pre-Neocomian equivalency, there is of course no hiatus in the observations of those who have dealt with the upper boundaries of the Jurassic— always so uncertain because in both Europe and America the marine Jura is followed by the formation of fresh- to brackish-water beds most difficult to divide, though containing the most striking fossils. The reviewer had the pleasure of hearing Professor Marsh defend his hypothesis many times, and perhaps mainly because of that fact finds some difficulty in regarding the question as fully and finally closed. It does appear, however, that, as Professors Ward and Fontaine insist, the evidence that the Wealden is an unconformable transition series has much increased. It is also to be urged that the direct evidence of marine Jurassic superposition, as in the still doubtful cases like the Glen Rose beds of the Trinity group in Texas, must still be awaited with much interest ; that the origins of animal and plant forms are always being traced further and further back ; and finally, that it is a very significant fact that the dicotyls creep in as if by stealth in both the Arundel (*Rogersia*), and near the Minnewaste limestone in the Black Hills (*Sapindopsis*).

This appearance of new species with a strong invasive power may well mark profound physical changes within Potomac time, though such may be locally difficult to determine.   G. R. W.

2. *Geology and Paleontology of the Judith River Beds ;* by T. W. STANTON and J. B. HATCHER. Bull. 257, U. S. Geol. Surv., 1905, pp. 174, pls. 19.—During the year 1902, there was published a series of short, but interesting discussions between Osborn, Hatcher and Stanton, showing considerable difference of opinion regarding the position of the Judith River beds and their correlation with the Belly River beds of Canada. These difficulties were worked out satisfactorily in the field during 1903, in northern and central Montana and adjacent areas of Canada. The principal conclusions of Stanton and Hatcher are as follows :

" (1) The Judith River beds are distinctly older than the Laramie, being separated from the latter by at least several hundred feet of marine shales identical in their faunal and lithologic features with the Pierre to which we have given the local name Bearpaw shales, from the Bearpaw Mountains about which they ' are well exposed.

" (2) The Belly River beds of Canada are identical with the Judith River beds of Montana. The name Judith River beds, having priority, should be the accepted name for this formation and the terms Belly River and Fish Creek should be dropped.

" (3) The marine sandstones and shales immediately underlying the Judith River beds do not represent either the Benton, as some Canadian geologists have supposed, or the Fox Hills and upper Pierre, as most geologists of the United States who have examined them have believed, but they constitute a distinct horizon within the Montana group which we have called the Claggett formation, from old Fort Claggett at the mouth of Judith River, near which they are well developed.

" (4) The Eagle formation, from its stratigraphic position and faunal relations, marks the base of the Montana group in this region.

" (5) The Bearpaw shales, the Judith River beds, the Claggett and the Eagle formations all belong to the Montana group, and together probably form the equivalent of the Pierre as that term is generally understood, though the possibility is recognized that in the typical area the Pierre may have more restricted limits.

" (6) Faunas similar to that of the Fox Hills sandstone have a great vertical range and are likely to be found at any horizon within the Montana group where a littoral or shallow-water facies is developed. The use of the term Fox Hills as a formation or horizon name outside of the original area in South Dakota is therefore of doubtful propriety, as experience has shown."

The vertebrate fauna is described by Hatcher. "A considerable number of genera and species pertaining to all five of the known classes of vertebrates have been described. Unfortunately these genera and species are for the most part based on exceedingly fragmentary and unsatisfactory material." Of fishes there are 8 species ; of tailed Batrachia, 5 ; Plesiosauria, 3 ; Chelonia, 14 ; Rhynchocephalia, 4 ; Crocodilia, 2 ; Dinosauria, 37 ; birds, 1 ; mammals, 2. "When considered in its entirety, the vertebrate fauna of these beds is remarkably similar to, though distinctly more primitive than, that of the Laramie. Almost or quite all of the Laramie types of vertebrates are present, though, as a rule, they are represented by smaller and more primitive forms. The similarity between this fauna and that of the Laramie contrasts strongly with the great dissimilarity between the vertebrates of the Judith River and those of the Atlantosaurus beds, the next older fresh-water horizon in this region."

Of invertebrates, Stanton notes 35 species of Pelecypods, 30 Gastropoda, 1 Placenticeras, and 1 cockroach. "The species enumerated . . . fall into the three general categories of marine, brackish-water, and fresh-water forms, the latter including a few more or less doubtful land shells." The brackish-water fauna contains *Ostrea, Mytilus, Modiola, Anomia, Corbicula, Corbula, Panopœa, Rhytophorus,* and *Goniobasis.* As a rule, the fresh-water forms are found in distinct beds associated with land Mollusca and land vertebrates. "It is evident that after the deposition of the Claggett formation a considerable area in north central Montana and in Alberta and Assiniboia emerged from the sea and became the habitat of land and fresh-water animals.

Since there was no obvious break in the sedimentation, it is probable that the larger part of the area was covered by low-lying swamps and lagoons. For some time there were slight oscillations that occasionally for brief intervals brought large parts of the area down to sea-level and gave the lagoons sufficient connection with the ocean to allow the growth of oysters and other brackish-water forms over areas that had been occupied by fresh waters. Then for a longer period, during which 300 or 400 feet of sediments were formed, there was no connection with marine waters, though it is not probable that the area was ever very many feet above tide. During this epoch the general upward movement was reversed, and when the subsidence progressed more rapidly than deposition connection with the sea was soon again established, bringing in, first, brackish waters with their oyster beds, over nearly the entire area, with probably local bays and straits having more open and direct oceanic connections, such as is indicated by the occurrence of marine fossils in the Judith River on Cow Creek. Finally marine conditions were fully established over the entire area, so far as known, and continued during the deposition of the Bearpaw shales."

The fossil plants of the Judith River beds are described by Knowlton. There are 28 species. Of these, 8 are conifers, "and when the actual number of individual specimens is considered it is safe to say that fully nine-tenths belong to these species."

"It appears that the flora of the Judith River beds that has thus far come to light shows very little affinity with the true Laramie or the Fort Union, but does exhibit an undoubted relationship with that of the Dakota group or with the Cenomanian and Senonian of the Old World, or, in broad terms, with the lower and middle portions of the Upper Cretaceous."   c. s.

3. *Paleontology of the Malone Jurassic Formation of Texas;* by F. W. CRAGIN. Bull. 266, U. S. Geol. Surv., 1905, pp. 172, pls. 1–29.—It is not often that American Paleontology is enriched by a work describing a marine Jurassic fauna, and this bulletin is therefore all the more desirable. The region from which the fauna was gathered is about Malone Mountain, or about 75 miles southeast of El Paso, in Texas. On the basis of the ammonites, this fauna shows the closest affinities with that of the Tithonian of Europe. The nearest relations of American localities with that of Malone are in Mexico, having been described by Castillo and Aguilera. The relation of the Jurassic with the overlying Lower Cretaceous could not be made out, because no continuous section connecting the two systems was seen. An important feature of this work is a chapter of eleven pages by Stanton, entitled "Stratigraphic notes on Malone Mountain and the surrounding region, near Sierra Blanca, Tex."

The fauna consists of: Corals, 1 (new); Echinoidea, 2 undetermined forms; Vermes, 3; Bryozoa 1 (new); Pelecypoda 56 (40 new); Gastropoda, 18 (17 new); Cephalopoda 10 (5 new). No land vertebrates were seen, only fragments of fishes and swimming reptiles.   c. s.

4. *The Copper Deposits of Missouri;* by H. F. BAIN and E. O. ULRICH.   U. S. Geol. Surv., Bull. No. 267, 1905, pp. 52.— " Copper is found only in the southern part of Missouri, within the region broadly known as the Ozark uplift."   The annual output has thus far been small ; for 1903 it was $30,210.

The stratigraphic sequence and the extensive synonymy of the Ozark rocks are worked out in detail by Ulrich, and as it will be of service throughout the Mississippi Valley, his table of formations is presented herewith :

System.	Series.			Formation.	Thickness.
Ordovician	Saratogan and Lower Ordovician	Lower Ordovician	Potosi or Yellville group	Joachim limestone _ _ _ _ _ _ _ _ _ _ _ _ _	0–150
				St. Peter ("Crystal City") sandstone	0–200
				Jefferson City limestone_ _ _ _ _ _ _ _ _ _	50–250
				Roubidoux formation_ _ _ _ _ _ _ _ _ _ _	70–225 +
				Gasconade limestone_ _ _ _ _ _ _ _ _ _ _ _	450–650
Cambrian		True Saratogan		Elvins formation _ _ _ _ _ _ _ _ _ _ _ _ _	0–120
		Acadian		Bonneterre limestone _ _ _ _ _ _ _ _ _ _ _	_ _ _ _ _
				La Motte sandstone _ _ _ _ _ _ _ _ _ _ _	0–300
Archean granites and porphyries					

<div align="right">c. s.</div>

5. *Developmental Stages in the Lagenidae ;* by JOSEPH A. CUSHMAN.   Amer. Nat., Aug., 1905, pp. 537–553.—This readable short paper for the first time applies Hyatt's Principles of development to the unicellular animals.   The growth stages in compound forms are easily determined, and phylogenies of considerable importance are established.   The simplest form in the family is *Lagena*, and the *Lagena*-stage is present in *Nodosaria, Marginulina, Dimorphina, Polymorphina,* and *Cristellaria.*   Old age characters, uncoiling, and the development of spinose or " wild growths " are also clearly shown.   The paper gives a remarkably clear exposition of how Hyatt's Principles may be applied to the Foraminifera.   c. s.

6. *Revised Nomenclature of the Ohio Geological Formations;* by CHARLES S. PROSSER. Geol. Surv. Ohio, 4th ser., Bull. 7, 1905, pp. i–xv, 1–36.—As the title of this paper indicates, it revises the names applied to the geological formations of Ohio, in accordance with modern usage. It is a revision and elaboration of a similar paper published by the same author in the Journal of Geology, Oct., 1903, pp. 519–547.

7. *Mesozoic Section on Cook Inlet and Alaska Peninsula;* by T. W. STANTON and G. C. MARTIN. Bull. Geol. Soc. America, June, 1905, pp. 391–410, pls. 67–70.—This is a very important paper describing in some detail the Upper Triassic (2000 feet), Lower Jurassic (1000), Middle Jurassic (1500–2500), Upper Cretaceous (1000), and Tertiary (2000) strata of the Cook Inlet region. The writers also illustrate a very interesting local unconformity, which they were able to trace for about a quarter of a mile. "The fact that the same fauna is found both above and below this unconformity is evidence that the erosion interval was geologically brief, and it probably did not affect a wide area."

8. *New York State Museum; Report of the Director, 1904.* JOHN M. CLARKE. 1905, pp. 1–146.—This is the report of the Director of the Science Division of the Education Department, the State Museum, and the State Geologist and Paleontologist, for the year ending September, 1904. The report states what has been done during the year, and the work now in hand.

9. *The Geology of Miller County;* by S. H. BALL and A. F. SMITH.—Mo. Bureau Geol. and Mines, I, sec. ser., 1903, pp. i–xvi, 1–207, many plates and a geological map.—Describes the geology of the Cambrian, Ordovician, Mississippian, Pennsylvanian, and Pleistocene formations of the county.

10. *The Quarrying Industry of Missouri;* by E. R. BUCKLEY and H. A. BUEHLER. Ibid., II, sec. ser., 1904, pp. i–xv, 1–371, many plates and a geological map.

11. *The Geology of Moniteau County;* by F. B. VAN HORN and E. R. BUCKLEY. Ibid. III, sec. ser., probably 1905, pp. i–viii, 1–104, many plates and a geological map.--There is no date on the title page of this book, it being replaced by the stamp of the "Typographical Union." It is to be hoped that this practice will be relegated to the rear, as the date of a book is worth far more to its users than the fact that the work was set up by a given typographical union.

In this volume, the geology of the Cambrian, Ordovician, Devonian, Mississippian, Pennsylvanian, and Pleistocene formations of the county are described.

12. *Note on the use of Buena Vista as the name of a geological terrain;* by CHARLES S. PROSSER. (Communicated.)—In the December (1905) number of this Journal, Professor H. D. Campbell proposes the name " Buena Vista shale," derived from a town of that name in Virginia, for the upper formation of the Cambrian system in the middle portion of the Valley of Virginia

(vol. xx, pp. 445, 446). So far as the writer is aware, Buena Vista as the name of a geological division was first used by Dr. Edward Orton in his report of Pike county, Ohio, and published in 1874. The term·was applied to a subdivision of the Subcarboniferous (Mississippian) rocks of southern Ohio, and Dr. Orton's statement was as follows : " This subdivision has a definite base, viz., the upper surface of the Waverly black slate [now known as the Sunbury shale] ; but there is no characteristic stratum that constitutes a convenient superior limit. As the most valuable of the building rock, however, that is furnished by this part of the series in southern Ohio occurs within fifty feet of the slate, these fifty feet next above the slate may be somewhat arbitrarily taken as a subdivision. It may be designated as the Buena Vista section—the name being derived from a locality on the Ohio River that furnishes a large amount of stone of unequaled quality." (Rept. Geol. Surv. Ohio, vol. ii, Pt. I, p. 626.) This name was revived, the upper limit of the terrain defined, and applied to the lower member of the Cuyahoga formation in southern and central Ohio by the writer in December, 1904 (Amer. Geol., vol. xxxiv, f.n. on pp. 341, 342). In view of the above facts it does not appear to the writer that Buena Vista is available for the name of a Cambrian formation of Virginia.

13. *The Configuration of the Rock Floor of Greater New York ;* by WILLIAM HERBERT HOBBS. 1905. Bull. No. 270, U. S. G. S. Pp. 96, Plates V, figs. 6.—The present is an especially favorable time to study in detail the structure of the rock floor of Greater New York by means of the bore holes and excavations which have been made in the course of engineering operations. This information if not now collected would be ultimately largely lost and Professor Hobbs, perceiving this some years ago, has collected a large amount of geological information which will be of the highest importance to engineers engaged in construction work. The details also have bearings, as Professor Hobbs points out, upon structural problems in the geology of the region.   J. B.

14. *Formation of Phenocrysts in Igneous Rocks.*—In his opening address before the Geological Section of the British Association for the Advancement of Science at the meeting in South Africa, Prof. H. A. MIERS, president of the section, alluded to a number of important problems in geology whose elucidation is greatly aided by experimental research. Chief among these is the difficult question of the differentiation of igneous magmas and the origin of igneous rocks. After mentioning the results attained by different workers in this field the speaker gave some of his own results obtained in the study of the cooling and crystallization of saturated solutions which tend to throw light on rock textures.

Ostwald had previously shown that a saturated solution can exist in such a condition that crystallization may take place spontaneously or be readily induced by shaking,·etc.; this is termed the *labile* state. On the other hand, the solution may be in such a

condition that no amount of stirring or shaking or introduction of foreign substances can make the solution crystallize and it appears that this can only be done by the introduction of a crystal, or the part of one, of the dissolved substance. This latter is called the *metastable* state.

Prof. Miers has made experiments to ascertain the exact limits between these two states in a given solution, determining the changing concentration by an optical method, and the temperature at which the change into the labile state occurs. Thus it was found that in a solution of sodium nitrate containing 48 per cent of the salt, if dust (containing assumably submicroscopic particles of $NaNO_3$ or "germs") be not excluded, crystals make their appearance on the surface of the liquid, grow, and sink, but although they may be actively stirred about no new ones form and the liquid remains in the metastable state till a temperature somewhat below 16° is reached, when the labile region is entered and a cloud of new crystals make their appearance. Thus in a cooling supersaturated solution from which germs have not been excluded there are two periods of growth; one in which a comparatively small number of isolated crystals are growing regularly and a subsequent period in which a shower of small crystals is produced. If the rate of cooling is slow enough or the stirring violent enough to keep the liquid in the metastable condition there will be no second period or sudden production of small crystals. These events were found to take place in all of the solutions studied and the same process is suggested as an explanation of the porphyritic texture found in igneous rocks; "in a silicate magma in all probability the temperature is sufficiently high to be that of the metastable condition, the rate of cooling sufficiently slow to keep the liquid in that condition for a considerable time and the viscosity sufficiently great to prevent the growing crystals from sinking at once; we have therefore all the conditions favorable for the growth of *porphyritic* crystals; these must have generally originated throughout the liquid as spontaneous nuclei if the magma entered the labile state, or may have been started by inoculation or cooling at the margin if the magma as a whole remained in the metastable state. In the latter case suppose that further somewhat sudden cooling brings the magma to the labile condition, then there will be a sudden and spontaneous second growth of nuclei which will not be able to attain the dimensions of the porphyritic crystals; we have here all the conditions necessary for a *second generation* of one of the constituents of the rocks." L. V. P.

15. *Beiträge zur chemischen Petrographie;* von A. Osann, *II Teil, Analysen der Eruptivgesteine aus den Jahren, 1884–1900.* Pp. 266, 8vo. (Stuttgart, 1905.)—This work is in fact a continuation of that of Roth, whose well-known Tabellen proved for many years of such value to petrographers. It will be used chiefly by Europeans, as in this country it is replaced by Washington's great work, but since in the latter the analyses are

arranged according to the new quantitative system, the book referred to will also be of service, as in it they are arranged according to the classification of Rosenbusch and thus supplement his well-known work. The book has been made up in a way that makes it very convenient for reference and its whole arrangement evinces both industry and careful compiling.

L. V. P.

16. *Beiträge zur Petrographie des westlichen Nord-Grönland;* von M. BELOWSKY. Zeitschr. d. deutsch. Geol. Gesellsch. lviii, pp. 15–90, 1905.—The material upon which this investigation is based was collected and brought back by Drygalski in his expedition to the west coast of Greenland in the years 1891–1893. It consists chiefly of pebbles from glacial moraines. As a result of the work the author concludes that northwest Greenland consists chiefly of crystalline schists referred to the Archean and of Cretaceous strata penetrated by basalt.

The crystalline schists are gray mica and hornblende gneisses with inclusions of hornblende rocks of various kinds and cut by granite intrusions. All these gneisses are supposed to be of eruptive origin. One of them is interesting from the fact that it contains a blue alkali hornblende referred to astochite, the rock thus representing among the gneisses, the alkali series of the igneous families. The hornblende included masses are referred to altered peridotites.

The pebbles in the moranial material show that not only crystalline schists but rocks of higher horizons are covered by the inland ice. The later eruptive rocks which break through the Cretaceous are feldspar basalts. The author suggests that the petrographic characters of the Greenland gneisses allies them with those of the Scandinavian peninsula and that they may be of the same age. L. V. P.

17. *Recherches géologiques et pétrographiques sur les Laccolithes Environs de Piatigorsk (Caucase du Nord);* par VERA DE DERWIES. Pp. 84, 4°; 12 figs. and 3 plates (map). Geneva, 1905.— On the northern outslopes of the Caucasus lies a hilly area, celebrated for its mineral springs which have rendered it one of the health resorts of Russia. Several small towns, whose existence is largely due to the influx of patients desiring to avail themselves of the curative properties of these waters, have grown up in this region. The best known of these is Piatigorsk (Five Hills) connected by a branch with the main railway line to Vladikavkas and the Caucasus. The main topographic features of the area, through which the branch line runs to Piatigorsk, are a group of scattered hills which are formed by a number of laccoliths intruded into the Jurassic beds. As has been frequently found to be the case in western America they occur on the outer flank of the main mountain chain, where the sedimentary strata begin to be flexed by orogenic disturbance.

These laccoliths present every stage of erosive dissection from examples, in which the covering has not only been removed but

the igneous mass has been so deeply bitten into that only a remnant remains, to those where only at the top is a small portion of it revealed and finally the case where no igneous rock is seen but must be inferred from the structure and associations of the domed elevation. The igneous rocks composing these masses present several varieties of feldspar porphyry, quite similar to those found in the laccoliths of Colorado and Montana.

This region was visited and briefly studied in the autumn of 1897 by those geologists who took part in the excursion to the Caucasus of the VIIth International Congress at St. Petersburg and it afforded to the European members of the party an excellent and instructive example of geological phenomena which many of them had until then regarded as confined to America, and which hitherto they had not had an opportunity of seeing.

The area has now been studied and mapped by the author quoted above and the results of the work which have been carried out under the direction of Prof. Duparc of Geneva, are given in full, especially on the petrographic side. The rocks of the different occurrences have been analyzed and in the conclusion a number of deductions are drawn. This work will be of especial interest to many American geologists for its confirmation, in another part of the world, of the results of their studies of the phenomena of laccolithic intrusions. L. V. P.

18. *Physikalische Krystallographie und Einleitung in die krystallographische Kenntnis der wichtigsten Substanzen ;* von P. GROTH. Pp. 820, with 750 figures and 3 colored plates. Leipzig, 1905 (Wilhelm Engelmann).—It is interesting to compare the volume which has just appeared with its three predecessors published at intervals during the past thirty years. The increase in size from the 528 pages of the first edition (1876) to the present volume, one-half larger, is the most apparent change, but more important still is the development and expansion which the successive works show in the principles and their applications as they concern the topics embraced under Physical Crystallography. The author has a happy power of assimilating and making use of all that is most valuable and novel in the work of others, and at the same time his own independent investigations enable him not only to make important contributions of his own, but also to bring the whole into a compact and homogeneous system. The changes which the present edition exhibits most particularly are those concerned with the classification and mutual relations of the different physical properties. Something of this will appear from the classification given in the Introduction.

The physical characters of crystals are distinguished first as *scalar* and *vectorial.* The former are those which are independent of direction, as density, specific heat, etc., for crystals and all the properties of amorphous substances. The latter embrace those in which the direction is essential ; further in regard to them, the term "bivectorial" is used for properties not acentric, that is, similar in opposite directions from a given point. The bivec-

AM. JOUR. SCI.—FOURTH SERIES, VOL. XXI, No. 122.—FEBRUARY, 1906.

13

torial physical characters are, further, classified into those of higher and lower symmetry. The former are called " ellipsoidal characters " because their numerical values for all possible directions are determined by at most three different values in directions at right angles, corresponding in general to the axes of an ellipsoid. Here belong, for example, the optical characters, according to which all crystals fall into five divisions. The bivectorial characters of lower symmetry embrace these concerned with elasticity and cohesion and the lowest grade of all is shown by those involved in the molecular growth and resulting structure of the crystal, where thirty-two classes are required to embrace all possible types. The discussion in succession of all the various characters, beginning with those involving light, is clear and complete. The subject of the molecular structure of crystals, from the theoretical side, is also clearly presented, and it is shown how the fundamental laws of rational indices and zones follow. The second half of the volume is devoted to the description of the successive systems, with the various classes falling under them and the special forms belonging to each. The methods employed in the investigation of crystals are treated in the last one hundred and fifty pages.

19. *Preliminary Notice of a New Meteorite from Texas ;* by KENNETH S. HOWARD (Communicated).—A new aërolite from the Staked Plains of northwestern Texas has just been secured by Ward's Natural Science Establishment. It will be known as the Estacado, having fallen near the place of that name in 1882. The following results are taken from an unfinished analysis by Mr. John M. Davison :

Specific gravity 3·63. Metallic part 16·41 per cent. Stony part 83·59 per cent, of which 53·61 per cent is insoluble in HCl and 29·98 per cent is soluble. The analysis of the metallic portion calculated to 100 per cent is

Fe	89·45%
Ni	9·99
Co	·56
P	trace
Cu	trace
	100%

A complete account will be published shortly.

20. *Mineralogical Survey of Ceylon, Report for 1904 ;* by A. K. COOMARASWAMY, Director. Pp. 21 with map and 3 plates.— This Report gives much valuable information in regard to the occurrence of gems and rare minerals in Ceylon, including the remarkable thorianite. An interesting occurrence is described on the Haldummulla estate, where corundum occurs in violet, pink and purplish crystals loose in the soil, and also in blocks of a sillimanite rock. These were not found in place, but doubtless

came from a point not far distant. The sillimanite rocks have been found in certain parts of Ceylon somewhat abundantly in the garnetiferous leptynites. The author remarks: "The silli- manite-bearing rocks have a strong resemblance to the khonda- lites of Southern India; they do not, however, occur in the same way above the charnockite series, but completely incorporated with it, forming probably bands and lenticular masses; the rocks have, however, been rarely seen *in situ*, and it has not been possi- ble to study closely their relation to the charnockites proper. It must be pointed out that there is a complete transition to the ordinary granulite type. On the one hand, we have a rock com- posed wholly of sillimanite, and all varieties from this, through quartz-feldspar-sillimanite-garnet schist, to garnetiferous leptynite with very little sillimanite, and ordinary garnetiferous and non- garnetiferous leptynites can be collected."

Intrusive granite rocks which have been called the " Balangoda group " have afforded a number of rare and interesting minerals, including, thorianite, thorite, allanite, baddeleyite, geikielite and cassiterite. The thorianite occurs in moderate quantities near Kondrugala in Bambarabotuwa, Sabaragamuwa. It is found in heavy black crystals, more or less water-worn, associated with zircon and pebbles of ilmenite. It is obtained by the same method used in washing gems, and it is stated that the whole amount thus far removed from Bambarabotuwa is less than 30 cwt., and it is not probable that more than a total of 5 tons could be obtained from the Kuda Pandi-oya valley; two other localities mentioned might yield half a ton additional.

An interesting account is given of the occurrence of gems and the methods of gemming in Ceylon; this is supplemented by some excellent illustrations reproduced from photographs. The gem-bearing gravel, or illam, occurs in beds, patches, or pockets deposited by streams and rivers, and may be found at any depth, up to 120 feet, the greatest depth observed, viz : at Botiyatenna, Rakwana. Where the illam is found in its typical form, it con- sists largely of white quartz pebbles, ranging in size from a small shot to a football, indeed in all gradations of size up to that of the bowlders associated with the illam.

21. *The Production of Precious Stones in 1904;* by GEORGE F. KUNZ (Extract from Mineral Resources of the United States, U. S. Geol. Survey).—The annual reports in regard to the Pro- duction of Precious Stones always contain matter of interest. Of recent discoveries in this country the most important noted are those of Southern California, particularly in San Diego county, which has yielded near Ramona fine blue and white topaz ; also rose-colored beryl at Mesa Grande and Pala, and axinite at Bon- sall. The colored tourmalines, both in California and Maine, have been mined extensively, and the new locality of peridot at Talklai, Gila Co., Arizona, has yielded large quantities of fine gems. Much interesting information is given in regard to the diamond industry, particularly in South Africa.

22. *Celestite in Canada* (Communicated).—HENRY LAMPARD notes the occurrence of crystals of celestite at Longue Pointe on the Island of Montreal. They are found in a vein, with fibrous structure, in the Trenton limestone near where it is cut by an igneous dike.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *American Association.*—The fifty-fifth annual meeting of the American Association for the Advancement of Science was held at New Orleans during the week beginning Dec. 29, with Prof. C. M. Woodward as President. Six affiliated societies met at the same time. The next meeting of the Association has been appointed for New York City in Convocation week, beginning Dec. 27, 1906. Professor W. H. Welch has been elected President.

2. *Ostwald's Klassiker der exakten Wissenschaften.* Leipzig, 1904 (Wilhelm Engelmann).—The following are the titles of the latest additions to this highly valuable series of scientific classics:

No. 146.—Über die Lösung der unbestimmten Probleme zweiten Grades ; von JOSEPH LOUIS LAGRANGE (1768). Pp. 131. Aus dem Französischen übersetzt und herausgegeben von Eugen Netto in Giessen.

No. 147.—Beitrag zur physiologischen Optik ; von JOHANN BENEDIKT LISTING. Pp. 52, with portrait and two plates. Herausgegeben von Prof. Dr. Otto Schwarz, Leipzig.

No. 148.—Über das Gedächtnis als eine allgemeine Funktion der organisierten Materie ; von EWALD HERING. Pp. 21. Vortrag gehalten in der feierlichen Sitzung der Kaiserlichen Akademie der Wissenschaften in Wien, am XXX Mai, MDCCCLXX.

No. 149.—Tastsinn und Gemeingefühl ; von ERNST HEINRICH WEBER. Pp. 156 with portrait. Herausgegeben, von Ewald Hering.

No. 150.—Bestimmung des Brechungs-und Farbenzerstreuungsvermögens verschiedener Glasarten in Bezug auf die Vervollkommung achromatischer Fernröhre ; von JOSEPH FRAUNHOFER. Pp. 36, with portrait, 1 plate and 6 text figures. Herausgegeben, von Arthur von Oettingen.

The Science Year Book, with Astronomical, Physical and Chemical Tables, Summaries of Progress in Science, Directory and Diary for 1906 (Second year of issue). Edited by MAJOR B. F. S. BADEN-POWELL. Pp. 208 ; 365 ; vi. London, 1905. (King, Sell & Olding, Ltd).—The Preface states that in this issue of the Science Year Book, "a number of additions and alterations have been made. New maps of the Constellations and of the Moon replace the old ones. Maps of Magnetic Variation and Rainfall are added, as are tables of Geology and of the Animal Kingdom. In addition to many new notes, among those in Physics and Chemistry is a table of Spectra. In the Directory, a list of Universities with Professors of Science is included ; also a list of Colonial Scientific Societies, and many new names are added to the Biographies."·

CONTENTS.

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics—Determination of Nitrous and Nitric Acids, Weisenheimer and Heim : Modifications of Antimony, Stock and Siebert, 170.—Quantitative Determination of Bismuth, Staehler and Schaffenberg : Distillation of Gold, Moissan, 171.—Fluoride of Bromine, Lebeau : Properties of the α-Rays from Radium, E. Rutherford : Emission Spectrum of the Auer burner, H. Rubens, 172.—Afterglow produced by Lightning Discharges, B. Walter : Specific Heat of Superheated Steam, L. Rubens and F. Henning : Use of the Microphone Contact for Telegraphic Relays, and for Detection of Weak Currents, C. Jensen and H. Sieveking, 173.—Mathematical and Physical Papers, G. G. Stokes : Lehrbuch der Physik, O. D. Chwolson : Polariscope in the Chemical Laboratory, G. W. Rolfe, 174.

Geology and Mineralogy—Status of the Mesozoic Floras of the United States (Second Paper), L. F. Ward, 175.—Geology and Paleontology of the Judith River Beds, T. W. Stanton and J. B. Hatcher, 177.—Paleontology of the Malone Jurassic Formation of Texas, F. W. Cragin, 179.—Copper Deposits of Missouri, H. F. Bain and E. O. Ulrich : Developmental Stages in the Lagenidae, J. A. Cushman, 180.—Revised Nomenclature of the Ohio Geological Formations, C. S. Prosser : Mesozoic Section on Cook Inlet and Alaska Peninsula, T. W. Stanton and G. C. Martin : New York State Museum, J. M. Clarke : Geology of Miller County, S. H. Ball and A. F. Smith : Quarrying Industry of Missouri, E. R. Buckley and H. A. Buehler : Geology of Moniteau County, F. B. Van Horn and E. R. Bookley : Note on the use of Buena Vista as the name of a geological terrain, C. S. Prosser, 181.—Configuration of the Rock Floor of Greater New York, W. H. Hobbs : Formation of Phenocrysts in Igneous Rocks, H. A. Miers, 182. —Beiträge zur chemischen Petrographie, A. Osann, 183.—Beiträge zur Petrographie des westlichen Nord-Grönland, M. Belowsky : Recherches géologiques et pétrographiques sur les Laccolithes Environs de Piatigorsk (Caucase du Nord), V. de Derwies, 184.—Physikalische Krystallographie und Einleitung in die krystallographische Kenntnis der wichtigsten Substanzen, P. Groth, 185.—Preliminary Notice of a New Meteorite from Texas, K. S. Howard : Mineralogical Survey of Ceylon, Report for 1904, K. Coomaraswamy, 186.—Production of Precious Stones in 1904, G. F. Kunz, 187.—Celestite in Canada, H. Lampard, 188.

Miscellaneous Scientific Intelligence—American Association : Ostwald's Klassiker der exakten Wissenschaften, 188.

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[FOURTH SERIES.]

Art. XII. — *Magnetic Field and Coronal Streamers*; by
John Trowbridge.

In the course of an investigation of the phenomena pre-
sented by electric discharges in strong magnetic fields, it was
soon apparent that phenomena appear at high voltages together
with strong steady currents which do not manifest themselves
at lower voltages and lesser currents. I have, therefore,
employed comparatively large tubes; voltages ranging from
3000 to 8000 between the discharge terminals; currents from
5 milliamperes to 20 milliamperes.

The most practical form of resistance I have used is a col-
umn of running tap water under constant pressure in glass
tubes of suitable diameter. Graphite resistances mounted on
quartz have a large temperature-coefficient, and also a remark-
able counter electromotive force. The glass tubes containing
rarified air ranged from cylindrical tubes 30^{cm} long, 4^{cm} internal
diameter to cylindrical tubes 48^{cm} long and 10^{cm} internal diam-
eter. The experiments described in this paper were per-
formed with tubes 30^{cm} long and 4^{cm} internal diameter.

At pressures varying from 1^{cm} to 1^{mm} the cathode light on a
circular aluminum plate 3^{cm} in diameter forming the pole of a
powerful magnet, the magnetic lines of which are directed
along the line of electric discharge, is driven to the circum-
ference of the disc, forming to the eye an apparently steady
circular discharge. When the tube, however, is covered with
black paper, exposing only the light of the disc, and this light
is examined in a revolving mirror, it is seen that we have an
interesting case of unipolar rotation. Fig. 1 is a photograph
taken of the reflection in the revolving mirror. The glass

walls of the tube and the necessary obliquity in the reflection
modify the sharpness of the image. The speed of revolution
increases with the degree of exhaustion of the rarified air.
When the free path of the ions increases, the progressive effect
along the magnetic lines becomes more than the rotational
effect of the magnetic field. When the plate forms the anode
and also the end of a magnetic pole the lines of magnetic force
being directed along the line of electric discharge, the light
at the anode is separated into two distinctly different lights;
one (in rarified air), a plume-like rosy light, the other a plume-
like violet light. These discharges also revolve around the
pole near the center of the disc instead of on the circum-

1
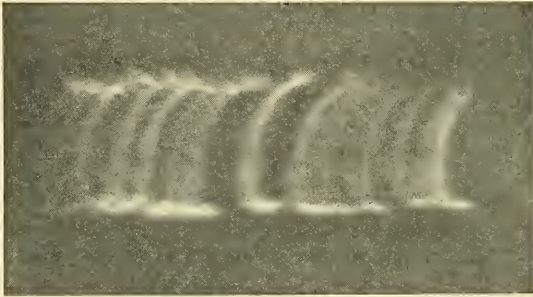
ference, as in the case of the cathode disc. On account of the
number of individual discharges on the anode it is difficult to
follow their motions in a revolving mirror or by the eye,
or to photograph them. It is certain, however, that they
revolve about the pole.

The unipolar rotation which I have described leads my
mind to connect the phenomenon of coronal streamers seen at
the poles of the sun in an eclipse, with the effect of a magnetic
field on possible electrical discharges between the equatorial
regions of the sun and the poles of the sun. If we suppose
that a difference of electrical potential can arise between the
swiftly moving strata of gases or from the eruptions which
take place mainly along the equatorial belt and the polar
regions, the supposed magnetic poles of the sun would undoubt-
edly tend to cause the resulting electric discharges to revolve
about the pole. On account of the vast circumferential area
about the poles a number of discharges could occur at different
points around the pole and each discharge would revolve under
the effect of the pole. In observing the effect of a strong mag-
netic pole on plate terminals in wide tubes of rarified air, at
comparatively high pressure of air under conditions of high

electromotive force and great current density, one can observe phenomena of rotation which cannot be photographed yet which present to the eye a strong analogy to the appearance of coronal streamers.

2

I arranged a number of collections of bristles on a disc which was then set in rapid rotation. Fig. 2 is a photograph of the appearance of such revolving streamers, which repre-

3

sent fairly well what may be seen at the terminal of a discharge tube in a magnetic field.

There is, however, another magnetic phenomenon which may have a bearing upon the coronal streamers at the poles of the sun. When the lines of magnetic force are at right angles, or transverse to the direction of the electric discharge, at comparatively high pressures, one to two centimeters, with currents

from 5 to 20 centimeters, 3000 to 8000 volts in wide tubes, streamers radiate from the position of the magnetic pole. Fig. 3 is a photograph of such streamers or stratifications. It will be noted that these striæ make their appearance at a much higher pressure than that of the usual striæ in rarified gases.

Electric discharges around or toward the poles of the sun transverse to the lines of magnetic poles of the sun could be separated into streamers.

Effect of a Magnetic Field on the Production of X-Rays.

The ordinary form of X-ray bulb does not lend itself easily to the application of the magnetic field, either at the anode or the cathode, and even in the special form of bulb, fig. 4, which I have used in this investigation, it was not possible to develop magnetic lines of force over the entire surface

4
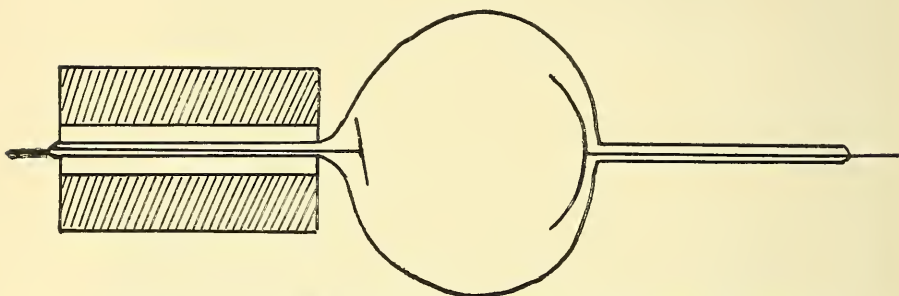
of anode or the cathode. The cores of the electromagnets were hollow in order to allow of the approach of the coil of the electromagnet to the terminals of the bulb, the glass seals of these terminals thus projecting into the hollow iron cores; only a circular area, therefore, on the cathode or anode forms the effective magnetic field. It seems probable that the best results would be obtained by enclosing the iron core entirely inside the bulb, platinizing the end of the iron core forming the anode, placing the aluminum mirror forming the cathode directly in the end of an iron core and nickel plating both iron cores to prevent the constant escape of gases from such large surfaces of iron. I had a bulb of this general description constructed, but found it impossible to exhaust it to the X-ray stage on account of the escape of gases from the iron; the iron was not nickel plated, however. The bulb was exhausted while it was strongly heated in an oven.

Fig. 5 is a photograph of the discharge in the X-ray bulb somewhat before the X-ray stage ; a dark space surrounds the cathode.

Fig. 6 is a photograph of the same tube when the magnetic field is applied to the anode. This cone of rays is

solid until just before the X-ray stage; then it becomes hollow; and at the X-ray stage it appears only at the instant the

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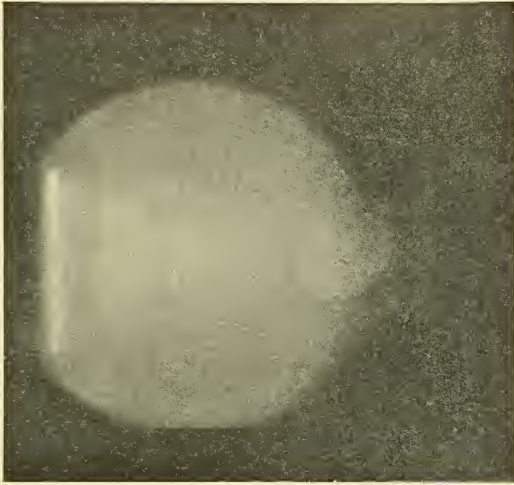
magnetic field is excited as a violet light, and then becomes indistinguishable in the fluorescence of the bulb. A violet brush, however, persists on the surface of the anode at the X-ray stage. When the vacuum was increased to so high a degree that the bulb could not be excited by a coil giving a six-inch spark, the application of the magnetic field immediately resulted in the production of the rays.

When the cathode mirror of an ordinary X-ray bulb is made the anode instead of the cathode, the current passing in the usually unfavorable way for the production of the rays, and at the same time is also the pole of a powerful electromagnet, the bulb gives out X-rays in great abundance. This is not the case when the magnet is not excited. The magnetic field, therefore, causes the anode to produce X-rays, probably by an increased energy of bombardment of the platinum focal plane by the positive ions.

Fig. 7 is a photograph of the X-ray bulb when the cathode mirror has been made the magnetic pole. Without the excitement of the magnetic field the bulb could not be made to give the X-rays even with a coil producing a six-inch spark; the vacuum having increased greatly during the previous use of the bulb.

When the field was excited, however, a brilliant fluorescence was produced, without any appearance of X-rays. The

negative ions, apparently, did not reach the anticathode, but instead formed fluorescent rings around the cathode. The cathode is thus made part of a hollow hemisphere of, in this case, orange light; when, however, the bulb was excited by a coil giving a twenty-inch spark with Leyden jars the bulb gave very brilliant X-rays at the moment of exciting

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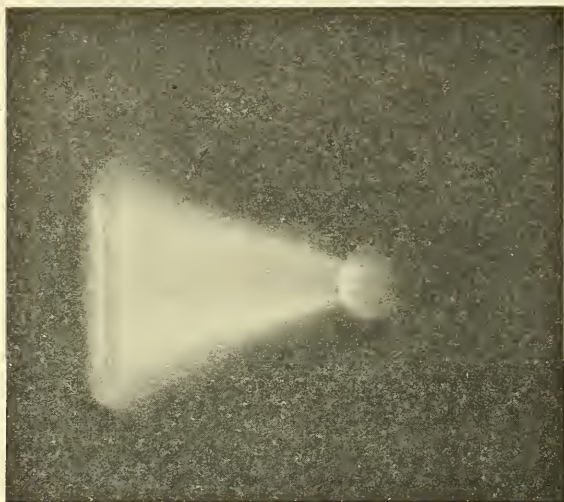
the magnetic field; in the case of the use of the six-inch spark coil, there were no Leyden jars in the circuit.

Besides the scientific side of the manifestations of the effect of the magnetic field on discharges in high vacua, there seems to be a practical use of the electromagnetic field in connection with the regulation of the discharge in X-ray bulbs. At present, when the vacuum has risen so high that the bulb cannot be excited, one is forced to apply heat to various regulators in order to drive out gases to increase the conduction. All regulators hitherto used are uncertain and dangerous to the life of the bulb in their application. I believe that a magnetic regulator applied to the anode would be of great service in hospital plants where a suitable electrical equipment can be had. The magnetic regulator is entirely safe and is constant in its action. It also enables one to pass readily from the production of hard rays to that of soft rays by the modification of the strength of the magnetic field; a modification difficult to accomplish without the application of the magnetic field.

The results are as follows:

1. When the anode in an X-ray bulb is also the end of a powerful electromagnet the application of the magnetic field results in the production of X-rays from a bulb which cannot be excited without the application of heat.

2. When the cathode forms the magnetic pole a violet

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brush-like light appears on the cathode, on the side away from the electromagnet; while the fluorescent light is forced somewhat beyond the cathode.

3. The use of Leyden jars in the case of low potential coils greatly modifies the effect of the application of the magnetic field, while with coils giving sparks over 20 cm. with comparatively large Leyden jars in circuit the application of the magnetic field to either anode or cathode results in greatly increased production of X-rays.

4. The application of a strong magnetic field at the anode with lines of force along the line of electric discharge forms a safe and useful method of regulation of X-ray bulbs.

5. An electrometer connected to the terminals of the exhausted tube shows a diminution of the apparent resistance of the tube when the anode is made the magnetic pole ; and a rise in resistance when the cathode constitutes this pole. With Leyden jars in circuit the magnetic pole separates the oscillations, and rectifies the discharge to a certain extent.

Art. XIII.—*On the Glaciation of Orford and Sutton Mountains, Quebec ;* by Alfred W. G. Wilson.

In a report published some years ago Dr. Chalmers,* the Pleistocene geologist of the Canadian Geological Survey, places the upward limit of glaciation in the Eastern Townships of Quebec at 1800 feet above sea level. In a paper read a few months later at the Boston meeting of the American Association for the Advancement of Science, in 1898, Professor Hitchcock† drew attention to the fact that Orford mountain is striated from bottom to top and that the ice movement was in a southeasterly direction. Hitchcock however gives the height of Orford mountain as about 5000 feet. Principal Dresser,‡ a year later and working independently, drew attention to the presence of exotic materials and striæ on the summit of Orford mountain (2800 feet approx.) over 800 feet above the highest limit set by Chalmers. In a recent report to the State geologist of Vermont, Hitchcock§ restates his original observations and adds additional data. In a still later article, published in the Ottawa Naturalist for May 1905, Chalmers‖ not only reasserts his original position without indicating in any way that he has re-examined the area in the vicinity of Mount Orford, but attempts to question the accuracy and veracity of both the observers whose results do not agree with his own.

During the past few years the writer has been collecting data for a study of the physiography of the St. Lawrence Plain and the adjacent areas. In carrying out these investigations it has been found necessary to review in the field practically all the work that had been done previously. New and it is believed more accurate determinations of the heights of all the prominent elevations on the St. Lawrence Plain have been made and independent studies of the Pleistocene geology of the district are under way.

While the physiographic studies are not sufficiently advanced to permit of immediate publication, the time seems opportune to offer the results of independent investigations which bear directly on the problem of the glaciation of Mount Orford and the adjacent peaks and ridges. Three new elevations are given which are based on barometric determinations that are

* Chalmers, Annual Report of the Geological Survey of Canada, vol. x, Part J, 1897.

† Hitchcock, Proceedings Amer. Asso. Adv. Sci., Boston, vol. 47, p. 292. 1898.

‡ Dresser, Canadian Record of Science, vol. viii, pp. 223–225, 1900–1902.

§ Hitchcock, Report of the Vermont State Geologist, p. 72, 1903–1904.

‖ Chalmers, Ottawa Naturalist, vol xix, pp. 52–55, 1905.

thought to be more accurate than the majority of the earlier observations. The method employed was as follows: An observer is stationed with one or two barometers at a point whose elevation is known from a railway profile. This observer takes readings during the working day at half-hour intervals and the data obtained are used to plot a time-pressure curve. In the field, barometers which were compared with the base barometers, both at the beginning and at the end of the day, were employed. The time of observation and the temperature were noted in each case when the field readings were taken. In cases where more accurate results were desired the field barometers were kept at the field stations for several hours and were read at half-hour intervals simultaneously with the readings of the base barometers. The elevations were later determined by reducing the readings obtained, corrections being applied for atmospheric temperatures. In this way a series of sixteen pairs of observations were taken and the six most closely accordant sets of readings were used in finding the height of Mount Orford as given here. In a series of over one thousand readings made by this method during the past two years, the writer has obtained some very satisfactory results where checks were afterwards obtained from railway profiles to determine the probable accuracy of the method employed.

### General Character of the Topography of the District.

The eastern margin of the plain of the St. Lawrence is formed by the edge of a belt of crystalline and igneous rocks, the northward extension of the Green mountain range into Canada. The general trend of the structural lines of this belt of rocks is about 20 degrees to the east of north and we find that the trends of the main ridges and valleys in the vicinity of Orford and Sutton mountains are in conformity with the trends of the structural lines. The Sutton ridge, of which Sutton Mountain is the most important peak, consists of a central mass of gneiss flanked by quartzites and schists. It is the western of the two ridges which occur in this locality. Orford Mountain is the culminating peak of the Orford ridge, a topographic feature which extends into Canada from south of the Vermont boundary and lies immediately to the east of the Sutton ridge.

The central core of the Orford ridge is a diabasic rock and it is flanked by schists and serpentines. Between Orford mountain and the International boundry several minor peaks are developed on the ridge, occurring in the order named— Hog's Back, Sugar Loaf, Owl's Head, and Bear Mountain, the

latter lying in part to the south of the boundary.   Three miles
west of Bear Mountain a similar ridge known as Hawk Moun-
tain is a prominent topographic feature.

West of the Sutton ridge, near the boundary, St. Armand
Pinnacle is the culminating peak of a minor ridge of metamor-

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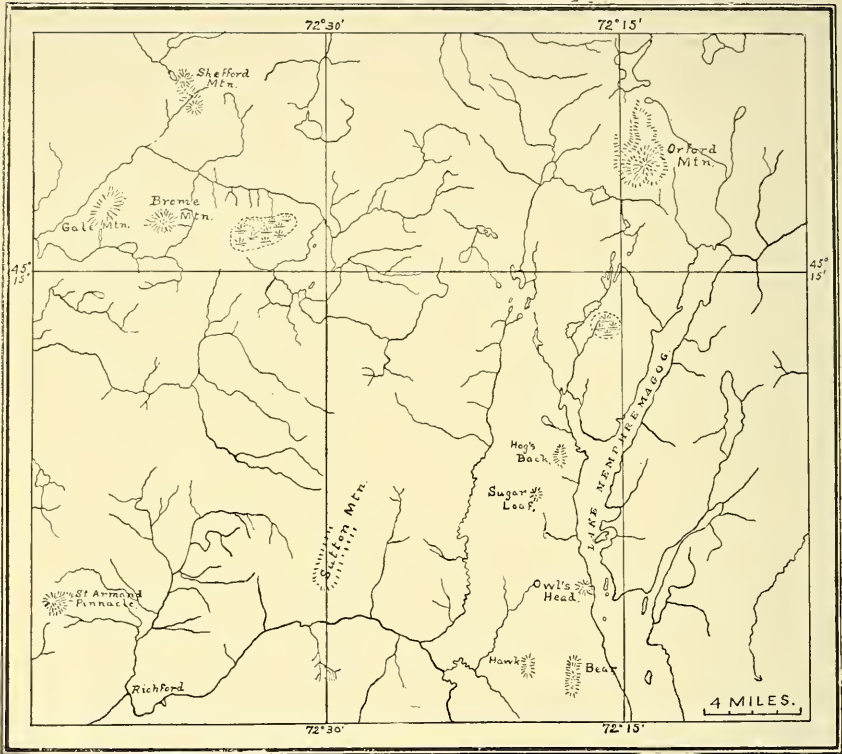
Sketch plan of the area west of Lake Memphremagog, Quebec.

phic rocks which has a greater development south of the
boundary.

The valley between Sutton ridge and Orford ridge is cut on
softer schists and serpentines.   It is drained by the east
branch of the Missisquoi River.   This branch crosses Sutton
ridge in a deep gorge (two miles south of the boundary line),
through which the Canadian Pacific Railway runs, and joins
the north branch of the same stream at Richford, Vt.   The
valley west of the Sutton ridge, between it and St. Armand
ridge, is drained by the north branch of the Missisquoi River.

East of Orford ridge the lowest portion of a broad valley is occupied by Lake Memphremagog, a long narrow lake which receives a considerable amount of drainage from south of the boundary. The waters of Lake Memphremagog pass out northeastward by the Magog River—a tributary of the St. Francis—and eventually reach the St. Lawrence River. On the Orford ridge Mount Orford has an elevation of 2820 feet; Owl's Head, 2465 feet; Hog's Back, Sugar Loaf, and Bear Mountains are considerably lower. The lowest parts of the transverse depressions on either side of Owl's Head stand at elevations of about 1250 feet above sea level. Sutton Mountain rises to 3120 feet, and the depression to the south through which the Canadian Pacific railway runs has an elevation of about 500 feet near Mansonville station. The Missisquoi River at Richford, Vt. stands at 443 feet. St. Armand Pinnacle has an elevation of over 2500 feet (Dresser). The surface of Lake Memphremagog stands at 682 feet (Feb. 3, 1892) above sea level.

Character of the Surface of the Area.

In the valleys the surface of the bed rock is usually buried under a cover consisting of both modified and unmodified drift. In a number of localities small outcrops showing striated surfaces are known. The directions of the striations indicate that the general direction of the ice movement in the valley was controlled by the structural trends of the valley sides.

On the higher ridges even to the very summits a cover of drift materials, more or less mingled with recent debris from local sources, is found. The rock exposures are usually more numerous than in the valleys, and the striated surfaces indicate that the general direction of ice movement has been in a direction lying about thirty degrees to the east of south.

Special Localities.

Orford Mountain.—The Orford ridge reaches its highest elevation about twenty miles north of the International boundary in the mass usually called Orford Mountain. The highest point of the mountain is located on a rounded dome-like prominence near the southern end of the local ridge that constitutes the mountain. The summit of the dome is marked by a small nearly level area a little less than a quarter of an acre in extent. In detail this summit plain consists of low ridges of trap with rounded contours, the general trend of these local ridges being about S. 35° E. The hollows between these small ridges are filled with loose debris which contains a few fragments of the bed rock, but the greater portion of which consists of material foreign to the mountain. The small bare

rounded rock ridge which constitutes the very summit of the mountain rises about two feet above the surface of the soil cover which lies in the adjacent hollow to the east of it.   On the south side of the summit area one of the rounded ridges still shows small rounded hollows on its surface which are the markings Dresser referred to when he wrote of the occurrence of glacial striations on the summit of the mountain.   The
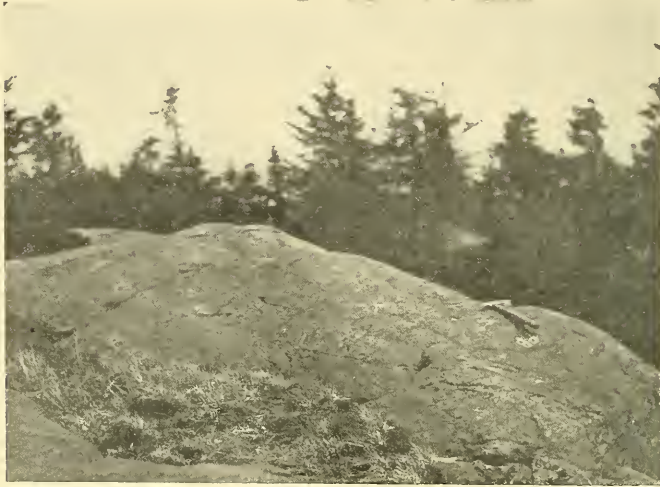
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Figure 2.   Summit of Orford Mountain, a small rounded dome with glacial scorings.

writer has examined these markings carefully, but could find no evidence to show that these furrows were produced by weathering processes acting on joint planes, as suggested by Chalmers.*   Indeed, of all the loose material occurring at the summit, only a very small percentage can be attributed to the local disintegration of the rock in situ.   The depth to which the decomposition due to weathering has visibly penetrated the exposed rock surfaces is very slight, except along fracture planes.   Microscopically all of the primary minerals are found to be much altered for a considerable depth, but the rock is not disintegrated.   The distribution of the effects of weathering is found to be fairly uniform, specimens from the base having practically the same appearance as those from the summit. On the west side of the summit dome, a few feet from the

* Ottawa Naturalist, vol. xix, p. 53.

locality where the striations were noted, is a furrow about
three feet in depth and of slightly greater breadth, partly filled
with loose debris at its southeast end. The form and shape
of the hollow suggest that a joint block was removed by the
ice and that the cavity was afterwards somewhat rounded out
by the corrasive action of the ice sheet.

The soil at the summit consists in part of a sandy material
containing many small chips and fragments of loose rock.
The writer made a collection of rounded, subangular, and
angular fragments derived from 12 different kinds of rock,
all of which were foreign to the summit of the mountain.
Among the fragments are pieces of schist from near the base,
and a number of small pieces of pink granite, gneisses of sev-
eral types, and vein quartz. Hitchcock also has recorded the
finding of a fifteen-pound bowlder of gneiss in the same local-
ity. The latter fragments are all unquestionably derived from
the rocks to the north of the St. Lawrence river. The greater
portion of the soil at the summit consists of a slightly arenace-
ous fine-textured grey clay which assumes a greyish-white
color on drying. A qualitative chemical and a microscopic
examination showed the presence of very small amounts of
iron salts and of carbonates. Quartz sand is present in con-
siderable amount, approximately 8 per cent, and the balance
consists chiefly of kaolin, with a small percentage of mica,
probably sericite.

A soil derived from the disintegration of the diabase of
which the summit of the mountain is composed would be
expected to contain much larger amounts of carbonates, would
show a very much larger percentage of iron salts, and would
normally be free from quartz. It is recognized that by the
process of leaching the excess of the carbonates and of the iron
salts might be removed in some cases, and that the quartz
might be formed by the decomposition of the silicates. In
this locality the soil is fine-textured close to the bed rock and
it is not found to gradually grade downward into the underly-
ing undecayed rock. It is also to be noted that this soil occurs
less than three feet vertically below and horizontally, within a
very few feet of the highest point of the mountain, and there-
fore it is not in a position favorable for the leaching action of
soil waters. On the other hand, not only is the soil similar to
that which is normally produced by the disintegration of the
Archean rocks to the north, but also when its character is con-
sidered in conjunction with the other features already de-
scribed, the cumulative evidence is such as to lead one to the
conclusion that this soil also is of exotic origin. Since it is
found to contain only a very small percentage of carbonates,
one would infer that the limestones in the plain to the north

between the mountain and the main Archean areas had contributed but a very small percentage of the material of this soil.

On the slopes of the mountain, between the summit and the 2000 foot contour, erratics are fairly plentiful. The soil in which the trees and bushes on the slopes of the mountain are growing is similar to that at the summit and consists almost wholly of glacial till.

In conclusion it may be said that not only on the slopes adjacent to the summit but at the very summit of the mountain

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FIGURE 3. Profile view of Owl's Head looking towards the northeast, showing the stoss and lee sides of the ridge.

itself are found practically all those data which are usually accepted by glacialists as evidence of ice transgression—till containing a large percentage of foreign material, erratics, and rounded and striated surfaces preserved on comparatively little decayed rock.

Other minor summits.—The Hog's Back and the Sugar Loaf mountains stand at a much lower level than Orford and were not specifically examined.

On Owl's Head at the summit rounded contours were observed on the northern and northwestern slopes, with a steep cliff face, presumably due to the plucking action of the ice, on the southeast [figure 4]. No striae were observed at the summit although the surface is well rounded, the curvature

being of the type that one would normally refer to the action of glacial ice even in the absence of striations, which would not be preserved on a rock surface where there was no protecting soil cap. In cracks and crevices at the summit there is an abundance of a sandy clay very similar to that found on Orford mountain. This soil contains numerous chips, many of which are of local origin. The summit rock is nearly bare except for the small amount of this soil found in the crevices and no large erratics were noticed. About twenty feet below

FIGURE 4. View showing the cliff face on the southeast side of the summit of Owl's Head.

the summit two pieces of vein quartz were picked up. On the slopes above the 2000 foot contour several small erratics were found in the soil cover, which consists largely of till.

Sutton Mountain.—The summit of Sutton Mountain, the highest ridge of the district, is heavily forested, and the surface of the ground is nearly all concealed beneath a moss carpet. Here and there the tops of minor ridges which cross the summit of the main ridge obliquely toward the southeast show rock outcrops. The soil appears to be much the same as on the other ridges of the district. At the summit the writer did not find any erratics, but this cannot be taken as conclusive that they do not occur within a few feet of it since they might easily be concealed by the vegetable growth of the area. A

number of erratics were found between 300 and 500 feet below the top.   These included several pieces of a coarse grit which was probably derived from a basal member of the Potsdam formation, fragments of schists from the valley to the northwest, and a fragment of a coarse pegmatitic granite.   At 300 feet below the summit a large bowlder of Laurdalite from Brome Mountain, 14 miles to the northwest, was found. Several similar pieces were picked up below this contour.

The most interesting feature of Sutton Mountain, however, is the occurrence of a series of remarkably well developed V-shaped notches which cross the summit of the main ridge in
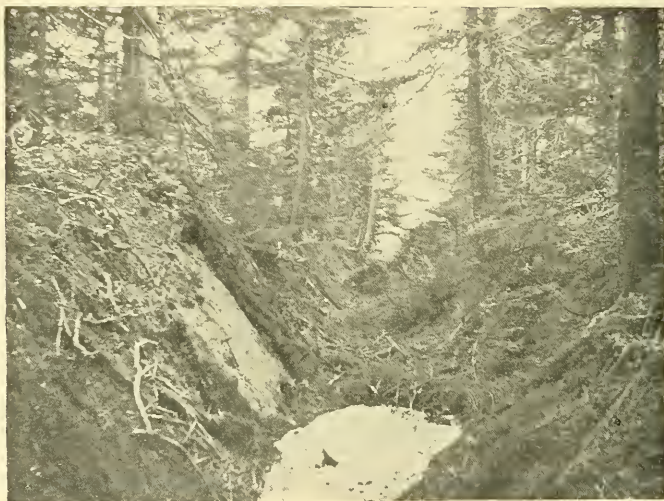
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FIGURE 5.   Summit of Sutton Mountain.   A V-notch ten feet in depth with smooth sides, cut in gneiss, looking northwest.

a direction about S. 25 E.   The sides of these small notches are planed off very smoothly, the west sides being the smoother of the two, in each case examined.   The depth of these notches varies from four to about ten feet.   The west side of one had a dip of 50° and the east side of the same notch was only a little less steep.   This notch, whose form may be taken as typical of the form of all of them, was about ten feet deep and the ridges between it and the adjacent notches on either side had sharp crests as well defined as the ridge of the roof of a house.   On the striated sides of these notches the large quartz masses in the gneiss were found planed off even with the rest of the surface.   In all, twelve of these remarkable gullies were

noted and it is possible that others also occur along the crest of the mountain. They seem to owe their origin primarily to a system of joint fractures which loosened the blocks that once occupied the hollows. The smooth, even, striated sides are to be attributed to ice scouring.

Many of these small gullies cross the summit of the ridge and open out on each side over very steep cliffs. They constitute, in fact, very perfectly developed hanging valleys, but of a most unusual type in those instances where the hollow goes completely across the summit ridge.

St. Armand Pinnacle.—At St. Armand Pinnacle, on the lower slopes of the mountain, the writer has observed smoothed and striated surfaces on the bed rock. At the summit Mr. Dresser has noted similar striae trending to the east of south. A profile view of the peak from the west shows a gently ascending slope on the north side and a well developed cliffed face to the south—the latter presumably a plucked face.

Summary and Conclusions.

In conclusion it may be stated that not only in the depressions in this area, but also on all the important summits of the district, distinct and unmistakeable evidence of glacial transgression have been found. The cumulative character of this evidence has already been referred to, and one seems justified in concluding, with Mr. Dresser and Professor Hitchcock, that the height to which the ice sheet reached in this portion of eastern Canada is as yet an undetermined quantity.

Department of Geology, McGill University, Montreal.

Art. XIV.—*On the Drawing of Crystals from Stereographic
and Gnomonic Projections;* by S. L. Penfield.

In a previous communication by the present writer,* some
methods for drawing crystal forms from a stereographic pro-
jection were described, and, after the publication of the paper,
there was observed in a recent volume by Professor C. Viola
of Rome,† a method, based upon different principles, which
is so simple and ingenious that it seems wise to give a brief
description of it, for the benefit of those readers of this journal
who may be interested in the subject: this paper may also
serve as a supplement to the writer's earlier article, referred to
above.

In explaining the method, a general example has been
chosen; the construction of a drawing of a crystal of axinite,
of the triclinic system. Figure 1 represents a stereographic
projection of the ordinary forms of axinite, *m* (110), *a* (100),
M (1$\bar{1}$0), *p* (111), *r* (1$\bar{1}$1) and *s* (201). As shown by the figure,
the *first meridian*, locating the position of 010, has been
chosen at 20° from the horizontal direction *SS'*: This is wholly
arbitrary, but it makes a good starting point for the con-
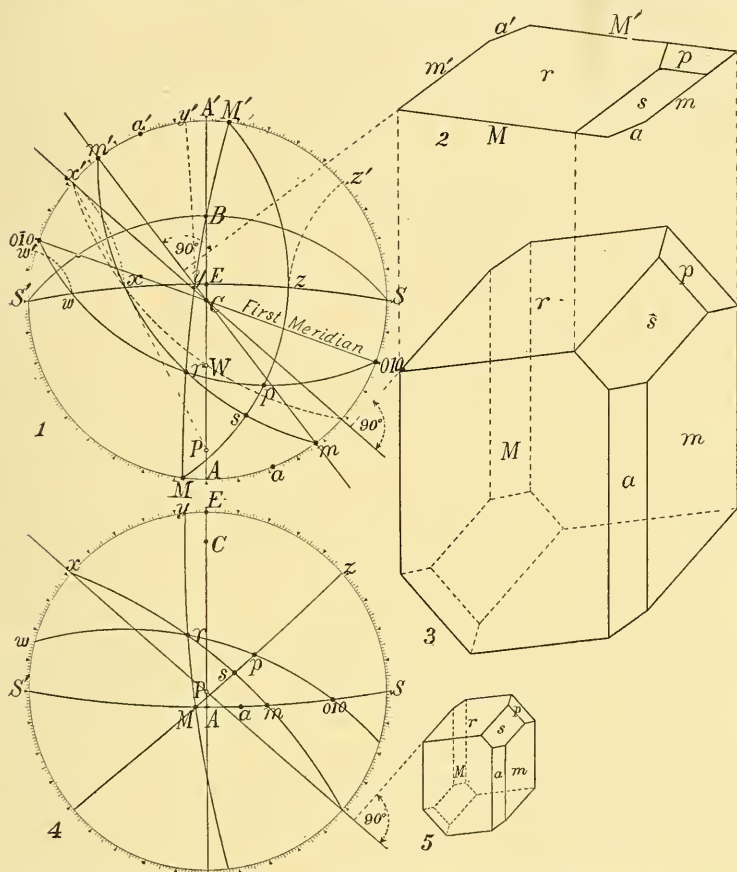struction of a stereographic projection.

Figure 2 is a *plan*, or an orthographic projection of an axi-
nite crystal, as it appears when looked at in the direction of
the vertical axis. It may be derived from the stereographic
projection in a simple manner, as follows:—The direction of
the parallel edges made by the intersections of the faces in the
zone *m*, *s*, *r*, *m'*, figure 1, is parallel to a tangent at either *m*
or *m'*, and this direction may be had most easily by laying a
straight edge from *m* to *m'* and, by means of a 90° triangle,
transposing the direction to figure 2, as shown by the construc-
tion.

The construction of figure 3, which is called by Viola a
parallel-perspective view, may next be explained: It is not a
clinographic projection like the usual crystal drawings from
axes, but an orthographic projection, made on a plane inter-
secting the sphere, represented by the stereographic projection,
figure 1, along the great circle *SES'*; the distance *EC* being
10°. The plane on which a drawing is to be made may, of
course, have any desired inclination or position, but by making
the distance *CE* equal 10° and taking the first meridian at 20°
from *S*, almost the same effects of plan and parallel-perspec-
tive are produced as in the conventional method of drawing
from axes, where the eye is raised 9° 28' and the crystal turned

* This Journal (4), xix, p. 39, 1905.
† Grundzüge der Krystallographie, p. 29, W. Engelmañ̃, Leipzig, 1904.

18° 26′*; in fact, even when drawn on quite a large scale, the plan and parallel-perspective views, figures 2 and 3, are so nearly identical with corresponding figures of axinite, page 73 of the writer's earlier paper just referred to, that the eye can

FIGURES 1 to 5.   Development of a plan and parallel-perspective figure of axinite, triclinic system, from a stereographic projection.

scarcely detect any difference between them, even when placed one above the other.

The easiest way to explain the construction of figure 3 from figure 1 is to imagine the sphere, represented by the stereographic projection, as revolved 80° about an axis joining S and S', or until the great circle SES' becomes horizontal. After such a revolution, the stereographic projection shown

* This Journal (4), xix, p. 40, 1905.

in figure 1 would appear as in figure 4, and the parallel-perspective drawing, figure 5, could then be derived from figure 4 in exactly the same manner as figure 2 was derived from figure 1. This is, for example, because the great circle through m, s and r, figure 4, intersects the graduated circle at x, where the pole of a vertical plane in the same zone would fall, provided one (artificially constructed or otherwise) were present; hence the intersection of such a surface with the horizontal plane, and, consequently, the direction of the edges of the zone, would be parallel to a tangent at x: In other words, figure 5 is a *plan* of a crystal in the position represented by the stereographic projection, figure 4. Although not a difficult matter to transpose the poles of a stereographic projection so as to derive figure 4 from figure 1, it takes both time and skill to do the work with accuracy, and it is not at all necessary to go through the operation. To find the direction of the edges of any zone in figure 3, for example m s r, note first in figure 1 the point x, where the great circles m s r and SES' cross. During the supposed revolution of 80° about the axis SS', the pole x follows the arc of a small circle and falls finally at x' (the same position as x of figure 4) and a line at right angles to a diameter through x', as shown by the construction, is the desired direction for figure 3. Similarly for the zones pr, MrM' and $MspM'$, their intersections with SES' at w, y and z are transposed by the revolution of 80° to w', y' and z'. The transposition of the poles w, x, y and z, figure 1, to w', x', y' and z' may easily be accomplished in the following ways:— (1) By means of the transparent, small-circle protractor described by the writer,[*] the distances of w, x, y and z from either S or S' may be determined and the corresponding number of degrees counted off on the graduated circle. (2) Find first the pole P of the great circle SES', where P is 90° from E or 80° from C, and is located by means of a stereographic scale or protractor: A straight line drawn through P and x will so intersect the graduated circle at x', that $S'x$ and $S'x'$ are equal in degrees. The reason for this is not easily comprehended from figure 1, but if it is imagined that the projection is revolved 90° about an axis AA', so as to bring S' at the center, the important poles and great circles to be considered will appear as in figure 6, where P and C'' are the poles, respectively, of the great circles $ES'E'$ and $AS'A'$, and x is $41\frac{1}{4}°$ from S' as in figure 1. It is evident from the symmetry of figure 6 that a plane surface touching at C', P and x will so intersect the great circle $AS'A'$ that the distances $S'x$ and $S'x'$ are equal. Now a plane passing through C'', P, x and x', if extended, would intersect the sphere as a

* This Journal (4), xi, p. 17, plate I, 1901.

small circle, shown in the figure, but since this circle passes through C', which in figure 1 is the pole of the stereographic projection (antipodal to C), it follows that it will be projected in figure 1 as a straight line, drawn through P and x.[*] (3) In figure 6, B is located midway between E and A', $BS'B'$ is a great circle, and W, 40° from C, is its pole: It is now evident from the symmetry of the figure that a great circle through W and x so intersects the great circle $AS'A'$, that the

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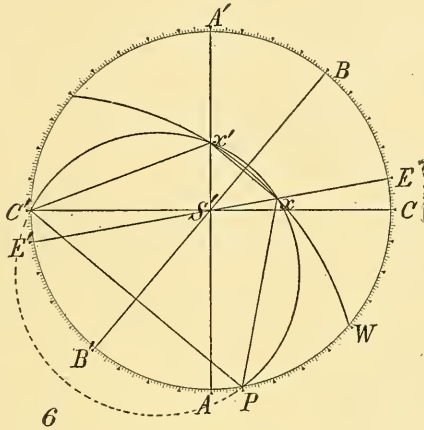
distances $S'x$ and $S'x'$ are equal. Transferring the foregoing relations to figure 1, W, 40° from C, is the pole of the great circle SBS', and a great circle drawn through W and x falls at x'. However, it is not necessary to draw the great circle through W and x to locate the point x' on the graduated circle: By centering the great circle protractor, described by the writer,[†] at C, and turning it so that W and x fall on the same great circle, the point x may be transposed to x', and other points, w', y' and z', would be found in like manner.

The three foregoing methods of transposing x to x', z to z', etc., are about equally simple, and it may be pointed out that, supplied with transparent stereographic protractors, and having the poles of a crystal plotted in stereographic projection, it is only necessary to draw the great circle SES' and to locate one point, either W or P, in order to find the directions needed for a parallel-perspective drawing, corresponding to figure 3. Thus, with only a great circle protractor, the great circle through the poles of any zone may be traced, and its intersection with SES' noted and spaced off with dividers

from either S or S'; then the great circle through the intersection just found and W is determined, and where it falls on the divided circle noted, when the desired direction may be had by means of a straight edge and 90° triangle, as already explained.

The gnomonic projection is preferred by many for representing crystallographic relations, and it seems best, therefore, to indicate how readily the methods just explained may be adapted to this kind of projection. This subject has received careful treatment from Goldschmidt[*] and G. F. H. Smith,[†] hence what follows might seem somewhat superfluous; but although the final results of the crystal drawings are essentially the same as those of the authors just mentioned, the presentation and explanations here given are somewhat different, and it is hoped that some of the suggestions may be of service to students of crystallography.

As an illustration, the method of drawing a simple combination of barite has been chosen. The forms shown in figures 7, 8 and 9 are c (001), m (110), o (011) and d (102). The location of the poles in the gnomonic projection is shown in figure 7, where, as in figure 1, the *first meridian* is taken at 20° from the horizontal direction SS'. A simple method for locating the poles o and d on their respective meridians is by means of the stereographic scale No. 3, described by the writer,[‡] by laying off with this scale double the angle $c \wedge o$ and $c \wedge d$; for both stereographic and gnomonic scales are derived from a table of natural tangents, 2° of the former being equal to 1° of the latter. The poles of the prism m and the locations of S and S' (compare figure 1) fall in the gnomonic projection at infinity. In any plan, such as figure 8, the direction of an edge made by the meeting of two faces is at right angles to a line joining the poles of the faces, shown in figures 7 and 8 by the direction at 90° to the line joining m'' and c.

The parallel-perspective view, figure 9, is an orthographic projection (compare figures 1 and 3) drawn on a plane passing through S and S', and intersecting the sphere on which the gnomonic projection is based as a great circle,[§] passing through E, figure 7, and drawn parallel to SS', the distance cE being 10°. This great circle is called by Goldschmidt the *Leitlinie*. To find such intersections as between m''' and c, and m and d, figure 9, note, as in figure 1, where the great circles through the poles of the faces intersect the *Leitlinie*; thus, the one

    * Zeitschr. Kryst., xix, p. 352, 1891.
    † Min. Mag., xiii, p. 309, 1903.
    ‡ This Journal (4), xi, p. 7, 1901.
    § All great circles in the gnomonic projection are represented by straight lines.

through m''' and c at x, and that through m and d (through d parallel to $m\, m''$, since m and m'' are at infinity) at y. Next imagine the points x and y transposed as in figure 1 to x' and y', which latter points, however, are located at infinity: This transposition is done by locating first the so-called *Winkel-punkt*, W, of Goldschmidt, 40° from c in figure 7, and as in figure 1, 90° from a point B, which is an equal number of
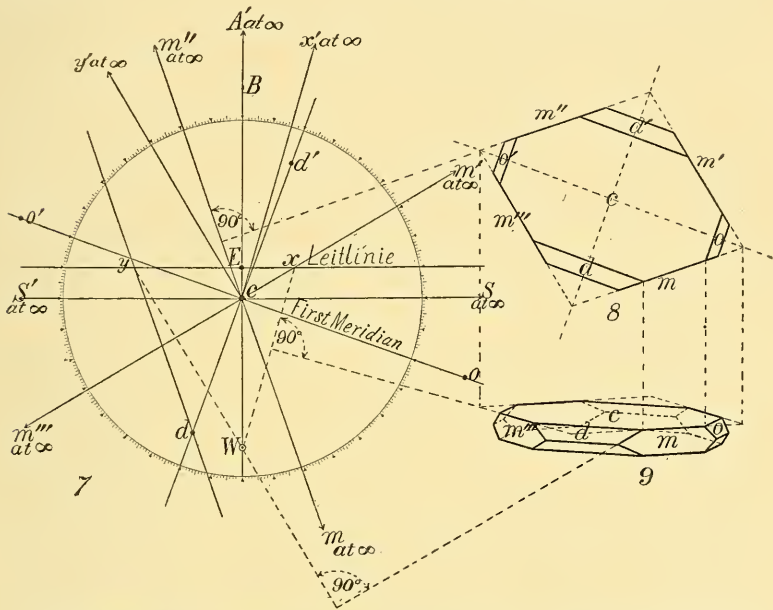
FIGURES 7 to 9.   Development of a plan and parallel-perspective figure of barite, orthorhombic system, from a gnomonic projection.

degrees from E and A' (compare figure 6). Of the three methods given on pages 208 and 209 for transposing x and y to x' and y', the third may be easily applied in the gnomonic projection. Great circles, or straight lines, through W and x and W and y, figure 7, if continued to infinity, would determine x' and y', which is accomplished by drawing lines parallel to Wx and Wy through the center. It is not necessary, however, to draw the lines Wx and Wy, nor the parallel lines through the center; all that is needed to find the directions of the edges $m''' \wedge c$ and $m \wedge d$ is to lay a straight edge from W to x, respectively W to y, and with a 90° triangle transpose the directions to figure 9, as indicated in the drawings. The principles are exactly the same as worked out for the interrelations of figures 1 and 3. As in the case of the stereographic projection, it is

evident that, given the poles of a crystal plotted in the gnomonic projection, it would be necessary to draw only one line, the *Leitlinie*, and to locate one point, the *Winkelpunkt*, *W*, in order to find all possible directions for a plan and parallel-perspective views, corresponding to figures 8 and 9.
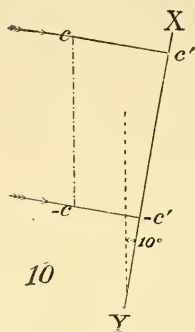
In any parallel-perspective drawing cor responding to figures 3 and 9, it is impor-tant to keep in mind that, since the projec-tion is orthographic and made on an inclined surface, there will be some fore-shortening of vertical lengths. Thus, if one has in mind a certain height of a crystal, or the length of a vertical axis $c,-c$, figure 10, and if XY is the trace of the plane on which the projection is made, the length $c,-c$ would become fore-shortened to $c',-c'$.[*] The fore-shortening is best done graphically, or it would be the length $c,-c$ times the sine of $10°$, provided E, as in figures 1 and 7, is $10°$ from the center.

The methods of drawing, as developed in the foregoing pages, have been such as to yield parallel-perspective figures essentially like the conventional ones found in treatises on crystallography and mineralogy; but, as already stated, the plane on which a drawing is to be made may have any desired position, and it may not be out of place to indicate briefly, by an example, how easily the methods may be modified to suit varying requirements. Figure 11 represents a stereographic projection of augite, the forms being *a, b, m* and *s* ($\bar{1}11$), and it is desired to draw a parallel-perspective on a plane parallel to the pyramid face *s*, $\bar{1}11$. Through *s* draw a diameter, and on it locate *E*, 90° from *s*; then draw the great circle *SES'*: Under the conditions, the pole corresponding to *P* of figure 1 is *s* in figure 11. In the parallel-perspective, figure 12, such directions as the edges $a' \wedge s$ and $m'' \wedge s'$ are found by noting in figure 11 where the great circles a' *s* and m'' *s'* cross SES' (at *x* and *y*) and then following out the construction indicated by the figure, as previously explained.

In figure 12, the plane angles of *s* are the same as those of an actual crystal, and the angles, or their supplements, may always be measured on the great circle *SES'* of the stereo-graphic projection. To measure the angle made by the edges $a's$ and $m's$, figure 12, the great circles through the poles, figure 11, are at right angles, respectively, to the two edges, and their intersections with *SES'* are at *x* and *w*, hence the angular distance *x* to *w*, measured with a stereographic pro-tractor as 47°, is the supplement of the desired angle, or 133°.

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[*] Compare figure 5, page 41 ; this Journal (4), xix, 1905.

Certainly the methods of getting both a plan and a parallel-perspective from either a stereographic or gnomonic projection appeal strongly to one at first, both because of their simplicity and the doing away with the multiplicity of construction lines which frequently are needed in drawing from axes. To convince himself of the relative advantages of the different methods of drawing crystals, the writer has taken special pains to experiment with those explained in this paper, and it is his belief that most persons, especially beginners, will find it easier to draw from axes, while at the same time finished
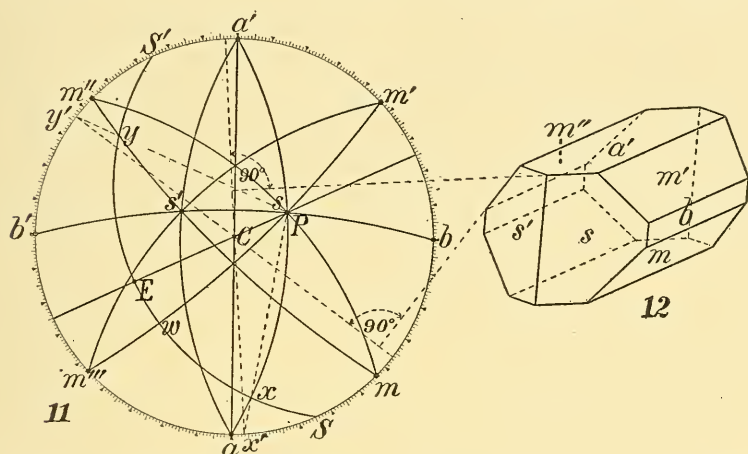
FIGURES 11 and 12. Development of a parallel-perspective of augite, drawn on a plane parallel to *s*, $\bar{1}11$.

drawings will in most cases be completed more quickly and, probably, with greater accuracy. It certainly would seem as though with the axes constantly before one, they must be of value to a student in developing the symmetry of a crystal figure during the process of drawing. When it comes to a complicated problem, such as one in the triclinic system, it may be questioned whether it is easier to incline the axes and draw from them, or to make either a stereographic or gnomonic projection and draw from it: The determination of such a question would depend somewhat upon the data at hand, and largely upon one's familiarity or facility with either the one or the other method. Certainly, as is often the case, having made either a stereographic or gnomonic projection for the purpose of study, it would be easier to draw from the projection than to plot the inclined axes and draw from them. Every one who is at all interested in crystal drawing would do well to become familiar with the methods based on the use of

the stereographic and gnomonic projections, for they may be employed to advantage when drawing from axes becomes difficult or impossible. For example, in some twin crystals, when drawing from axes, serious difficulties are at times encountered in finding the intersections of interpenetrating surfaces; difficulties readily overcome, however, by drawing from the projections, if the poles of the twin crystal have been plotted; or again, the projections may be employed in drawing some odd shape or some obscure crystal, the planes of which cannot be referred to axes.

To any one desiring to make much use of the methods of drawing from either of the two projections, it is recommended to employ a T-square and, in connection with it, special triangles, figure 13, similar to those previously described by the writer*, as follows :—The drawing paper is fastened to a board so that a T-square gives the direction SS', figures 1 and 7. A 20°, 90° triangle, *I*, gives the direction of the first meridian of the two projections, and, in any plan, the direction of the front-to-back, or $a, -a$ axis, and, triclinic system excepted, the right-to-left, or $b, -b$ axis. A 90°, 25° 30′ triangle, *II*, is used
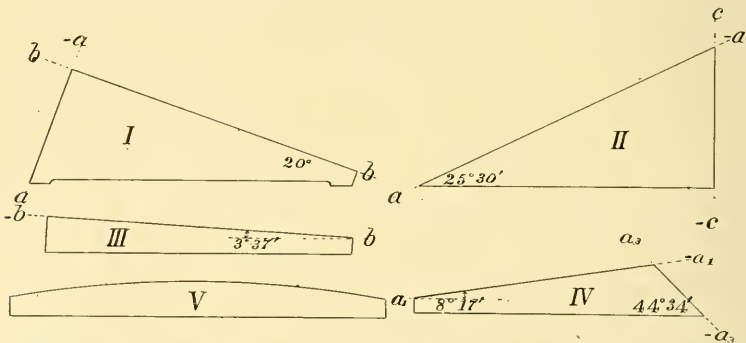

FIGURE 13. Special triangles to be used in connection with a T-square when drawing from the stereographic or gnomonic projections.

for uniting corresponding points of plan and parallel-perspective figures, parallel to the $c, -c$ axis, and it also gives the front-to-back or $a, -a$ axis in any parallel-perspective figure, when the axis is 90° to the vertical. A truncated 3° 37′ triangle, *III*, gives the direction of the right-to-left or $b, -b$ axis of parallel-perspective figures, provided the system is not triclinic. An 8° 17′, 44° 34′ triangle, *IV*, gives the directions of two of the horizontal axes in the hexagonal system, triangle *III* giving the third. Lastly, a circular arc, *V*, is used for

* This Journal (4), xix, p. 53, 1905.

drawing the great circle *SES'*, figure 1. The angles of the triangles, figure 13, are based upon the data chosen for constructing figures 1 and 7 ; namely, the first meridian 20° from *S*, and *E* 10° from the center of the projections: For any desired variation from these data the angles could be calculated readily. The writer has found triangles made from heavy bristol-board in every respect serviceable for pencil work, and if cut, for example, as shown in figure 13–*I*, so that only two extremities of the base line touch the T-square, they may first be made approximately right and then accurately adjusted by taking off a little from one end or the other by rubbing against sandpaper. Referring to figure 8 ; having determined the direction $c \wedge m'''$, and knowing the orthorhombic symmetry of the crystal, the remaining lines could all be determined by means of triangle *I*. From figure 8 ; and by use of the triangles *II* and *III*, figure 9 could be constructed by finding only one direction, for example, $d \wedge m$. The triangles thus serve as time-savers to any one engaged in this kind of crystal drawing, and likewise insure increased accuracy in the work.

Art. XV.—*A Suggested Cause of Changes of Level in the Earth's Crust;* by Rev. O. Fisher, M.A., F.G.S., Cambridge, England; Author of the "Physics of the Earth's Crust."

Dr. Spencer in America,[*] and Prof. Hull in England,[†] have for some years past been drawing the attention of geologists to the great changes in the relative levels of land and ocean on both sides of the Atlantic, evidenced by the drowned plains bordering the continents intersected by deep canyons, which are the now submerged continuations of existing river channels. These changes of relative levels amount frequently to a mile or more.

Great changes of level are among the rudiments of the grammar of Geology. But the recency of those described, viz. Pliocene or early Pleistocene times, is remarkable.

It rests with those who believe that the earth is solid to explain these phenomena on that hypothesis. But for those geologists who think that a liquid substratum of unknown depth underlies the cooled crust, the following explanation appears plausible.

It being granted that the earth is a cooling body, if the cooling takes place in a liquid which expands by heat it will do so by convection currents. Hence convection currents must exist in the substratum. The action of such currents has not yet been brought under the dominion of mathematical methods, but the general principle of their action appears to be as follows: Suppose a mass of liquid consisting of parallel layers increasing in temperature with the depth. It would be in unstable equilibrium, and that state could not continue; somewhere a column of the fluid would begin to ascend, and to flow away horizontally at the surface. The waste in the lower parts of the ascending column would be supplied by the inflow of the surrounding liquid, which would depress the isotherms in it, and the whole of the region affected would become cooler. But momentum will have been gained in the

* Reconstruction of the Antillean Continent, Bull. Geol. Soc. America, vol. v, p. 103, 1895. Great Changes of Level in Mexico, Bull. Geol. Soc. Amer. vol. ix, p. 13, 1898. Submarine Valleys off Amer. Coast and in the North Atlantic, Ib. vol. xiv, p. 207, 1903. The Submarine Great Cañon of the Hudson River, this Journal, vol. xix, p. 1. 1905. Physiographic Improbability of Land at the North Pole and Bibliography of Submarine Valleys of North Amer., Ib. p. 333, 1905. Reply to Mr. Huddleston, Geol. Mag., vol. xi, p. 559, 1899.

† Submerged Terraces and River Valleys bordering the British Isles, Trans. Victoria Institute 1897-8; also Geol. Mag., vol. x, p. 351, 1898. The Submerged Platform of Western Europe. Geol. Mag., p. 478, 1898. Suboceanic Physical Features, Geol. Mag., vol. vi, p. 132, 1899.

column and in the whole region affected, which will carry on the movement until any given level in it contains liquid cooler, and therefore more dense, than the average of the general mass at the same level. Gravity and friction will gradually arrest the motion, and, on account of the greater density, the liquid in the region affected will begin to descend. The cooling process will in the meanwhile be taken up by an ascending column elsewhere. If we had begun the cycle with a descending current, the reasoning and final result would have been similar.

The surface of the liquid above an ascending column will be somewhat elevated, and above a descending one depressed; thus the whole mass of liquid will experience the alternate elevation and depression of regions of its surface, and if there were a cooled crust floating upon it, in areas sufficiently wide to compensate for the rigidity, it would partake in the changes of level of the surface of the substratum.

If a limited coastal region were elevated the change of level would be local and merely confined to that region,—the effect on the actual sea level being small. But if the region of the sea bottom were depressed the level of the surface would be everywhere lowered, and the coastal regions all over the globe would apparently be raised; and vice versa. The phenomena seem to point to this depression or elevation of extensive regions of the sea bottom as being the cause of the simultaneous recession from or approach to the coasts of the sea margins.

There appears to me no possible way of accounting for the change of level indicated, unless upon the hypothesis of a liquid substratum beneath the cooled crust. I am pleased to notice that Dr. Nansen seems to approve of this theory. Accepting this view, we get the important consequence of isostacy which seems to have been confirmed by observations, and on that theory I have explained the anomalies of the deflection of the plumb line in India, in a paper which the Superintendent of the trigonometrical surveys has thought worthy of being printed as an appendix to a future report.

Thus we have a suggestion offered for the cause of the changes of level of the earth's surface, which appears worthy of consideration as a working hypothesis. If the substratum is liquid, this kind of movement must necessarily take place in it; but whether it would be quantitatively competent to produce the observed phenomena cannot easily be decided. That would apparently depend chiefly upon the depth of the liquid involved in the process.

The amount of the elevation or depression of the surface of the lithosphere, whether continental or suboceanic, would be approximately measureable from the sea surface. And if an area partly continental and partly oceanic were affected,

that is one including a coast line, the whole change of level would be indicated on the coast line, although there might be no change in the relative levels of the land and the sea bottom.

By a somewhat complicated mathematical investigation,* I believe that I have proved that if the continents contain extensive areas nearly at the sea level, as is the case at the present day, the substratum beneath these areas must be more dense than the average beneath the oceans ; and that consequently descending currents may be expected to be now in progress beneath those low-land areas ; and on the whole, ascending currents beneath the oceans, the suboceanic crust of which may be partly supported by the upward currents pressing against it ; and in that case it would rise or fall in accordance with the play of the currents. The present general low level of the land areas may probably be exceptional, being the final and temporarily stationary stage of a period of depression. Unfortunately my mathematical method does not lend itself to the comparison of densities in the case of a land area raised above the sea level ; but it seems reasonable to expect that in such a case there would be a reversal of the direction of the convection currents. Thus where land areas can be proved to have existed formerly, where the ocean now rolls, it seems probable that a change in the direction of the currents in the substratum from up to down may be the cause of their subsidence.

I would therefore hazard the suggestion that the apparent elevation or depression of the continents, which I gather from the recent papers mentioned probably takes place simultaneously over the whole globe, are caused by the fall or rise of areas of the sea bottom through the play of convection currents. I conclude that during the periods of land elevation there have been no extensive tracks of low land near sea level, but that entire continents have stood higher ; as favored by Nansen and lately considered by Spencer ;—unless this is the case, I do not think my suggestion will hold, because the assumption on which I prove the substratum in the ocean to be less dense than that of the land is, that the continental area is at present on the average not much raised above the sea level. If it were much raised I think the lesser density would not appear as the result of the calculation.

If instead of beneath the ocean an upward convection current were to occur beneath the continent, the change of level would be local and would affect the superincumbent area only. This would cause the kind of uplift which is found in plateau regions without much crumpling of the strata.

* Proceedings Cambridge Phil. Soc., xiii, Part II, p. 106, 1905.

The investigations of Dr. Spencer, Prof. Hull, and Dr. Nansen* have introduced to us the knowledge of much more recent great change of level than I think had previously been suspected. This circumstance seems to favor the explanation now suggested, because the cyclical changes in convection currents in the substratum beneath the crust might be expected to recur at frequent intervals.

Addendum to a Suggested Cause of Changes of Level in the Earth's Crust, Jan. 3, 1906.

Since forwarding the above I have received an important paper by Lieut.-Colonel Burrard, R.E., F.R.S., Superintendent of the Trigonometrical Surveys of India, " on the intensity and direction of the force of gravity in India,"† in which I meet with a statement that appears of much interest in connection with my suggestion about convection currents in the substratum of the earth's crust.

" Between 1865 and 1873 observations were taken at 31 stations in India by Captains Basevi and Heaviside, with the Royal Society's seconds pendulum." In 1903–4 renewed observations were taken by Major Lenox Conyngham with a half second pendulum. " His first station was Dehra Dun. His results there were astonishing, for they show that Basevi's value was no less than 0·103 centimeters too small." [Note] " This extraordinary difference could only mean that Basevi's final value of N [the number of vibrations in 24 hours] was too small by four whole seconds of time. Basevi's observations at Dehra Dun lasted five months, and included 234 independent swings, taken at pressures varying from half an inch to 28 inches, and at temperatures varying from 48° to 102° Fahr.

" The force of gravity as observed by

	Basevi and Heaviside 1865–73. cms.	Lenox Conyngham. 1904. cms.	Difference. cms.
Dehra Dun	978·962	979·065	+ 0·103
Madras	978·237	978·281	+ 0·044
Bombay	978·605	978·632	+ 0·027
Mupooner	978·751	978·795	+ 0·044 "

Colonel Burrard remarks that these differences are not affected by any constant quantity, and that, " Basevi's and Heaviside's observations were taken with a care that it is difficult for us to equal." " The only faults which have been

* Bathymetric Features of the North Polar Sea, with a Discussion of the Continental Shelves and previous Oscillations of the Shore Line (Christiana 1904).
† Phil. Trans. Royal Soc., Series A, vol. ccv, 1905.

found with their work are such as would tend to produce constant error." Is it not possible that the large difference in the force of gravity at Dehra Dun may be to some extent due to a *real* change of density beneath that station in the interval of between thirty and forty years? We know that during 1905 a severe earthquake was experienced at Dehra Dun; and the stress which caused it must have been accumulating since Basevi's time. May not that process have been accompanied by a gradual change of density which Conyngham's observations revealed in progress?

Taking the mean force of gravity to be 978 centimeters, a change of density amounting to $1\frac{1}{2}$ per cent in a depth of 50 miles in the underlying magma at Dehra Dun would have been quite sufficient to cause the whole of the observed difference in gravity, supposing the higher density of the two to be 3.

It seems, therefore, that if this change of gravity at Dehra Dun cannot be accounted for by errors of observation, it amounts to a proof that changes of density, and therefore movements, have taken place in the substratum of the earth's crust in sub-Himalayan regions within the last thirty years.

Art XVI.—*North American Plesiosaurs: Elasmosaurus, Cimoliasaurus, and Polycotylus;* by S. W. Williston. (With Plates I–IV.)

During the past two years I have had the opportunity of studying nearly all the specimens of plesiosaurs preserved in the American museums, a study undertaken in the preparation of a monographic revision of the American forms, and, it is hoped, of the genera of the world also. The accumulation, however, of material recently has made the completion of the task a more arduous one than was at first suspected. I have therefore determined to publish from time to time the more important results obtained, with the hope eventually of gathering the whole together in a final monographic revision. Furthermore, I am convinced that specimens of this order of reptiles are not as rare in America as has been believed, and hope to continue field search until the more important characters of the group have been established. I have already said, and I repeat, that the taxonomy of the plesiosaurs is very perplexing; I doubt if that of any other order of reptiles is more so, chiefly because of the fragmentary nature of much of the known material.

I desire in this place to express my sincerest thanks to those gentlemen who have generously aided me by the communication of material under their charge, and in particular to Dr. Witmer Stone of the Philadelphia Academy of Sciences, Professor Henry F. Osborn of the American Museum of New York City, President Slocum and Professor Cragin of Colorado College, and to my old friend, Mr. William H. Reed, curator of paleontology of the University of Wyoming. I am especially grateful for the generosity with which Professor Charles Schuchert, the curator of the Geological Department of the Yale Museum, has placed freely at my disposal the rich collections of that museum, collections which I had, for the most part, assisted in making a good many years ago; and to which were added many useful notes made by the late Professors Marsh and Baur, and by myself while an assistant in that museum twenty years or more ago. Professor Marsh had begun, before his death, the critical study of the plesiosaur material of the Yale Museum, and had had much of it prepared and some illustrations made. All of this has been placed at my disposal. Professor Marsh had not definitely determined any of his species, and had only tentatively located some of them in genera, aside from the Jurassic species described by him as *Pantosaurus striatus.* Most of the observa-

tions of his notes have been anticipated by myself or others; others new to me I shall fully acknowledge in each case. The present paper will deal chiefly with this material, that especially belonging to the genus *Elasmosaurus*. Other material in the collection will be discussed in later papers, so far as the more important characters are concerned.

Cimoliasaurus.

The genus *Cimoliasaurus* has been, and yet is, poorly understood. Lydekker subordinated a dozen or more generic names as synonyms, some of which have been accepted as such by later writers. Professor Marsh was inclined, as his notes show, to accept the name *Cimoliasaurus* in lieu of *Elasmosaurus* for the species now in the Yale Museum. A brief review, therefore, of the real characters of that genus, as interpreted by the light of considerable material, will not be out of place here.

The type of the genus and species *Cimoliasaurus magnus* Leidy is a number of dorsal and cervical vertebræ from Monmouth county, New Jersey, probably from rocks of an epoch corresponding with the Fort Pierre Cretaceous, and they have been, for the most part, well figured by Leidy in his "Cretaceous Reptiles." With the original specimens he later associated a series of fourteen vertebræ, or rather centra of vertebræ, from the same locality, and he speaks of such bones being common in the deposits of New Jersey. Leidy, however, sadly misinterpreted the positions of his centra in the vertebral column, nor was Cope much more correct in his interpretation of them. I would interpret figures 13–15 of Plate V of the above-mentioned work as of a posterior cervical centrum; figure 16, a more posterior cervical or early pectoral; figures 17–19, a median or postero-median cervical. Figures 1–3 of Plate VI represent a dorsal centrum; figure 4 is of an anterior dorsal, as is also figure 5; figures 6 and 7 are of a posterior cervical; 8–15, of median cervicals; 16–19, of an anterior cervical.

Leidy's description of the genus *Discosaurus* appeared on the page following that of *Cimoliasaurus*, and was based upon two caudal vertebræ from the Cretaceous of New Jersey (Plate V, figures 1–3) and an anterior caudal vertebra from the same region. Other vertebræ from the Cretaceous of Mississippi (figures 10, 11) he afterwards separated as the type of a distinct species, and was probably correct in so doing. Cope long ago showed the similitude of these vertebræ to those of *Cimoliasaurus* and made the name *Discosaurus* a synonym, in which Leidy acquiesced.

We may therefore assume that all these vertebræ, save those from Mississippi, pertain not only to *Cimoliasaurus*, but to

the type species as well; from which certain definite generic characters are evident. Cope erred in most of the distinctive characters that he assigned to the genus *Elasmosaurus*, but was correct in an important one,—the length of the neck. We shall see that in all the known species assigned to *Elasmosaurus*, of which this part of the skeleton is known, the neck is very long, and that all of its vertebræ, save the most posterior ones, are longer than broad. *Cimoliasaurus* is, therefore, a relatively short-necked plesiosaur, though not so short as in the genus *Polycotylus*. Nothing is known of the pectoral girdle or of the skull of *Cimoliasaurus*, and more decisive characters may be,—I believe will be, forthcoming when these parts of the type species are known. Unfortunately, here as among the mosasaurids, it may be a long time before the subject is cleared up finally. I am, however, firmly of the opinion that the two genera are distinct, and therefore object to the indiscriminate use of *Cimoliasaurus* in the way that it has been used, both in this country and in Europe.

While we may assume the distinction between *Cimoliasaurus* and *Elasmosaurus*, we can by no means do so for the genus *Brimosaurus*, described long ago by Leidy from a dorsal vertebra from the Cretaceous, probably Benton, of Clark county, Arkansas. I believe that this genus will comprise species now located under *Elasmosaurus*, and possibly, if not probably, the type species of that genus. For the present, however, we do know pretty nearly what *Elasmosaurus* is, and I shall therefore use this name as the designation of at least ten species of the genus known to me, so far as they can be distinguished by true generic characters. I should perhaps except one of the species described below, *Elasmosaurus (?) marshii*, because I am of the opinion that it will eventually be necessary to locate it elsewhere. Indeed I should do this now, did I not feel doubtful of its relationships to some other, as yet poorly distinguished genera.

Elasmosaurus.

The type species of *Elasmosaurus* was founded by the late Professor Cope, and based upon a specimen ascribed to the Niobrara Cretaceous of western Kansas, in the vicinity of old Fort Wallace. From the locality given for the type specimen I long ago concluded that its horizon was really basal Fort Pierre Cretaceous, and not Niobrara; and an examination of the type specimen, now in the Academy of Natural Sciences of Philadelphia, to which much of the original matrix yet adheres, confirms this determination. Though the type specimen included a large part of the skeleton, yet through some

misinterpretation of its parts by Professor Cope, and the absence of other, essential parts, it has remained until the present time not well understood. Nor is it possible yet correctly to define it in all its details, since in no one species do we know the complete skeleton ; and it is possible, even more, it is probable, that there are two or more concurrent genera among the following species, which may eventually have to
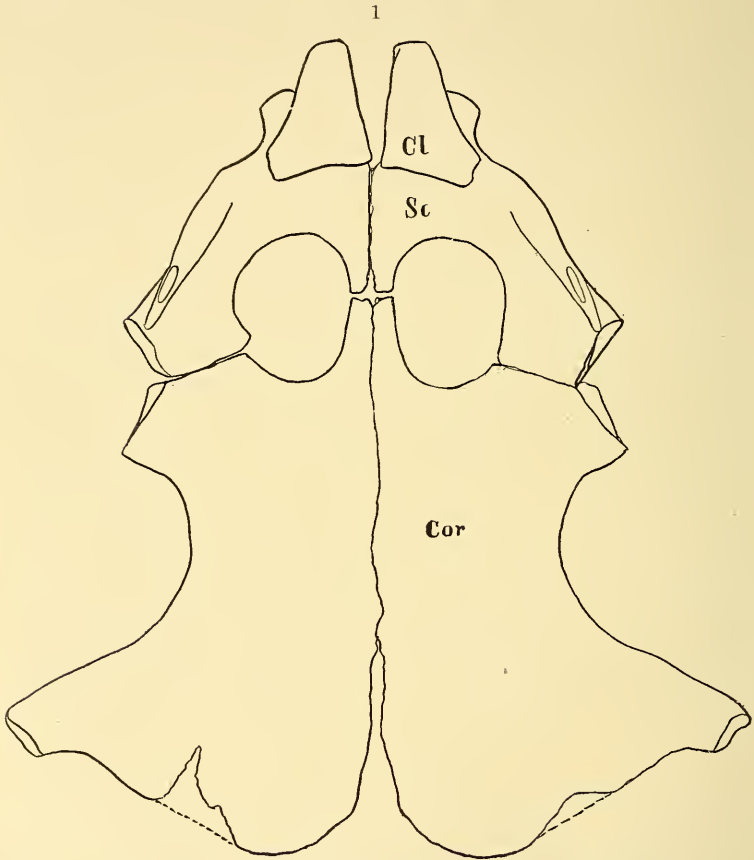

FIGURE 1.—Pectoral girdle of *Cryptoclidus oxoniensis* Phillips. From drawing of articulated specimen, American Museum of Natural History.

be distinguished from each other. Its relationships are nearest with the genus *Cryptoclidus* of Europe, a figure of the pectoral girdle of which, copied from a drawing kindly made for me from an articulated specimen in the American Museum of New York City, is given herewith (text-figure 1). But the two genera are very distinct. Indeed I am not at all sure but

they are distinguishable by more than generic characters, for the family *Elasmosaurus* is a distinct one, though its characters are not quite those assigned to it by Professor Seeley. I may add that so far, from a prolonged study of the American specimens and descriptions, I am of the opinion that no single species of American plesiosaurs can be placed in any known European genus.

Unfortunately, the type specimen of *Elasmosaurus* no longer has the girdles described by Cope. What has become of them is not known. There are some parts of these, especially the clavicular arch, that are necessary for a correct understanding of the genus. However, from an attentive study of this type specimen and of several other specimens which can be with much probability, if not certainty, referred to the same species, I am enabled to give the following characters for the genus *Elasmosaurus*. Those characters derived from the type specimen or type species are given in italics; those derived from other species referred to the genus, in roman :—

Elasmosaurus. Symphysis of mandible short ; teeth anisodont. Neck with seventy-six true cervical vertebræ and three pectorals, the centra increasing in length to the fifty-eighth, and then decreasing to the dorsals ; thence nearly uniform through the thoracic region ; posterior cervicals and dorsals much wider than high, and wider than long ; spines of vertebræ wide and not high ; zygapophyses weak. Pectoral girdle with large scapulæ meeting each other in the middle line. No interclavicular foramen.

Coracoids broadly separated posteriorly to the interglenoid thickening, the posterior end not much dilated. Cervical ribs single-headed. Ischia short. Skull short ; parietal crest much elevated ; supraoccipital bones parial ; palatines separated by pterygoids. Cervical vertebræ from sixty to seventy-six in number. Scapulæ approaching or meeting in middle line. Propodial bones short ; two epipodial bones only, not wider than long ; digits much elongated.

Elasmosaurus platyurus Cope. Fort Pierre Cretaceous of Kansas.

A detailed description of this specimen, in completion or correction of that given by Cope, will be given later. Certain measurements and remarks may be appropriate here.

The very broad, depressed, posterior cervical vertebræ of the posterior third, or say the posterior seven feet, prohibited much motion in the living neck, either vertically or horizontally. The motility of the neck practically ceased at the fifty-eighth vertebra. Thenceforward the neck was more slender, very slender toward the head. It was to this part that most, if

not all, motility was confined. The total length of the neck in this species in life, allowing six millimeters only for the thickness of the interarticular cartilages between adjacent vertebræ, was exactly twenty-three feet. A close approximation to the length of the trunk is nine feet ; of the tail, eight feet. The length of the head, using *E. snowii* for comparison (and the remains of the type preserved show that there must have been great resemblance between these two forms in the skull), was less than two feet. The entire length of the animal in life, then, was a little over forty-two feet, an estimate somewhat less than that reached by Cope. Other specimens referred to this genus exceeded these dimensions very materially, indicating, if their proportions were alike, an extreme length of not less than sixty feet. The elasmosaurs doubtless were the longest, if not the largest, of all known marine reptiles.

In the extreme elongation of the neck, *Elasmosaurus* exceeded all other vertebrated animals of the past or present, and was, if we assume a diphyletic origin of the short-necked forms, the most specialized of all plesiosaurs, since in no other genus do we know of any species having as many as fifty cervical vertebræ. But I am rather of the opinion that the short-necked types were descendants of earlier and longer-necked forms. Unless this is the case, we know of no early plesiosaurs which could have been the progenitors of such forms as *Polycotylus* with twenty-six cervical vertebræ, or *Brachauchenius* with as few as thirteen. In their paddles, the elasmosaurs were very generalized, in that the epipodials were scarcely broader than long, and their number is but two. In the clavicular arch, *Elasmosaurus* was specialized, while in the coracoids it seems to have retained generalized characters.

As to the habits of these long-necked plesiosaurs in life, I am satisfied that they were in general scavengers, living largely in shallow waters, as well as often out at sea. Numerous remains were found the past season in Wyoming, in the Upper Cretaceous, associated with longirostral and brevirostral amphicœlian crocodiles, dinosaurs, and lepidosteal fishes, as well as with turtles of marsh or fresh-water habit. And especially noticeable was the large number of immature or quite young animals found in these deposits.

It was with a specimen of an elasmosaur (*E. snowii*) that Mudge first noticed the occurrence of the peculiar siliceous pebbles which he described ; and it was also with another, a large species yet unnamed, from the Benton Cretaceous, that the like specimens were found described by me in 1892. That this habit was not confined to this type of plesiosaur, however, is certain, since I have also observed it

in different species of *Polycotylus* and *Trinacromerum*, both relatively short-necked and long-headed plesiosaurs. Much doubt and even ridicule have been thrown upon this supposed habit and the use of the pebbles by these reptiles. But the cumulative testimony of writers, both on this and the other side of the Atlantic, is quite conclusive. It has been assumed that the plesiosaurs could not have utilized the pebbles as a means of digestion in a muscular stomach. Dr. Eastman, who has vigorously opposed the idea of the possession of such a bird-like structure on the part of the plesiosaurs, seems to have been quite unaware of the fact that the modern crocodiles have a real, bird-like and muscular gizzard, and so described by Dr. Gadow. The crocodiles have a similar habit, or at least such a habit has been imputed to them, and it is not at all unreasonable to suppose that, strange as it may seem, the plesiosaurs had a real, muscular bird-like gizzard, which utilized the pebbles in whatever way the crocodiles may utilize them.

Elasmosaurus orientalis Cope. Cretaceous of New Jersey.

This species was based upon two mutilated and isolated cervical centra from New Jersey. It seems far more probable that these vertebræ really belong with *Cimoliasaurus*. Cope afterwards associated with this species an excellent series of vertebræ from the Pierre of Montana, which I have studied in the American Museum. I have not the least doubt but that Cope was in error in this collocation. I am not sure of the distinction of this specimen from *E. platyurus*, though a careful comparison of the measurements and sketches made by myself will, I think, decide their identity. If not *E. platyurus*, the species is doubtless entitled to a new specific name.

Elasmosaurus intermedius Cope. Fort Pierre Cretaceous of Montana.

This species was based upon nineteen centra without processes, and all more or less mutilated; now in the museum of the Academy of Natural Sciences at Philadelphia. I can not distinguish them specifically from *E. platyurus*.

Elasmosaurus serpentinus Cope. Niobrara Cretaceous of Nebraska.

This species was based upon much better material than was either of the foregoing ones, and it is both recognizable and distinct. Unfortunately, no figures have ever been given of the type specimen, and I have not had, so far, an opportunity to study the specimen. As in his other descriptions, Cope iden-

tified some of the vertebræ wrongly. The first dorsal verte-
bra, as he describes it, is in reality a posterior cervical, while
his seventh is either the last pectoral or the first true dorsal.
From his description, I make out sixty-two as the number of
cervical vertebræ preserved, and eighteen dorsals. As this
number of dorsals is smaller than is known in any other
species of plesiosaurs, I am confident that the series was not
complete. If Cope was correct in the serial relations of the
cervical vertebræ described, the species is quite distinct from
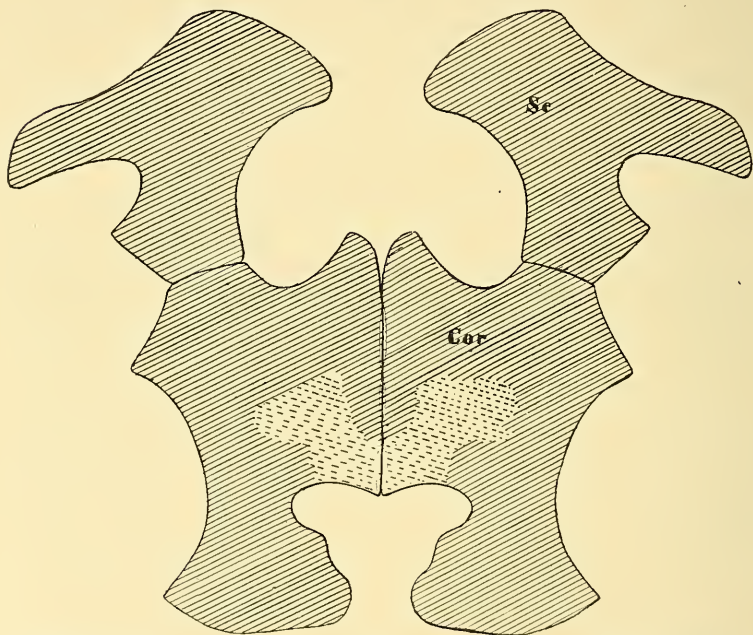anything otherwise described. His descriptions of the pec-

FIGURE 2.—Scapulæ and coracoids of *Elasmosaurus snowii* Williston.
Specimen No. 636, Yale Museum.

toral and pelvic girdles and of the limbs indicate an excellent
specimen now in the Field Museum, which will be shortly
described by Mr. E. S. Riggs, and a perfect humerus from
the Hailey shales in the collection of the University of
Chicago.

Elasmosaurus snowii Williston.   Niobrara Cretaceous of Kansas.

This species, based upon an excellent skull and a connected
series of eighteen cervical vertebræ in the museum of the
University of Kansas, I identify with much certainty in an

excellent specimen in the Yale collection (No. 1644), collected in 1874, by the late Professor B. F. Mudge, with my assistance, on Plum Creek, in western Kansas. It was the first specimen of plesiosaur that I ever saw. The locality of its collection is only a few miles distant from, and in almost precisely the same horizon as, that of the type specimen of the species, which was obtained from Hell Creek by the late Judge West, in 1890. Fortunately, the Yale specimen has, in addition to numerous vertebræ which quite agree with those of the Kansas specimen, parts of the girdles and limbs. I suspect that the specimen represents a somewhat immature animal; if not, it offers almost generic differences from the *E. platyurus*. The coracoids are of the true elasmosaurian type, that is, with the
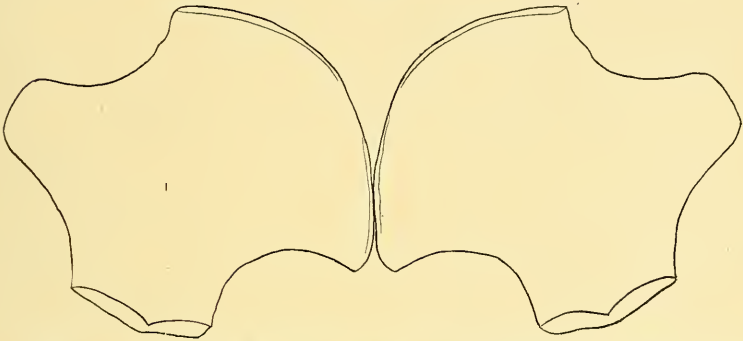
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FIGURE 3.—Pubes of *Elasmosaurus snowii* Williston. Specimen No. 636, Yale Museum.

posterior parts broadly separated (text-figure 2), though this part is unusually wide and short. It has, on the other hand, scapulæ of the usual type, not very much widened in the proscapular part. The humerus is quite elasmosaurian also, resembling that of *E. ischiadicus*, though shorter (Plate III, figure 3). The pubis is, however, very distinctive, readily distinguishing the species from *E. ischiadicus*, in that the anterior and external borders are markedly concave, and the symphysial border is much prolonged (text-figure 3). Another specimen of much larger size, in Yale Museum (No. 1641), has a pubis strikingly like this, though the femur is elongated and the epipodials are short.

Elasmosaurus (?) marshii n. sp. Niobrara Cretaceous of Kansas.

The specimen upon which this species is based is No. 1645 of the Yale Museum, collected in 1889 by Mr. H. T. Martin, in the chalk of Logan county, Kansas. It consists of thirty-two vertebræ, a scapula, and a nearly complete fore limb.

The scapula, save the tip of the dorsal process, and the paddle are in excellent preservation. The vertebræ have suffered much from compression, as is usually the case with the soft-boned plesiosaurs in the Kansas chalk.

The scapula is figured in outline herewith (text-figure 4). Its inner part is greatly expanded and produced to meet its mate broadly in the middle line. At their symphysis the two bones are extended backward in a narrow, elongated process, which did not, however, unite with the coracoid, as was the case with *E. platyurus*. In front, the two bones leave a broad, angular interval for the clavicle or interclavicle. Neither of these bones has ever been certainly defined in this genus, though Cope figured the pectoral girdle of *E. platyurus*
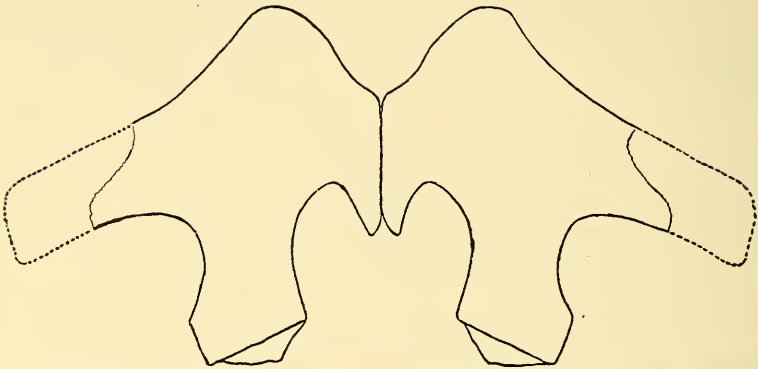
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FIGURE 4.—Scapulæ of *Elasmosaurus marshii* Williston.   No. 2062, Yale Museum.

as meeting broadly in front, as though the clavicle were fused with the scapulæ. I believe that the missing bone is the interclavicle, and that the clavicles will be found to be as in *Cryptoclidus*.

The structure of the paddle is clearly shown in Plate II, figure 2, as arranged under the supervision of Professor Marsh. I do not know under what conditions the bones were collected, but doubtless they were sent in from the field with the different parts dissociated. A careful study of the mounted specimen, however, assures me of the essential correctness of the restoration. The peculiar form of the humerus, quite unlike that of any other species of plesiosaur known to me, will enable this species to be readily recognized, though the characters of the scapulæ and vertebræ may possibly be insufficient. The bone is short, as is seen,—an elasmo-

saurian character, but it differs from the propodial of any other elasmosaurian known to me, in having an additional facet for a supernumerary epipodial at its distal end. There is, also, an additional mesopodial bone, which is wanting in other species of *Elasmosaurus*. These characters are, I believe, of generic value, but until the structure of the coracoid is known I leave the species provisionally in this genus. The femur has a length of 370^{mm}, and a width of 218^{mm}.

Thirty-three vertebræ are preserved with the type specimen, but as already stated they have suffered much from distortion, and their exact measurements can not be given. They are all clearly from the posterior part of the neck and the dorsal region. Some of the posterior dorsals are missing, though one of the sacrals is preserved. Their characters, so far as they are shown, are clearly elasmosaurian. The ribs are of course single-headed; the spines are broad and not very high; the posterior dorsals are more flattened at their extremities, and their articular rims are sharp, with slight crenulations. The lengths of the centra are given in millimeters, as approximately as the crushed condition will permit, as follows :—

Cervicals : 135, 135, 135, 135, 135, 135, 133, 133, 130, 127, 125, 125, 125, 120.

Dorsals : 115, 115, 115, 112, 110, 110, 100, 95, 90, 90, 90, 90, 90, 90, 90, 90, 90, 85, 80 (sacral).

If this species had similar proportions to those of *E. platyurus*, its length in life was about fifty feet.

Elasmosaurus ischiadicus Williston. Niobrara Cretaceous of Kansas.

Polycotylus ischiadicus Williston, Field Col. Mus. Pub., Geol. Ser., vol. ii, p. 72, pls. x, xxvi, 1903.

This species, based upon the ischia, ilia, caudal and supposed cervical vertebræ, was originally referred provisionally to the genus *Polycotylus* by myself, though gravely doubting its correct location there. An excellent specimen in the Yale Museum (No. 1130), comprising the front paddle nearly complete, a number of vertebræ, and the nearly complete pectoral girdle, seems to be of the same species. I was at one time inclined to the belief that the specimen represented an undescribed species, notwithstanding the resemblance of the ischia, chiefly because of the differences in the structure of the ilia, and because of the characters of the vertebræ which I had identified as cervical. That all the centra preserved in the Kansas specimen are pygals seems hardly possible. If any of them are cervicals, the species are undoubtedly distinct. This question, however, I can not decide until I have had an oppor-

tunity of again examining the type specimen. I therefore place the Yale specimen for the present in this species.

The characters of the pelvis, that is, the short ischia especially, and the shape of the pubis, will be readily appreciated by an examination of Plate I. The paddle is especially noteworthy because of the primitive number of the epipodial bones (there are no supernumeraries), and this character I have also observed in the paddles of three other species of the genus. The paddle, it is also observed, is much elongated, and the femur is relatively short (Plate II, figure 1). The few vertebræ of the neck preserved are quite elasmosaurian in character. Other propodials of this species are preserved in the University of Chicago collections.

Elasmosaurus sternbergi n. sp.   Niobrara Cretaceous of Kansas.

The only parts referable with certainty to this species are two complete dorsal vertebræ and some additional fragments in the University of Kansas collection, obtained some years ago by Mr. Charles Sternberg in the yellow chalk of Gove county, Kansas. I describe them, nevertheless, since they indicate the largest plesiosaur of which I have any knowledge. If they belonged to a long-necked form like *E. platyurus*, the animal could not have been less than sixty feet in length. That they pertain to a long-necked form is quite certain, and the general characters of the vertebræ are like those of *Elasmosaurus*.

The dorsal centra are nearly circular in outline, somewhat broader than high, with their sides gently concave. The diapophyses are stout, directed upward and outward to a plane above the zygapophyses. The zygapophyses are separated by a notch and are rather small. The spine is flattened and elongate. Figures of these vertebræ will be given in a later communication.

Width of dorsal centrum _____	165^{mm}
Height of same _____	140
Length of same _____	80
Width of more posterior dorsal _____	155
Height of same _____	143
Length of same _____	78

This is the only specimen referable to this species that I have ever seen in the many years of my acquaintance with the Kansas saurians. Its extreme rarity will therefore justify the description of the rather meager material.

Elasmosaurus nobilis n. sp.   Niobrara Cretaceous of Kansas.

A very large specimen referable to a new species is represented by a considerable portion of a skeleton in the Yale

Museum, obtained a good many years ago from the Fort Hays limestone, or basal strata of the Niobrara Cretaceous, of Jewell county, Kansas, by B. F. Mudge. The specimen bears the catalogue number 1640. Unfortunately, the specimen had been injured in collecting before it fell into proper hands. Originally it is probable that the larger part of the pectoral girdle, and perhaps, also, of the pelvic girdle and hind limb had been present, in addition to numerous vertebræ, and all in an undistorted condition. The specimen, notwithstanding what it has suffered, is of much interest, since it is the only vertebrate of which I have any knowledge from the Hays limestone. Additional figures and descriptions will be given later. For the present, the figures of the femur, ilia, and dorsal and sacral vertebræ given in Plate IV will render the species recognizable. A massive fragment of the scapula shows a broad and firm union with its mate in the middle line. The posterior projection of the coracoid is very long and much constricted before its extremity, its distal width being a little less than twice that of its least width; the outer posterior angle is acute and not much produced. The femur shows facets for but two epipodial bones.

Length of femur _____ 337^{mm}
Greatest width distally _____ 206

A rather common species referable to this genus from the fence-post and lower horizons of the Benton is represented by a number of specimens in the Kansas University collections, and will be described later, with figures.

Two additional species also referable to this genus are known to me from the Hailey shales (probably equivalent to the Benton Cretaceous) of Wyoming, and will be described and figured later.

Polycotylus Cope.

The genus *Polycotylus*, described by Cope in 1870 from a number of mutilated vertebræ and fragments of podial bones, has remained hitherto much of a problem, and its characters have been very generally misunderstood. Fortunately, there is an excellent specimen in the Yale Museum (No. 1125), collected now many years ago by the late Professor Marsh in the vicinity of Fort Wallace, Kansas, from the Niobrara chalk, which I believe can be referred with certainty to the type species *P. latipinnis* Cope. That it belongs in the genus *Polycotylus* is beyond dispute, the vertebræ agreeing quite with the type as they do. This species seems to be the most common one of the order in the Kansas chalk, and is represented by several other specimens in the Yale Museum and by specimens in the University of Kansas collection. It is not at

all improbable that the validity of the generic name may be eventually called into question, since there seems to be no difference between the teeth of this form and that described by Leidy years before, from the Cretaceous, presumably Niobrara, of Minnesota, as *Piratosaurus*. However, as the identity must remain for many years, if not always, more or less doubtful, it would be very unwise to make any changes at the present time.

The Yale specimen, presenting as it does not a few interesting morphological and structural characters, will be fully described and figured later. It comprises the larger part of the skeleton, with the lower jaws, parts of the skull, teeth, etc. From the study of this specimen, supplemented by other specimens, clearly conspecific, the generic characters may be stated as follows:—

Polycotylus. Teeth rather slender, with numerous well-marked ridges. Face with slender beak. Cervical vertebrae twenty-six in number; dorsals twenty-eight or twenty-nine, inclusive of three pectorals; all short and all of nearly uniform length. Chevrons articulating in a deep concavity; all the vertebrae, and especially the cervicals, rather deeply concave, and with a broad articular rim. Pectoral girdle with distinct clavicles, interclavicles, and interclavicular foramen; the scapulae not contiguous in the middle. Coracoid with a long anterior projection, united in the middle, back of the interglenoid bar, to the posterior margin; a foramen on each side, back of interglenoid thickening. Ischia elongated. Paddles with four epipodial bones, all much broader than long.

The foregoing characters, it will be seen, are very much like those already given by me for *Dolichorhynchops*, and I am somewhat in doubt as to the validity of that genus, or rather of *Trinacromerum* Cragin, of which, as I suspected, *Dolichorhynchops* is a synonym. The only important distinctions are the deep concavity of the centra and the mode of articulation of the chevrons. In none of the known species of *Trinacromerum* are there more than three epipodial bones, while in the two species referred to *Polycotylus* there are four well-formed ones. This may be, in addition to the vertebral characters, sufficient to distinguish the genera.

I give herewith some additional figures of *Polycotylus latipinnis*, made from the Yale specimen 1125 (Plate III, figure 1). The pelvic girdle, as will be seen, is remarkable for the great elongation of the ischia. The paddle figured by me in my previous paper on the plesiosaurs* was correctly assigned to the species, but is a hind paddle instead of a pectoral limb.

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*Field Col. Mus. Pub., Geol. Ser., vol. ii, pl. xx.

A front paddle preserved in the Yale collection, has, as usual, the humerus more expanded distally. An outline of the coracoids and scapulæ, as preserved, is given in text-figure 5.

Polycotylus dolichopus n. sp. Niobrara Cretaceous of Kansas.

A species quite distinct from *P. latipinnis* is represented in the Yale collection by two specimens, the one a femur and most of the paddle (No. 1642), the other a humerus and some
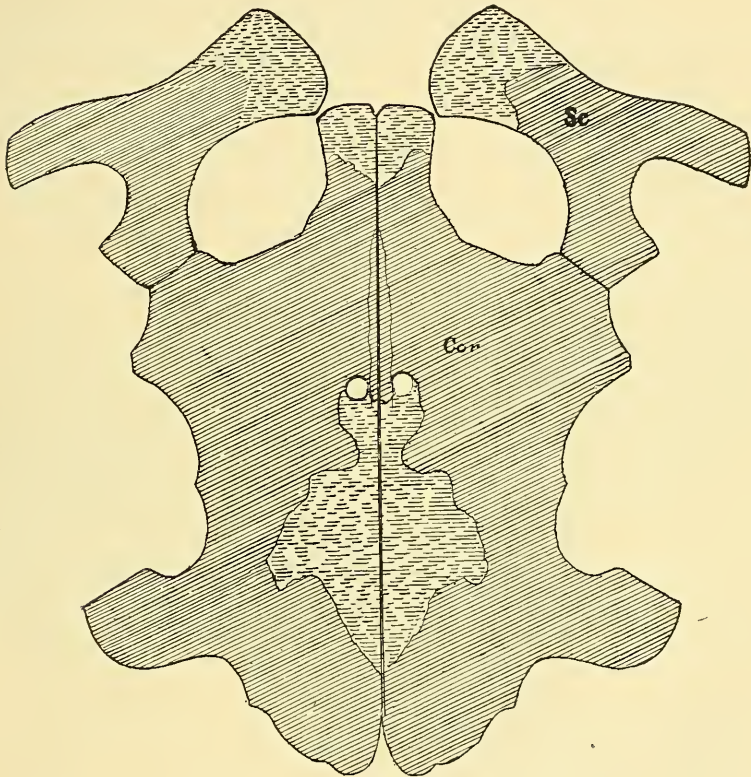
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FIGURE 5.—Scapulæ and coracoids of *Polycotylus latipinnis* Cope. No. 1125, Yale Museum.

of the mesopodial and epipodial bones (No. 1646), both from the Niobrara chalk of Kansas.

I am convinced that these two specimens are conspecific, judging especially from the shape of the epipodials, but in the possibility that they may prove to be distinct, specimen No. 1646 may be considered the type of the species. The species is especially characterized by the slenderness of the shaft of

the propodials, the great transverse dilatation of the epipodials, and the markedly greater concavity of the posterior border of the propodials (Plate III, figure 2). The metapodials and phalanges are also notable for their shortness and robustness. There are four facets on the distal extremity of the propodials for articulation with the epipodials.

> Length of femur (No. 1642) .... 311^{mm}
> Greatest distal expanse 154
> Length of humerus (No. 1646) 317
> Greatest distal expanse 172

An additional species of this genus is known to me, and will be figured and described in a later communication.

Trinacromerum Cragin.

The genus *Trinacromerum*, if it be distinct from *Polycotylus*, as I believe that it is, is represented in the Yale collection by a considerable portion of a skeleton (No. 1129), clearly identifiable with *T. anonymum* Williston, from the Benton Cretaceous. This specimen, which offers some additional facts of interest, will be figured and described in a later communication, in connection with the description of the type species of the genus, *T. bentonianum*, which I have recently studied in the Colorado College collection.

EXPLANATION OF PLATES.

Plate I.

Pelvic girdle of *Elasmosaurus ischiadicus* Williston.   *p*, pubis; *il*, ilium; *is*, ischium.   Specimen No. 1130, Yale Museum.

Plate II.

Figure 1.—Right pelvic paddle of *Elasmosaurus ischiadicus* Williston. Specimen No. 1130, Yale Museum.
Figure 2.—Left pectoral paddle of *Elasmosaurus (?) marshii* Williston. Specimen No. 1645, Yale Museum.

Plate III.

Figure 1.—Left half of pelvic girdle of *Polycotylus latipinnis* Cope. 1*a*, pubis; 1*b*, ischium; 1*c*. ilium.   Specimen No. 1125, Yale Museum.
Figure 2.—Right propodial and epipodial bones of *Polycotylus dolichopus* Williston.   Specimen No. 1642, Yale Museum.
Figure 3.—Right humerus of *Elasmosaurus snowii* Williston.   Specimen No. 1644, Yale Museum.

Plate IV.

Elasmosaurus nobilis Williston.   Specimen No. 1640, Yale Museum.

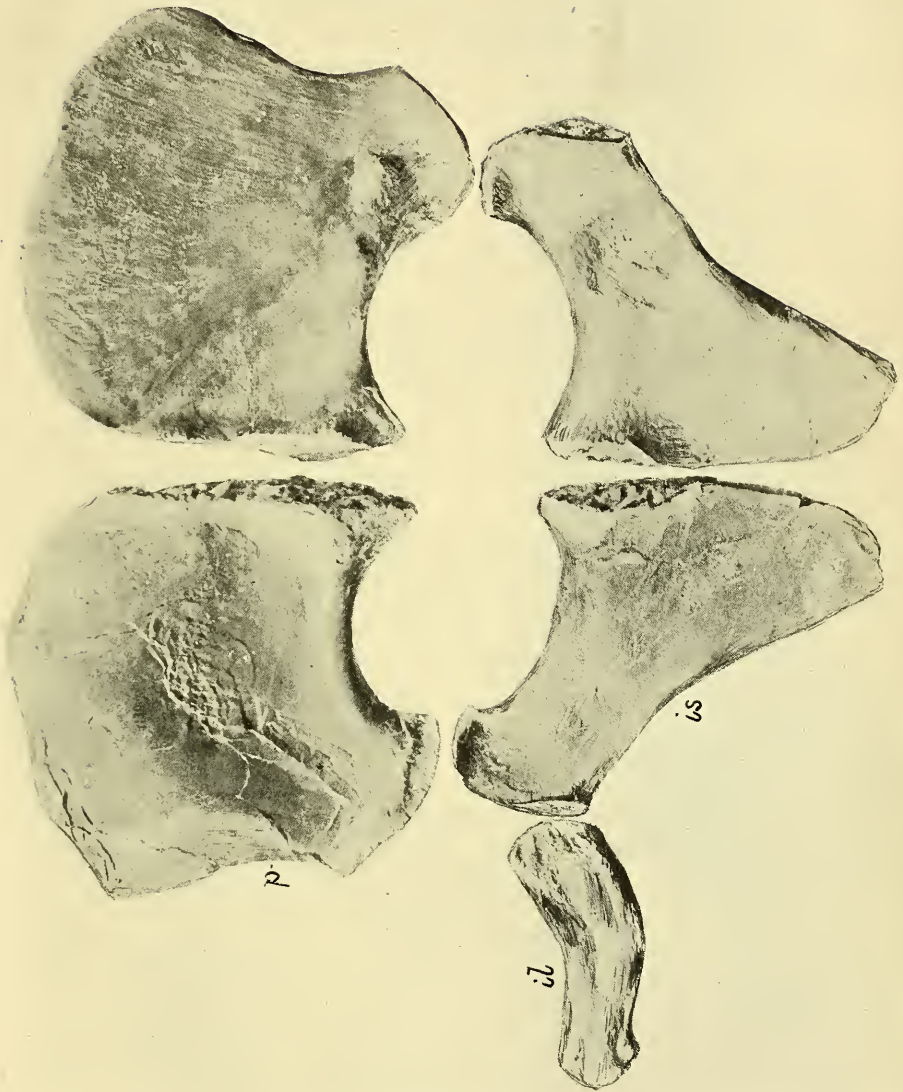Figure 1.—Right ilium.
Figure 2.—Left ilium.
Figure 3.—Right femur.
Figure 4.—Posterior sacral vertebra.
Figure 5.—First sacral vertebra.
Figure 6.—Anterior dorsal vertebra.
Figures 7, 8.—Posterior dorsal vertebræ.
Figure 9.—Middle sacral vertebra.
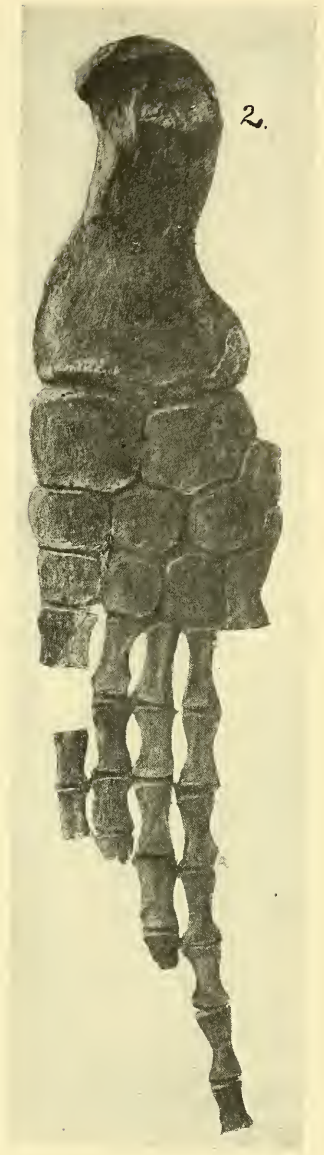
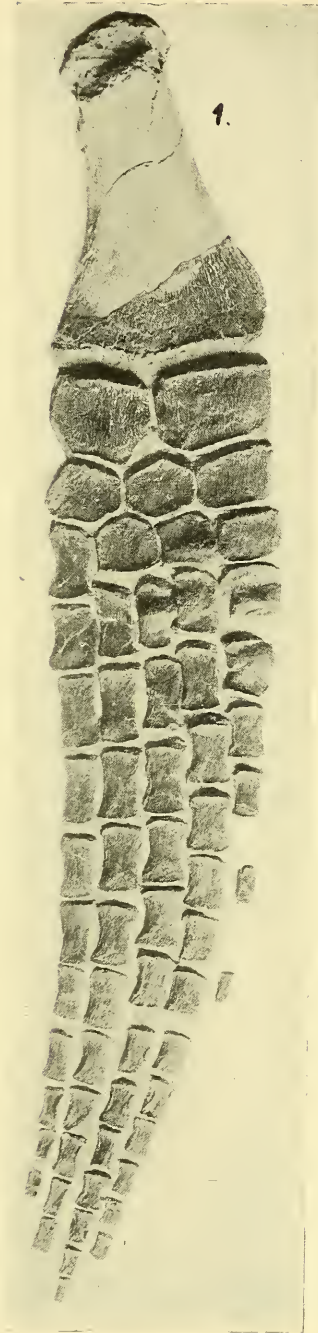*Elasmosaurus ischiadicus* Williston.

Plate II.

FIG. 1.   *Elasmosaurus ischiadicus* Williston.
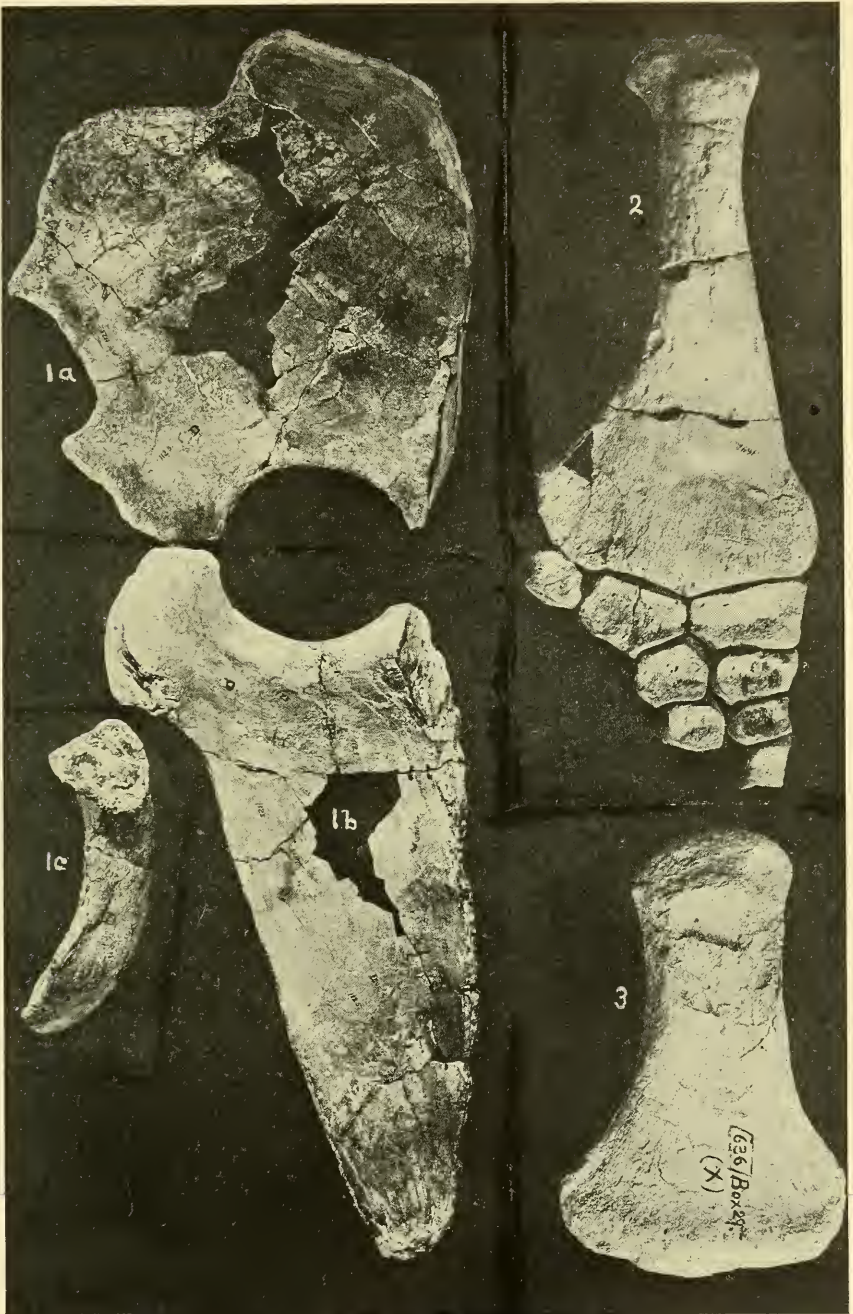FIG. 2.   *Elasmosaurus*(?) *marshii* Williston.

FIG. 1.   *Polycotylus latipinnis* Cope.   FIG. 2.   *P. dolichopus* Williston.
FIG. 3.   *Elasmosaurus snowii* Williston.

Plate IV.

Elasmosaurus nobilis Williston.

Art. XVII.—*The Occurrence of Sulphur and Celestite at Maybee, Michigan;* by E. H. Kraus and W. F. Hunt.

A. *Relation of Celestite-bearing Rocks to Occurrences of Sulphur and Sulphureted Waters.*

That celestite-bearing rocks occur quite extensively in New York and Michigan has been recently pointed out.[*]   Perhaps one of the best localities to study these rocks in respect to the formation of sulphur and sulphureted water is at the Woolmith quarry, midway between the towns of Scofield and Maybee, Monroe Co., Michigan.

Inasmuch as Sherzer[†] has reported in detail concerning the geology of this locality, it is sufficient to say that the nine different beds exposed at this quarry are assigned to the Monroe series, perhaps the equivalent of the Salina in New York. The rocks are for the most part dolomites, sometimes, however, quite siliceous. Many of the strata also contain a relatively large per cent of bituminous matter. It is also important to state that the strata at or near the surface are usually quite compact and vary much in color—from gray to brown—and are more or less blotched or streaked. These compact layers are characterized by an unusually high specific gravity. But since the rocks are not homogeneous, different values were obtained, ranging from 2·80 to 3·45, which are for the most part considerably higher than that of a normal dolomite, namely 2·80 to 2·90. This high specific gravity must, hence, be considered as indicative of the presence of some mineral, possessing quite a high specific gravity, disseminated throughout the rock.

As one descends into the quarry the rocks become more porous and cavernous. It is in these layers with cavities ranging from a few inches up to a foot or more in diameter that the native sulphur with its usual associates, celestite, calcite, and sometimes gypsum, is found. The occurrence of these minerals is clearly one of secondary formation.

The rocks near the surface, although compact where they have been protected, show, when exposed, the characteristic structure of leached celestite-bearing rocks. This, together with the high specific gravity already referred to it, would suggest the presence of celestite. In order to determine the presence of the mineral and also its probable percentage, an

[*] E. H. Kraus. "Occurrence of Celestite near Syracuse, N. Y., etc.," this Journal (4), xviii, 30–39, 1904; also "Occurrence and Distribution of Celestite-bearing Rocks," this Journal (4), xix, 286–293, 1905.
[†] "Geological Report on Monroe County," Geological Survey of Michigan, 1900, 75.

analysis of the uppermost layer, characterized as Bed A by Sherzer, was made.

As already indicated, this rock is by no means homogeneous and, hence, in order to obtain as near as possible the average composition of the same, many chips were taken from a specimen of approximately the following dimensions, $4 \times 5 \times 6$ inches. The specific gravity of most of the chips was determined and the following are some of the values obtained : 2·80, 2·87, 2·98, 3·17, 3·33, and 3·45.

The methods pursued in this and the following analyses were those recommended by Hillebrand.* Knowing that much would depend upon the careful separation of the earth alkalies, the utmost care was exercised in their determination. The precipitates were in every instance tested spectroscopically and, if necessary, the extraction repeated until in each case they could be considered free from contamination. We may, therefore, regard the results obtained as very accurate. They are as follows :

	Per cent.	Ratio.
SiO_2	0·58	
Al_2O_3 Fe_2O_3	0·37	
CaO	25·18	0·44884
MgO	18·11	0·44871
BaO	0·13	0·00085
SrO	*7·86*	0·07587
Na_2O	0·11	
K_2O	0·05	
P_2O_5	0·02	
Cl	0·04	
CO_2	39·55	0·89886
SO_3	*6·33*	0·07907
Organic matter	0·92	
H_2S	trace	
Total	99·25	

The percentages of the oxides of calcium, magnesium, strontium, and barium, together with the carbon dioxide and sulphur trioxide, are important. It is at once noticeable that the amounts of strontium oxide and sulphur trioxide are relatively high. A comparison of the combined ratios of the oxides of calcium and magnesium with that of the carbon dioxide,

$$\left. \begin{array}{c} \text{CaO} \ (\cdot 44884) \\ \text{MgO} \ (\cdot 44871) \end{array} \right\} : \text{CO}_2 \ (\cdot 89886) = 1 : 1 \cdot 0014,$$

shows that the rock is essentially a dolomite and, in fact, a normal dolomite. We, thus, have quite conclusive evidence

* Bulletins 148 and 176, U. S. Geological Survey.

that all of the calcium and magnesium oxides are doubtlessly present as carbonates and not in part as sulphates.

The unusually high percentages of strontium oxide and sulphur trioxide are extremely interesting. If we consider the small amount of barium oxide present as isomorphous with the strontium oxide, we obtain the following proportion :

$$\left\{ \begin{array}{l} \text{SrO} \ (\cdot07587) \\ \text{BaO} \ (\cdot00085) \end{array} \right\} : \text{SO}_3 \ (\cdot07907) = 1 : 1\cdot0306.$$

These values would indicate that the sulphur trioxide is combined with the oxides of strontium and barium and, hence, evidence is at hand that the mineral celestite is present in this uppermost layer to the extent of *14·32* per cent. The results of the analysis are, therefore, in harmony with what has already been said concerning the structure and specific gravity of the rock.

The very small amount of the combined oxides of aluminium and iron, namely 0·37 per cent, would preclude any appreciable quantity of pyrite or marcasite being present. It is, however, significant, as will be seen later, that organic matter and a trace of hydrogen sulphide were noted.

Descending into the quarry, not only do the strata become more porous and cavernous but at various levels water containing a considerable amount of hydrogen sulphide is encountered. As said, the porous layers contain native sulphur associated with celestite. Sherzer in discussing the probable origin of the sulphur at this quarry rightly refers the same to the hydrogen sulphide, which is to be observed to a very large extent in Southern Michigan. In the immediate vicinity of the Woolmith quarry most of the wells show varying amounts of it. These wells are from 18 to 20 feet deep and after passing through the drift penetrate rock to the extent of two to four feet. The layer, which is doubtlessly encountered, is the one called Bed A, an analysis of which was just given.

Sherzer thought that the hydrogen sulphide might be due to the decomposition of pyrite and marcasite, which were supposed by him to be present in considerable quantities. The analysis of the rock of Bed A, however, shows clearly that if these sulphides of iron are present in the upper strata, they must be present in amounts which are almost insignificant when compared with that of strontium sulphate. In some of the lower layers, in a few instances, pyrite has been noticed but always in very small amounts. Its occurrence is also clearly secondary. Without a doubt we are dealing with descending waters at this locality.

It is also of vast importance to call attention to the fact that when the rocks of the various layers in this quarry—the same

holds good of many of the celestite-bearing rocks of central New York—are treated with dilute acid, hydrogen sulphide is liberated together with the carbon dioxide. Even boiling in water is sufficient to give rise to the liberation of the sulphureted hydrogen. To be sure, in some instances, the amount is very small, but, nevertheless, even a trace is of great import, indicating that a sulphide decomposed by hot water is present. Such a sulphide is doubtlessly strontium sulphide. Hence, we must consider the theory that the decomposition of pyrite or marcasite by the formation and subsequent oxidation of hydrogen sulphide has given rise to the native sulphur at this quarry as untenable.

However, when we consider that the uppermost strata contain about 14 per cent of strontium sulphate, which is quite soluble in water and, hence, easily transported to the lower layers, and, secondly, that these and the lower strata contain considerable quantities of organic matter; thirdly, that there is only a negligible amount of iron present, and, lastly, that hydrogen sulphide is easily liberated by hot water, it seems evident that the celestite, present in a disseminated condition and which has by the action of the organic matter become partially reduced to the sulphide, must be considered as the source of the hydrogen sulphide.

Therefore, if the foregoing statements be true, an analysis of one of the more porous and cavernous layers, the cavities of which contain native sulphur, ought to show not only the presence of strontium as a sulphate but also as a sulphide, which would be indicated in the analysis as sulphur trioxide and sulphur, respectively. Such an analysis was made with the following results:

	Per cent.	Ratio.
SiO_2	20·14	
Fe_2O_3 Al_2O_3 }	ı0·86	
CaO	19·56	0·3493
MgO	15·32	0·3795
SrO	0·66	0·006371
BaO	0·07	0·000457
S	0·02	0·000587
SO_3	0·56	0·006994
CO_2	31·94	0·7259
Na_2O	0·09	
K_2O	0·07	
Cl	0·03	
Organic matter*	10·72	

100·00

* By difference after deducting the oxygen equivalent of the sulphur.

The sulphur was calculated from the hydrogen sulphide obtained directly by the liberation with hydrochloric acid, absorbed in potassium hydroxide, acidified and titrated with $\dfrac{N}{100}$ iodine solution.

The silica is present, no doubt, as free silica. The value of the ratios of the oxides of the calcium and magnesium, as also that of the carbon dioxide, give the following proportion :

$$\left\{ \begin{array}{l} \text{CaO} \ (\cdot 3493) \\ \text{MgO} \ (\cdot 3795) \end{array} \right\} : CO_2 \ (\cdot 7259) = 1 \cdot 004 : 1.$$

Hence, this rock may be considered as a siliceous dolomite. The sulphur trioxide represents the total amount of sulphur present as sulphate and sulphide, whereas the hydrogen sulphide is to be considered as being derived from a sulphide only. Hence, if we consider the hydrogen sulphide as being due to the decomposition of the strontium sulphide and, therefore, deduct from the percentage of strontium oxide given in the analysis, the amount necessary to unite with the 0·02 per cent of sulphur[*] to form strontium sulphide, the following relationship between the ratios of the strontium and barium oxides and the sulphur trioxide, actually present, is revealed :

$$\left\{ \begin{array}{l} \text{SrO} \\ \text{BaO} \end{array} \right\} \ \cdot 006174 : SO_3 \ \cdot 00516 = 1 \cdot 099 : 1.$$

These values are so close that we must consider the evidence in support of the above theory as very conclusive, namely, that the celestite as the source of the sulphur is partially reduced to strontium sulphide, which, when acted upon an acid and even by water under certain conditions,[†] will liberate hydrogen sulphide. Oxidation of the hydrogen sulphide will, of course, then give rise to the sulphur. That the sulphur should be associated with celestite is from the foregoing self-evident.

Osann,[‡] in reviewing Sherzer's theory of the origin of sulphur at the Woolmith quarry, suggested that it was doubtlessly due to the reduction of the strontium sulphate, as is now revealed by the analysis above to be the case. As to how the strontium sulphate has been reduced to the sulphide, nothing definite can be said at this time. Doubtlessly, it is the result of the action of the organic matter present, which may in some cases be quite high. Whether organic matter alone, or perhaps with moisture, but unaided by bacteria, can cause a reduction of the sulphate, is now being investigated.

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[*] Determinations from other portions of this same layer showed as much as 0·12 per cent hydrogen sulphide. The analysis was, however, not complete and, hence, is not given. These figures show, nevertheless, that sulphureted hydrogen may be liberated in appreciable amounts.

[†] Compare Bischof's Chemische Geologie, 1863, i, 833.

[‡] Groth's Zeitschrift für Krystallographie, etc., xxviii, 321, 1897.

The formation of hydrogen sulphide in this way is of great importance, for no doubt many of the sulphureted waters encountered in localities where celestite-bearing rocks have been noted are to be referred to the above process. These rocks are quite common in southern Michigan and here we also find many so-called " sulphur " wells.

The formation of sulphur by the reduction of celestite is analogous to the process which by many is supposed to have played an important rôle in forming the enormous deposits at Girgenti and vicinity on the Island of Sicily. Here it is, however, assumed that gypsum ($CaSO_4, 2H_2O$) has been reduced to the sulphide and then hydrogen sulphide liberated and subsequently oxidized.[*]

B. *Crystallography of the Celestite.*

As already shown, in the cracks, crevices, and cavities[†] of the lower strata at this quarry beautiful crystallizations of celestite are to be observed. Since crystals of celestite from this locality had not as yet been measured, a large number were collected with this in view.

The crystals were for the most part clear and transparent, possessing a slight bluish tint. The faces were bright and the images, on the whole, very good, so that measurements could be made with very great accuracy.

Two distinct types of crystals were observed and measured. Figure 1 represents the tabular variety. These crystals were about 10^{mm} in width and 2^{mm} thick and showed the following forms: $c\{001\}$, $m\{110\}$, $d\{102\}$, and $o\{011\}$. The other, prismatic, type is represented by figure 2. These were about 6^{mm} wide and 4^{mm} thick and showed the following additional forms : $a\{100\}$, $b\{010\}$, $n\{120\}$, and $z\{111\}$. On the prismatic type the pyramid $y\{122\}$ was also observed, but the images obtained were rather poor and, hence, the readings somewhat doubtful. On a few crystals the pyramid $L\{10·55·44\}$, $\frac{5}{4}$ $P\frac{11}{2}$, was noted, which up to now has not been observed on celestite. Although the indices are large, the reflections were of such a character that no mistake could have been made in the identity of the form. Also on several crystals a small prism face (410) was recorded. In this case, the readings are not to be considered as accurate as in the case of the pyramid just referred to, but nevertheless this prism, which is also new on celestite, must be considered as present. Although this form had not been noted on celestite before, it has been observed on barite.

[*] Brauns, Chemische Mineralogie, 1896, 384 and 389 ; also Kemp, The Mineral Industry, 1893, 585.
[†] This Journal [4], xix, 1905, 290.

As shown in the figures, the crystals were developed on one end only, having occurred attached.
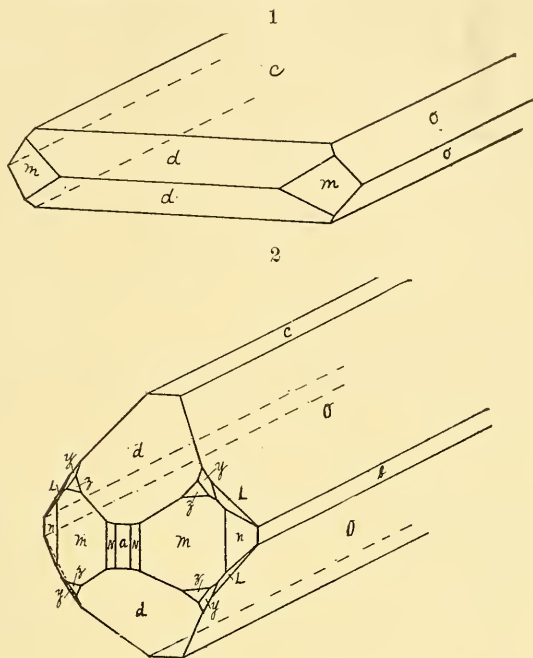
The forms observed are $a\{100\}$, $b\{010\}$, $c\{001\}$, $m\{110\}$, $n\{120\}$, N$\{410\}$, $z\{111\}$, $y\{122\}$, L$\{10\cdot55\cdot44\}$, $o\{011\}$, $d\{102\}$. The measurements are as follows :

Crystal system—Orthorhombic (holohedral).

Axial ratio : $a : b : c = \cdot7781 : 1 : 1\cdot2673$.

				Observed.		Calculated.	
$m : m =$	(110)	:	$(1\bar{1}0)$ =	75°	$46\frac{1}{2}'$*	- - - - - -	
$d : d =$	(102)	:	$(\bar{1}02)$	78	43*	- - - - - -	
$n : n =$	(120)	:	$(\bar{1}20)$	65	28	65°	27'
$o : o =$	(011)	:	$(0\bar{1}1)$	103	56	103	50
$c : z =$	(001)	:	(111)	64	$17\frac{1}{2}$	64	18
$c : y =$	(001)	:	(122)	56	26	56	36
$c : L =$	(001)	:	$(10\cdot55\cdot44)$	58	44	58	36
$z : z =$	(111)	:	$(\bar{1}11)$	90	32	90	40
$z : z =$	(111)	:	$(1\bar{1}1)$	67	$17\frac{1}{2}$	67	12
$L : L =$	$(10\cdot55\cdot44)$	:	$(10\cdot\bar{5}5\cdot44)$	112	6	112	26
$m : d =$	(110)	:	(102)	59	59	59	58
$m : o =$	(110)	:	(011)	61	1	61	6
$N : N =$	(410)	:	$(4\bar{1}0)$	22	32	22	1

C. *Chemical Composition of the Celestite.*

A number of clear, transparent crystals were selected for an analysis and the following results obtained:

	I.	II.	Average.
SiO_2	0·22	0·23	0·225
Fe_2O_3 $\}$ Al_2O_3 $\}$	0·15	0·13	0·140
CaO	0·45	0·47	0·460
MgO	0·12	0·14	0·130
BaO	1·26	1·32	1·290
SrO	53·75	53·78	53·765
SO_3	43·58	43·60	43·590
	99·53	99·67	99·600

The measured crystals possess a specific gravity of *3·979*. The determinations were made by means of the hydrostatic balance at a room temperature of 19·5 C., while that of the water was 20·5° C.

D. *Natural Etch Figures on Celestite.*

While examining the crystals from the Woolmith quarry, it was observed that many of the faces showed natural etch figures. Closer examination, however, showed that these figures could not be studied as well as those noted on some crystals obtained from the Island of Put-In-Bay, Lake Erie, where celestite also occurs in large quantities.
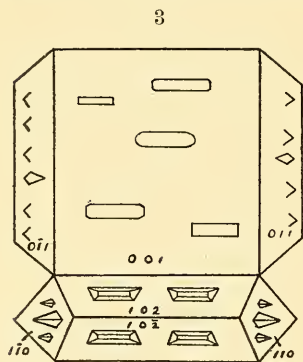
The natural etch figures are well defined and their form as well as their position on the various faces show conclusively the symmetry of the holohedral class of the orthorhombic system. Figure 3 shows these figures upon a crystal from Put-In-Bay. In form and distribution they are very similar to the artificial etch figures observed by Prendel.* The solvents used by Prendel were sulphuric acid in one case and potassium carbonate and hydrochloric acid in the other. To our knowledge, natural etch figures on celestite have never been described.

We are indebted to Prof. E. D. Campbell, Director of the Chemical Laboratory of this University, for valuable suggestions relating to the chemical portion of this paper.

Mineralogical Laboratory, University of Michigan,
    Ann Arbor, Mich., November, 1905.

* Cölestin von Dorfe Dorobany bei der Stadt Hotin, Gouvernement Bessarabien, Groth's Zeitschrift für Krystallographie, etc., 1898, xxx, 319.

Art. XVIII—*Local Predictions for the Total Eclipse of the Sun, 1907, January 13–14, in Turkestan and Mongolia;* by David Todd and Robert H. Baker.

[Contributions from Amherst College Observatory—lxxiii.]

Six total eclipses of the sun happen during the next six years, and it might be expected that contributions to knowledge of the corona would be correspondingly ample.

Of these eclipses, however, the tracks of those of 1908 and 1911 are wholly confined to the Pacific Ocean, with the possibility of observing stations on only two or three difficult islands; the eclipse of 1909 is too near the north pole and that of 1910 too near the south pole for ready observation; totality of 1912 can perhaps be excellently obtained in Brazil;* but of them all, that of 1907 seems least uncertain to yield significant results.

Following the last eclipse (1905, August 30) by an interval of seventeen months, the figure and type of the corona will doubtless have changed completely; so that it is in the highest degree important to photograph this totality.

Fortunately, the track of the eclipse of 1907, January 13–14, is wholly on land. But a good part of the region visited is so remote and difficult of access, in Mongolia and the Gobi desert, that it can be occupied only by equipping tedious and expensive expeditions. Only one station in Mongolia, Tsairosu (see table below given), seems likely to be considered.

But the western half of the track crosses Turkestan, a trans-Caspian region penetrated by the imperial railways of Russia. For travelers from the United States, it can readily be reached by Naples, Constantinople, the Black Sea, Tiflis, the Caspian Sea, Bokhara and Samarkand.

For Europeans a convenient route would be Berlin, Warsaw, Moscow, Samara, Orenburg and Tashkent. On this railway and about two-thirds of the way from Tashkent to Samarkand lies Jizak, only a few miles from the exact line of central eclipse. Other easily accessible places near Jizak, and well within the belt of totality, are Zaamin, Nau and Ura-tiube. The last is practically central. If we go farther east, the track of the eclipse leads into a region more and more difficult in every way, although the totality is a few seconds longer there, and the eclipsed sun a few degrees higher.

In order to exhibit the exact circumstances of the eclipse, throughout the entire length of its track, the indicated data have been calculated for eleven stations, as exhibited in the following table. Also the results of the calculated example in the British Nautical Almanac, for a station between Yarkand and Cherchen, are included.†

The computations are based on the Besselian elements of the American Ephemeris, and the geographical positions of the towns have, for the most part, been obtained from a map recently published by the Carnegie Institution of Washington.‡

* Todd, Total Eclipses of the Sun (Boston, 1900), p 249.
† The Nautical Almanac for the Meridian of Greenwich, 1907, p. 594–5.
‡ Pumpelly and Davis, Explorations in Turkestan (Washington, 1905), p. 157.

Total Solar Eclipse, January 13–14, 1907.

Time columns (Eclipse begins, Totality begins, Totality ends, Eclipse ends) are *Local mean time*. Sun's azimuth and Sun's altitude are *At middle of eclipse*.

| Name of station	Miles from central line	Latitude north	Longitude E. from Greenwich	Eclipse begins	Totality begins	Totality ends	Eclipse ends	Sun's azimuth	Sun's altitude	Duration of totality	Angle of position (direct image) First contact. From N. Pt. toward E.
TURKESTAN.											
Chimbai	3 S.	42° 56'	59° 49'	20h 8m 42s	21h 19m 0.8s	21h 20m 45.1s	22h 38m 58s	319° 45'	14° 47'	1m 44.3s	271.9°
Jizak	13 S.	40 8	67 48	20 44 50	21 59 58.4	22 1 55.2	23 23 47	328 3	21 34	1 56.8	271.3
Zaamin	15 S.	39 56	68 26	20 47 49	22 3 19.5	22 5 17.7	23 27 31	328 47	22 4	1 58.2	271.2
Ura-tiube	2 S.	39 59	69 0	20 50 52	22 6 37.1	22 8 40.9	23 31 1	329 38	22 21	2 3.8	270.9
Nau	14 N.	40 8	69 22	20 52 56	22 9 10.5	22 11 5.1	23 33 21	330 10	22 29	1 54.6	270.6
Sanku	12 S.	39 15	71 13	21 1 38	22 18 49.6	22 20 58.0	23 44 25	332 14	24 9	2 8.4	270.8
E. TURKESTAN.											
Tagharma Peak	2 S.	38 30	74 32	21 19 56	22 39 10.3	22 41 18.2	0 6 7	336° 44'	26° 27'	2m 7.9s	270.2°
Posgam	8 S.	38 15	77 19	21 33 37	22 54 21.4	22 56 39.2	0 22 1	340 44	27 50	2 17.8	270.4
Yarkand	4 N.	38 25	77 21	21 33 37	22 54 37.4	22 56 54.5	0 22 11	340 48	27 41	2 17.1	270.3
------	3 N.	38 12	79 54	21 45 18	23 10 1.0	23 12 21.0	0 37 6	----	----	2 20.0	267.0
Cherchen	3 S.	38 2	85 33	22 20 39	23 44 50.8	23 47 12.6	1 12 31	353 55	30 14	2 21.8	267.3
MONGOLIA.											
Tsair-osu	2 N.	44 43	106 41	0 29 58	1 49 41.6	1 51 36.7	3 5 56	25 14	19 23	1 55.1	261.5

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *Silicon-fluoroform.*—By the action of silicon-chloroform upon tin and titanium fluorides, RUFF and ALBERT have succeeded in preparing the hitherto unknown silicon-fluoroform, $SiHF_3$. Titanium fluoride is preferable to the tin compound for the preparation of the new compound. The reacting substances were heated in a copper bomb or in a well dried sealed-tube of glass for 18 hours at 100–120°, and the resulting product was collected by condensing with liquid air. The reaction is as follows:

$$3TiF_4 + 4SiHCl_3 = 4SiHF_3 + 3TiCl_4.$$
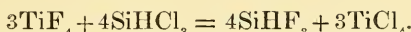
Silicon-fluoroform is a colorless gas which forms a liquid boiling at −80° and solidifying at about −110°. When brought into contact with sodium hydroxide solution it is decomposed with the liberation of an equal volume of hydrogen, according to the equation

$$SiHF_3 + 3NaOH + H_2O = Si(OH)_4 + 3NaF + H_2.$$
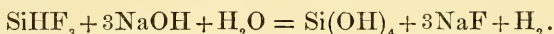
When heated in a closed tube to about 420° the gas is decomposed with deposition of silicon as follows:

$$4SiHF_3 = 2H_2 + 3SiF_4 + Si.$$
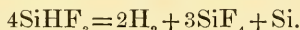
It is combustible in the air, and forms explosive mixtures with the same, possibly according to the equation

$$12SiHF_3 + 6O_2 = 3SiF_4 + 3SiO_2 + 4H_2SiF_6 + 2H_2SiO_3.$$
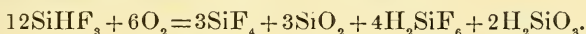
The preparation of silicon-fluoroform completes a series of halogen compounds in which the boiling-point rises rapidly with the atomic weight of the halogen as follows:

| Compound,	$SiHF_3$	$SiHCl_3$	$SiHBr_3$	$SiHI_3$
Boiling-point,	−80°	+33°	about 110°	about 220°

—*Berichte*, xxxviii, 52. H. L. W.

2. *Decomposition of Ammonium Sulphate by Hot Sulphuric Acid in the Presence of Platinum.*—It has been shown by DELÉPINE that the use of platinum sponge for regulating the boiling in the determination of nitrogen by Kjeldahl's method leads to a large or even a total loss of the ammonia. This fact has been confirmed by von Dam, who has shown that nitrogen gas escapes during the operation. The subject has now been studied further by Delépine, and the reaction has been satisfactorily explained by him. It was found that metallic platinum dissolves in strong, hot sulphuric acid, and that this solvent action does not depend upon the presence of nitrous acid as has been supposed. It was found also that in the presence of ammonium sulphate platinum sponge does not lose weight appreciably when treated with the hot acid, and it was shown that nitrogen gas and sulphur dioxide

were evolved under these circumstances in amounts exactly corresponding to the equation

$$(NH_4)_2SO_4 + 2H_2SO_4 = N_2 + 3SO_2 + 6H_2O.$$
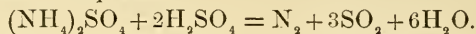
The part played by the platinum in the reaction is shown by the following equations:

$$4H_2SO_4 + Pt = Pt(SO_4)_2 + 2SO_2 + 4H_2O ;$$
$$3Pt(SO_4)_2 + 2(NH_4)_2SO_4 = 2N_2 + 3Pt + 8H_2SO_4.$$
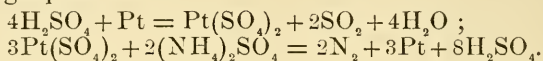
The truth of this interpretation was shown by the fact that a colored solution is obtained by treating platinum with sulphuric acid, and that this solution deposits most of its platinum when it is heated with ammonium sulphate. There is a further, indirect proof in the fact that sponges of metallic gold and iridium, which do not dissolve in sulphuric acid, cause no loss of ammonia under similar treatment.—*Bulletin*, xxxv, 8.   H. L. W.

3. *The Determination of Tellurous and Telluric Acids.*—To make these determinations BERG places the substance in a porcelain boat in a combustion tube which is drawn out in front, bent downward, and connected with two small U-tubes each containing 5^{cc} of water. Gaseous hydrochloric acid is then passed through the tube, and when the air has been expelled, the tube is rapidly heated below redness, while the current of gas is moderated, and thus tellurous chloride is formed and collected in the receivers. The liquid is transferred to a weighed porcelain capsule, 5^{cc} of pure nitric acid are added, the liquid is evaporated on a sand bath, and the residue is heated cautiously to decompose the basic tellurous nitrate without fusing the resulting oxide. Tellurous oxide is then weighed. When certain salts are thus analyzed, the metallic chloride remaining in the boat may be weighed. The author gives some satisfactory results obtained by this method.—*Bulletin*, xxxiii, 1310.   H. L. W.

4. *Manganese as a Fertilizer for Plants.*—The view was formerly held that the small quantities of manganese present in vegetable and animal substances were accidental and unnecessary, but recently many investigations have indicated that this metal is indispensable to the living cell. BERTRAND has recently shown by field experiments that the application of pure manganese sulphate to the soil at the rate of 50^{kg} per hectare showed a marked fertilizing effect upon a crop of oats, amounting to an increase of 22·5 per cent in the yield. An analysis of the crops to which manganese was applied showed no increase in its contents of the metal over the crop to which none was applied.— *Comptes Rendus*, cxli, 1255.   H. L. W.

5. *Conversations on Chemistry*, by W. OSTWALD. Authorized translation by STUART K. TURNBULL. Part II, *The Chemistry of the Most Important Elements and Compounds.* 12mo, pp. 373. New York, 1906, John Wiley & Sons.—The first volume of this work, by another translator, was recently noticed in this department of the Journal. Like its predecessor, the second part has many interesting and excellent features, and if the old conversa-

tional plan here adopted is approved, the book will be a good one for younger students of chemistry. H. L. W.

6. *Experimental Electro-Chemistry*, by N. MONROE HOPKINS. 8vo, pp. 284. (D. Van Nostrand Co., 1905.) Price, $3.00 net.— As the name indicates, this book deals more particularly with experimental electro-chemistry. The theory of electrolytic dissociation is presented with some experimental evidence to support it. Detailed directions are given for a number of electrolytic preparations. The action of primary and secondary cells is discussed and illustrated by experiments. An excellent bibliography of the more important works on electro-chemistry is given at the end. There are some rather surprising omissions. Thus, while two chapters are devoted to the theory of electrolytic dissociation, there is hardly a mention made of the electrical methods of measuring dissociation. Instead, the method depending on the depression of the freezing point is described in some detail, though this method is hardly to be classed under electro-chemistry.

H. W. F.

7. *Radiation from Ordinary Materials.*—NORMAN B. CAMPBELL sums up a paper on this subject, containing the results of work done in the Cavendish Laboratory, as follows : " If the object of this paper has been attained, it has been proved beyond doubt, that the emission of ionizing radiation is an inherent property of all the metals investigated ; and I see no reason why it should not be extended to all substances. It is not of course necessary that this ray emission should be identified at once with radio-activity—if that word be taken to mean a process of ray emission accompanied by atomic change. But the constant intensity of the rays and the probability that the greater proportion of them are a rays, which is suggested by the investigation of their charge and their penetration, afford considerable support for that hypothesis ; while I know of no other process which affords any analogy. But before the identity can be established irrefutably further work is required, which I hope to be able to supply in the future."—*Phil. Mag.*, No. 62, 1906, pp. 206–226.

J. T.

8. *Spark Potentials.*—Various observers have compiled tables of such values for the information of electrical engineers. M. TOEPLER gives the following table as the result of recent investigation.

Sparking distance in cm.	5	10	15	20	25	30	35	40	45
Kilovolt observed	31·6	46·6	63·1	78·9	94·6	112·2	125·1	139·1	153·8
Kilovolt calculated by Walter	31·6	47·1	62·7	78·2	93·8	109·3	124·9	140·4	156·0
Kilovolt calculated by Toepler	27·97	46·38	63·20	79·24	94·75	109·88	124·73	139·38	153·82

—*Ann. der Physik*, No. 1, 1906, pp. 191–209. J. T.

9. *Measures of Radiation in relation to Resonators in the Region of Short Electric Waves.* — It has been noticed by F. Kirchener that the optical properties of Lippeman's emulsion are changed when the emulsion is moistened ; and he explains this by the supposition that the swimming silver particles act as electrical resonators and that their time of vibration is changed by the increase of distance apart. M. PAETZOLD has studied the effect of gratings interposed between the electrical exciter and receiver of short electrical waves, guided by the analogy conceived by Kirchener. The gratings were placed at various distances from the receiver and at different angles. When a strait rod exciter was used to produce the waves, a wave component was discovered in a plane perpendicular to the exciter which differed 90° in phase from the ordinary component. The effect of a grating in certain positions is to produce often a combined effect of received and emitted radiations.—*Ann. der Physik*, No. 1, 1906, pp. 116–137.   J. T.

10. *Electrical Rectifier.*—In previous papers A. WEHNELT has described a rectifier for alternating currents which serves the purpose of the Cooper Hewitt mercury rectifier, or the Gratz aluminium rectifier. The cathode is covered with certain oxides which greatly diminish the cathode fall of potential. Such an electrode he terms oxide electrode. When this oxide electrode is properly heated and made the cathode, the difference of potential can be made only 18·20 volts, while if the neighboring cold anode is made the cathode, the potential rises to many thousand volts. The electrical current, therefore, will pass readily in one direction and with great difficulty in the opposite direction. Wehnelt ascribes the performance of the rectifier to an increase of ionization at the oxide electrode.—*Ann. der Physik*, No. 1, 1906, pp. 138–156.   J. T.

II. GEOLOGY AND MINERALOGY.

1. *United States Geological Survey. Twenty-sixth Annual Report, 1904–1905, of the Director*, CHARLES D. WALCOTT. 322 pp., 26 maps.—The volume contains besides the executive and financial statements brief reports from the chiefs of parties upon the scientific results of the year's work. The three great branches of work carried on by the Survey are the geologic, topographic and hydrographic. Connected with the latter is the Reclamation Service, by means of which considerable tracts of arid land will ultimately be brought under cultivation.

It is of interest to note the amount of the appropriations to the several divisions, as these are in some measure indicative of the lines along which the work of the Survey is being at present chiefly pushed. The entire appropriation aggregated $1,484,820, of which 309,200 was assigned for topographic work, 188,700 for geologic work, 14,000 for paleontologic work, 23,000 for chemical work, 200,000 for gauging streams, 50,000 for preparation of report

on mineral resources, 130,000 for survey of forest reserves. The preparation and printing of maps and reports also aggregates a large amount. In addition 80,000 was appropriated for continuation of the investigation of the mineral resources of Alaska and 60,000 for testing coals.

Among the many interesting results of the year's work may be singled out the finding on Cape Lisburne of 15,000 feet 0f Jurassic strata containing 150 feet of Jurassic coal distributed in over forty beds, at least ten of which are four feet or more in thickness, the first Jurassic coal to be found in Alaska. In addition the Carboniferous was found to contain some coal, being the only Paleozoic coal of economic value known in America west of the Rocky Mountains. The coal and petroleum deposits about Controller Bay have also been found to be of importance.

Under the subject of topography it is noted that the total area of new surveys was 21,296 miles, making a total of 955,996 miles surveyed, or 32 per cent of the area of the United States. Those familiar with the maps will have noticed the improved quality of those issued in recent years.

Sixteen folios, forming Nos. 110 to 125 of the geological atlas of the United States, have been published during the past year.

In the investigation of the mineral wealth of the United States and the education of the mining public in regard to the nature of economic deposits with consequent economization of time and money in their exploitation, the Survey has justified itself many times over ; but its chief claim for world-wide recognition is founded on the more purely scientific work done, which in the past quarter century has contributed either directly or indirectly more than any other one factor toward the advances of modern geology. J. B.

2. *U. S. Geological Survey. Recent Publications.*—The following list contains the titles of recently issued publications.

TOPOGRAPHIC ATLAS.—Ninety-nine sheets.

FOLIOS—No. 127. Sundance Folio : Wyoming–South Dakota. Description of the Sundance Quadrangle : by N. H. DARTON. Pp. 12, with 5 colored maps and 9 figures.

No. 128.—Aladdin Folio: Wyoming–South Dakota–Montana ; by N. H. DARTON and C. C. O'HARRA. Pp. 8, with index map and 4 colored maps. Washington : 1905.

No. 129.—Clifton Folio : Arizona; by WALDEMAR LINDGREN. Pp. 13, with 4 colored maps.

PROFESSIONAL PAPERS.—No. 37. The Southern Appalachian Forests ; by H. B. AYRES and W. W. ASHE. Pp. 291, with 37 plates, two figures, and two colored maps.

No. 40.—The Triassic Cephalopod Genera of America ; by ALPHEUS HYATT and JAMES PERRIN SMITH. Pp. 394, with 85 plates and one figure.

No. 43.—The Copper Deposits of the Clifton-Morenci District, Arizona; by WALDEMAR LINDGREN. Pp. 375, with 25 plates, 19 figures, and one colored map.

Mineral Resources of the United States. Calendar year 1904; by DAVID T. DAY, Chief of Division of Mining and Mineral Resources. Pp. 1264, with two plates.

BULLETINS. — No. 265. Geology of the Boulder District, Colorado; by N. M. FENNEMAN. Pp. 101; v, with 5 plates and 11 figures.

No. 268.—Miocene Foraminifera from the Monterey Shale of California; by RUFUS M. BAGG, JR. Pp. 78; v, with 9 plates and two figures.

No. 270.—The Configuration of the Rock Floor of Greater New York; by WILLIAM HERBERT HOBBS. Pp. 96; v, with 5 plates and 6 figures.

No. 272.—Taconic Physiography; by T. NELSON DALE. Pp. 49; III, with 14 plates and 3 figures.

No. 273.—The Drumlins of Southeastern Wisconsin (Preliminary Paper); by WILLIAM C. ALDEN. Pp. 43; III, with 9 plates and 8 figures.

No. 276. — Results of Primary Triangulation and Primary Traverse, Fiscal year 1904–5; by SAMUEL S. GANNETT. Pp. 263; III with 1 plate.

WATER SUPPLY AND IRRIGATION PAPERS. — No. 123. Geology and Underground Water Conditions of the Jornada del Muerto, New Mexico; by CHARLES ROLLIN KEYES. Pp. 42; V, with 9 plates and 11 figures.

No. 137.—Development of Underground Waters in the Eastern Coastal Plain Region of Southern California; by WALTER C. MENDENHALL. Pp. 140; III, with 7 plates and 6 figures.

No. 138.—Development of Underground Waters in the Central Coastal Plain Region of Southern California; by WALTER C. MENDENHALL. Pp. 162; III, with 5 plates and 5 figures.

No. 139. — Development of Underground Waters in the Western Coastal Plain Region of Southern California; by WALTER C. MENDENHALL. Pp. 103; III, with 8 plates and one figure.

No. 140.—Field Measurements of the Rate of Movement of Underground Waters; by CHARLES S. SLICHTER. Pp. 119; III, with 15 plates and 67 figures.

No. 142.—The Hydrology of San Bernardino Valley, California; by WALTER C. MENDENHALL. Pp. 124; III, with 12 plates and 16 figures.

No. 147.—Destructive Floods in the United States in 1904; by EDWARD CHARLES MURPHY AND OTHERS. Pp. 206; II, with 18 plates and 19 figures.

No. 150.—Weir Experiments, Coefficients and Formulas; by ROBERT E. HORTON. Pp. 189; I, with 38 plates and 16 figures.

No. 151.—Field Assay of Water; by MARSHALL O. LEIGHTON. Pp. 76; III, with 4 plates and 3 figures.

No. 152.—A Review of the Laws Forbidding Pollution of Inland Waters in the United States. Second edition; by EDWIN B. GOODELL. Pp. 149; III.

3. *The Triassic Cephalopod Genera of America ;* by ALPHEUS HYATT and JAMES PERRIN SMITH. Prof. Papers, No. 40, U. S. Geol. Surv., 1905, 214 pp., 85 pls.—This extensive monograph of marine Triassic cephalopod genera is practically the work of the junior author, " but the inspiration and general supervision of the work was [the late] Professor Hyatt's contribution." "In this work every genus of cephalopods known to occur in American Triassic strata is described, and a representative species under each one is described and figured."

The marine Triassic development of Idaho, Nevada, Oregon, and California is unusually complete. The lower (800′), middle (1000′), and upper (2000′) members " are represented by calcareous deposits, aggregating approximately 4,000 feet in thickness." In addition to a summary statement of the various sections and their cephalopod species, this work defines in detail 85 genera (20 new) and 88 species (66 new). For many of the species the stages of growth are also described. Of the genera, 80 are Ammonoidea, 1 belongs to the Belemnoidea, and 4 are Nautiloidea. Of the ammonoid genera, 22 are restricted to western North America ; the rest are also found either in Europe or Asia. Fifteen are common to America and Asia, 10 to Europe and America, and 33 to the three regions. Of species, 7 ammonoids and 1 nautiloid are common to the Alps and America.

From these statements, it is seen that the ammonoids are very widely distributed, and as early as Triassic time are, as is well known, likewise excellent horizon markers, not only for closely adjoining regions, but also for inter-continental correlations.

This work is of great value, not only to the student of the Ammonoidea, but as well to the stratigrapher of Triassic formations. c. s.

4. *Miocene Foraminifera from the Monterey Shale of California ;* by RUFUS M. BAGG, Jr. Bull. No. 268, U. S. Geol. Surv., 1905, 55 pp., 11 pls.—The Monterey shale is from 2000 to 2500 feet thick. The bulk is made up of diatom skeletons, but there is also present an abundance of well-preserved Foraminifera. The clay marl of Graves Creek, San Luis Obispo County, has yielded a fauna of 66 species in 17 genera. There are no arenaceous genera, warm-water Miliolidæ, and but one Nummulite, but a large number of rotaline types are present. This faunal composition, the author states, " shows the purity of the waters in oceanic circulation," and less than 500 fathoms deep. Most of the species are those of living forms. The illustrations are excellent. c. s.

5. *North Carolina Geological Survey. Vol. I, Corundum and the Peridotites ;* by J. H. PRATT and J. V. LEWIS. 8°, pp. 464, pl. xlv, figs. 35. Raleigh, 1905.—This volume presents very fully the geology, petrology and mineralogy of the belt of corundum-bearing rocks of western North Carolina. The peridotites and associated basic magnesian rocks are first taken up and the

various occurrences in the state are described with the aid of maps, sections and illustrations. Then follows a complete petrographic study of these rocks accompanied by many analyses. Their modes of alteration and decomposition and their origin are discussed, and this is succeeded by a mineralogical description of the North Carolina corundum together with an account of its technical properties and uses. The authors then describe its modes of occurrence in this region and elsewhere, following this with a statement of its distribution. Next comes a chapter devoted to the alteration of corundum and a study of the minerals associated with it, which contains a large amount of detailed observations upon many species. The work is concluded with an account of the chromite and other economic minerals of the peridotitic rocks of the region.

While a considerable part of the matter here given has, in more or less condensed form, been previously published elsewhere, especially in this Journal, the rest of it is new and the whole thus collected forms a most valuable compendium of the peridotitic rocks of the region and their associated minerals. As such it is, not only of local, but of general interest and will prove of service to the mineralogist, the petrographer and the economic geologist. The volume is well printed and illustrated and is a handsome specimen of the bookmaker's art.   L. V. P.

6. *Cancrinite-Syenite from Kuolajärvi;* by I. G. SUNDELL. Bull. Comm. Geol. de Finlande, No. 16, 1905, 20 pp.—The author has analyzed this rare and interesting rock type previously described by Ramsay and Nyholm (Ibid., No. 1, 1895), and the results of the work, which has been carried out in detail with great care, are as follows :

SiO_2, Al_2O_3, Fe_2O_3, FeO, MgO, CaO, Na_2O, K_2O, H_2O, CO_2, TiO_2
52·25, 20·46, 3·82, 0·68, 0·14, 2·39, 10·05, 6·18, 1·83, 1·69, 0·32 = 100·15

This includes traces, or minute quantities, of ZrO_2, NiO, MnO, SrO, BaO, P_2O_5 and SO_3, which total 0·34. The low silica and very high alkalies are notable. The calculation of the mineral composition shows that it contains nearly 27 per cent of cancrinite.   L. V. P.

7. *Opal Pseudomorphs from White Cliffs, New South Wales ;* by C. ANDERSON and H. STANLEY JEVONS.—The authors offer the latest explanation of these interesting pseudomorphs which in recent years have engaged the attention of a number of mineralogists. They show that the original mineral must have been monoclinic, with a good cleavage perpendicular to the symmetry plane, with certain interfacial angles and characterized by a certain geological mode of occurrence. It could not, therefore, have been either gypsum, sulphur, anhydrite or celestite, and the writers believe that glauberite, the sulphate of soda and lime, most nearly fills the required conditions and was the original mineral. (Records Austr. Mus., vol. vi, Pt. I, pp. 31–37, 1905.)
                    L. V. P.

8. *The Physical Geography, Geology, Mineralogy and Paleontology of Essex County, Massachusetts;* by JOHN HENRY SEARS. 1905, pp. 418, figs. 209, map in pocket. Salem, Mass. (Published by the Essex Institute.)—The region described in this handsome volume is both interesting and exceptionally varied from the geological point of view, especially as regards its igneous rocks and glacial geology. The author's intimate acquaintance with the county, based on many years of residence and study, renders his exposition detailed and authoritative. The numerous good illustrations are mostly from photographs, the type and paper irreproachable, and the publication is a valuable contribution to the geology of the Eastern States and highly creditable alike to its author and to the Essex Institute.   H. S. W.

9. *Lead and Zinc Deposits of Virginia;* by THOMAS L. WATSON. Geol. Survey of Virginia, Geol. Series Bulletin, No. 1. Pp. 156 with 14 plates and 27 figures, 1905.—This is an interesting account of the important lead and zinc deposits of Virginia, with a discussion on the genesis of the ores and the methods employed in mining and smelting. The lead and zinc mines group themselves into two divisions : (1) those of southwest Virginia limited to the Great Valley region and (2) those of the crystalline belt, or Piedmont region, east of the Blue Ridge mountains ; almost all the ore production has been from the former region. The estimated annual output from the Virginia mines, from 1894 to 1903, is given as not exceeding 15,000 tons ; the minerals forming the bulk of this are smithsonite and calamine.

10. *Asbestos : its Occurrence, Exploitation, and Uses ;* by FRITZ CIRKEL, M.E. Pp. 169, with 19 plates. Ottawa, 1905. Mines Branch, Department of the Interior.—The asbestos industry of Canada, which had its beginning in 1877, has now attained such magnitude that this monograph on the subject is of particular interest. The author states that there are now sixteen mills, with a capacity of 3500 tons per day, in active operation and that there is every prospect of this output being largely increased in the course of the present year.

Of the two mineral species included under this name, the only one which has any importance in Canada and the one which has proved to be much the more useful in application to the arts, particularly because of its relative strength of fiber, is the fibrous variety of serpentine, called chrysotile. The fibrous variety of amphibole, corresponding mostly to tremolite and in part to actinolite, while mined to some extent in Italy and elsewhere, and occurring in Hastings County, Ontario, has proved to be of much less importance. Fibrous serpentine occurs in the Laurentian formation, in the Templeton area, north of Ottawa, in connection with serpentinous limestone, and also in the eastern townships in the Province of Quebec. Deposits in the former area have been to some extent exploited, but without any great success. The region in which active work has been carried on now for nearly thirty years is that south of Quebec, including Thet-

ford, Black Lake area, and the Danville, Orford and Potton area not far distant to the southwest. The serpentines here are disconnected masses, generally of small extent, in the series of slates, schists and diorites designated as a part of the Cambrian. Serpentine also occurs extensively in the Gaspé Peninsula, but this region has not been developed to any considerable extent. A full account is given in this volume of the separate mines and the methods of working them; the various commercial purposes to which asbestos can be applied are also explained at length. It is now found possible to spin asbestos threads so that one, for example, weighing not more than an ounce per hundred yards, has a fair degree of strength. Asbestos cloth and rope are extensively made, and the material is also used for roofing and numerous other purposes, most of them equally familiar.

11. *The Cobalt-Nickel Arsenides and Silver Deposits of Temiskaming;* by WILLET G. MILLER, Provincial Geologist. Pp. 66. Toronto : L. K. Cameron, 1905. Report of The Bureau of Mines, 1905. Part II. Thomas W. Gibson, Director.—The remarkable development of the nickel industry in Canada lends interest to this report of a new deposit of cobalt-nickel arsenides and silver, discovered during the year 1904, during the building of the Temiskaming and Northern Ontario Railway. The minerals identified are native silver, smaltite, niccolite and chloanthite, and associated with these several silver and cobalt minerals of rarer occurrence. The veins are narrow, some 10–12 inches in width, and the ore from the silver-bearing veins is stated to contain 11·4 per cent of silver, 11·3 per cent of cobalt, while that from the veins not carrying silver shows 15·6 per cent of cobalt and 7·0 per cent of nickel. The veins occupy vertical cracks and fissures, cutting across the slightly inclined conglomerate slate series of the Lower Huronian.

12. *Economic Geology of the United States;* by HEINRICH RIES ; 435 pp., 25 pls., 97 figs. New York, 1905 (The Macmillan Company).—This recent publication by Professor Ries of Cornell University is another indication of the increasing consideration given to Economic Geology as an important department of the general subject of geology. An elementary text-book for class room use was greatly needed in this subject and the present book admirably fills that need. The book is about equally divided into two parts : Part I treats of non-metallic minerals and includes, besides others, chapters on coal, petroleum, etc., on building stones, clay, lime and cements, on salines, gypsum, fertilizers, and abrasives; Part II discusses the metallic minerals and, besides a chapter of general discussion on the subject of ore bodies and their formation, includes chapters which in turn treat of the occurrences of the important metals. The book is well and profusely illustrated with maps, geological sections, tables and half-tone engravings. A valuable feature is the long list of references which is given at the end of each chapter and which includes all the important papers dealing with the subject of the chapter.

<div align="right">W. E. F.</div>

13. *Handbuch der Mineralogie ;* von Dr. Carl Hintze. Erster Band. Elemente, Sulphide, Oxyde, Haloide, Carbonate, Sulfate, Borate, Phosphate. Neunte Lieferung. Pp. 1281–1440, with 30 figures. Leipzig, 1905 (Von Veit & Comp.).—The successive issues of Hintze's monumental work are always welcome even if they appear only at long intervals. The present part is entirely devoted to the species of quartz.

III. Miscellaneous Scientific Intelligence.

1. *Reports on the Scientific Results of the Expedition to the Eastern Tropical Pacific in charge of Alexander Agassiz, by the U. S. Fish Commission "Albatross," from October, 1904, to March, 1905, Lieut. Commander L. M. Garrett, U. S. N., commanding.*

General Report of the Expedition by Alexander Agassiz. Published as vol. 33, Memoirs of the Museum of Comparative Zoology at Harvard College. Cambridge, 1906, 75 pp., 96 plates and eight figures in the text.—The area selected for this cruise of the " Albatross " included the vast tract of the Eastern Pacific, some 3000 miles in latitude by 3500 in longitude, between Acapulco, the Galapagos Islands, Callao, Easter Island and Manga Reva, the easternmost of the Paumotu or Low Archipelago. The survey consisted in running lines between these points. There is no other oceanic area situated at so great a distance from a continental area and interrupted by so few islands.

But little was previously known of the hydrography of this area, only a few casual deep-sea soundings having been previously taken far from land. The biological material is now in the hands of specialists, but among the results already evident may be mentioned the localized extension of the abyssal oceanic fauna far from shore and its dependence upon the pelagic food derived by settling from the photobathic zone or brought to it by the great oceanic currents. Over an immense tract south of the Humboldt current running from near the Low Archipelago to within about ten degrees of the South American coast, the whole of the bottom area is barren of animal life and forms a great desert upon which drop the carcasses of a poor pelagic area.

Turning to the soundings, it is noted that 160 were taken, the Lucas sounding-machine being used, or about one per day, distributed over a distance of about 13,000 miles. The area is comparatively shallow, varying generally from 1800 to 2300 fathoms. The survey served to delimit the Albatross Plateau, named by the Challenger expedition, and to separate a new basin, named the Bowers Basin, lying off Callao, from the indefinitely known Buchan Basin located by the Challenger expedition.

This expedition has added a great deal of definite knowledge to the oceanography of this area : an inconsistency in the bathymetrical chart, Plate I, must however be noted, the Moser Deep and the Grey Deep being separated by a *single* 2500 fathom contour line. This inconsistency further results in the Moser Basin

being delimited by a 2500 contour line and lying within a much larger basin also bounded by a 2500 line. This region, however, lies outside of the present survey.

Plates 15 to 91 are most excellent reproductions, by the Helio-type Printing Company, from photographs of Sola y Gomez and Easter Islands, the Gambier Islands and Chatham Island. These give a good scenic idea of these little known lands and will be valuable for future reference. Numerous photographs of the stone effigies of Easter Island are also given. It must be said, however, that but little use has been made of many of the views in this report, some being of minor scientific value and repetitions being embodied of the same general landscape from slightly different points of view. It is realized that the time spent at these islands in coaling was brief and that land geology was not an object of the expedition. Nevertheless this part of the report would have been much improved by a fuller interpretation of the physiography of the lands represented, with possibly sketches to aid in interpreting certain of the photographs.

It is noticeable that the topography of Easter Island is very much softened, except in the case of a few of the craters, notably Rana Kao, 1327 feet high. The Gambier Islands, on the contrary, as noted by Agassiz, show a greater degree of dissection and especially many precipitous slopes, cliffs of 800 to 1300 feet rising within a horizontal distance of an eighth to a quarter of a mile. One of the most striking features however, as seen in the photographs, is a horizontal bench on the sides of Mount Duff at an elevation of from 300 to 325 feet above the sea (see plates 57 and 64). This has all the appearance of an old sea beach facing a cliff a thousand feet in height, but no mention is made of it in the report.   J. B.

2. *Carnegie Institution of Washington. Year Book, No. 4,* 1905. Pp. VIII, 303, with 7 plates and 4 figures. Washington : 1906.—The Fourth Year Book of the Carnegie Institution contains the usual statement in regard to the work that has been carried forward through the year, and gives also brief reports and abstracts of investigations that are now under way. During the year 1904–5 upward of $300,000 were devoted in large grants to important investigations in eleven different subjects, and $130,000 to about forty investigations of a minor grade. The Executive Committee has reached the conclusion that the policy of awarding numerous small grants is likely to break down in consequence of the importunities of those seeking them and the difficulty of the work of administration ; further such awards are regarded as, in general, not for the real benefit of the educational institutions concerned. On the contrary, the larger grants are not thus open to criticism and they seem to be those for which the available income can be most advantageously devoted. Of new projects under consideration are mentioned : an Astronomical Observatory in the Southern Hemisphere, and a Laboratory for Geophysical research at Washington. There can be no question but that the decision of the management is

wise in thowing the chief benefits of this fund in the directions named.

The following are recent publications : No. 38.—Writings on American History : 1903. A Bibliography of Books and Articles on United States History published during the year 1903, with some Memoranda on other Portions of America, prepared by A. C. McLaughlin, W. A. Slade, and E. D. Lewis. Pp. 172.

No. 42.—A Respiration Calorimeter with Appliances for the Direct Determination of Oxygen ; by W. O. Atwater and F. G. Benedict. Pp. 193, with 49 figures.

No. 45.—Catalogue of Stars within Two Degrees of the North Pole, reduced from Photographic Measures made at Vassar College Observatory ; by Caroline E. Furness, Ph.D. Pp. 85, with 16 tables.

3. *Report of the Secretary of the Smithsonian Institution for the year ending June 30, 1905 ;* by S. P. Langley.—The functions of the Smithsonian Institution are so varied and important that much interest attaches to the advance Report giving a statement of what has been accomplished by the Smithsonian Institution during the year ending June 30, 1905. In addition to the work upon the new Museum, which is progressing steadily, a mortuary chapel has been constructed to contain the tomb of James Smithson, whose remains were brought from Italy in January, 1904. Of the work done outside of Washington may be mentioned the archeological exploration of Dr. Fewkes in Mexico, the expedition to Alaska by Mr. A. G. Maddren and the glacier expedition on the Canadian Rockies and Selkirks under the direction of Prof. W. H. Sherzer. As usual, the Astrophysical Observatory has carried on some important investigations, particularly in the measurement of solar radiation; in regard to this, Mr. C. G. Abbot remarks: "The work of this and the two preceding years strongly supports the view that the radiation of the sun is frequently diminished and augmented for periods of a few weeks or months, in consequence of a variability of the transparency of the solar absorbing envelope, and that this variation of radiation causes and quickly produces changes of several degrees in the mean temperature of the land areas of the earth. It is hoped that the study of the solar radiation will soon prove a valuable aid in forecasting climate.

4. *Report of the Superintendent of the Coast and Geodetic Survey, showing the Progress of the Work from July 1, 1904, to June 30, 1905 ;* by O. H. Tittmann. Pp. 347, with 8 illustrations.—This volume gives the usual summary of the work of the Survey during the year, including what has been done in the outlying dependencies, especially in the Philippines. These results are summarized by the superintendent in the opening chapter, and discussed in detail in the appendixes which follow. The most noteworthy result accomplished is the completion of the line of precise levels connecting the Atlantic Ocean at Sandy Hook and the Gulf of Mexico at Biloxi, Miss., with the Pacific

Ocean at Seattle. Appendix III contains an account of magnetic observations made under the charge of Dr. L. A. Bauer; this special report has also been issued in separate form. It is stated that there have now been obtained exact magnetic data for determining the distribution of the magnetic elements and their secular change throughout the United States, so that a new set of charts may soon be expected for the year 1905. In regard to the secular change of magnetic declination, it is noted that at present the line of no annual change does not differ much from the agonic line, and that in general both the east and west declination are increasing.

5. *Publications of the United States Naval Observatory.* REAR ADMIRAL COLBY M. CHESTER, U. S. N., Superintendent. Second series. Volume IV, Appendix I. Pp. 307, with 69 plates. Washington, 1905.—This important volume is devoted to a discussion of the total solar eclipses of May 28, 1900, and May 17, 1901. The plates representing the corona, both from photographs and drawings, are most interesting.

6. *Bureau of American Ethnology.*—The following publications have been recently received :

Twenty-third Annual Report of the Bureau of Americal Ethnology to the Secretary of the Smithsonian Institution 1901–1902. Pp. xlv, 634. Washington, 1904.

Bulletin No. 28 : Mexican and Central American Antiquities, Calendar Systems, and History. Twenty-four papers by EDUARD SELER, E. FÖRSTEMANN, PAUL SCHELLHAS, CARL SAPPER, and E. P. DIESELDORFF ; translated from the German under the supervision of Charles P. Bowditch. Pp. 682, with 48 plates and 134 figures. Washington, 1904.

Bulletin 29 : Haida Texts and Myths, Skidegate Dialect ; recorded by JOHN R. SWANTON. Pp. 448, with 5 figures. Washington, 1905.

7. *Bulletins of the United States National Museum.* No. 54. —A Monograph on the Isopods of North America; by HARRIET RICHARDSON. Pp. liii ; 727, with 740 figures.

No. 55.—A Contribution to the Oceanography of the Pacific; by JAMES M. FLINT. Pp. 61, with 12 plates.

8. *Mazama: A Record of Mountaineering in the Pacific Northwest.* Vol. 2, No. 4. December, 1905. Pp. 284.—The Annual Number of "Mazama," published in December, 1905, contains several valuable and well illustrated articles on the high peaks of the northwest, particularly as regards their glaciers. Detailed views are given of ice pinnacles on Mt. Hood, and the various features of the ice and snow of Mt. Ranier. These descriptions have much more than a local interest.

9. *Elementary Mechanics;* by GEORGE A. MERRILL, B.S., Director of the Wilmerding School of Industrial Art, San Francisco. Pp. 267. New York, 1905 (The American Book Co.).— The usual topics treated in a work of this character are here presented with much clearness and freshness. The author relies on illustrations and numerical applications to the exclusion of all formal proofs. The numerical exercises are well chosen but limited in number.

MASTODON AMERICANUS, Cuvier.

(The "Shawangunk Skull")

A large public museum, for which we are now mounting a
Mastodon skeleton, has asked us to find a sale for a cast of
the head of this species which the actual skeleton will replace,
as well as for another large cast which is crowded out through
lack of floor-space. The former is figured above, and the
latter is our restoration of the giant tortoise, Colossochelys
atlas, from the Pliocene of the Siwalik Hills, India. Both
of these casts we furnished to the museum a few years ago.
They are to-day in excellent condition, but in order to effect
an immediate sale are offered at a reduced price. Full details
will be sent to anyone interested in their purchase.

Circular 59, just issued, lists casts of fossil mammals
and birds, suitable for museums and colleges. Send for
complete list of our circulars in all departments of natural
history.

Ward's Natural Science Establishment,

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CONTENTS.

SCIENTIFIC INTELLIGENCE.

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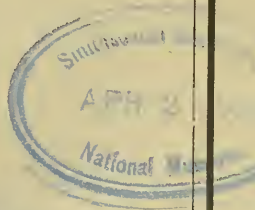**FOURTH SERIES**

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ART. XIX.—*Some Peculiarities of Rock-Weathering and Soil Formation in the Arid and Humid Regions;* by E. W. HILGARD.*

SOME of the differences in the processes and the results of weathering in the arid and humid regions respectively have been long commented upon; but we do not find anywhere a measurably full discussion of the subject. I have discussed the various phases as observed by myself, in various publications; but I desire to give in this place a summary of the points noted, especially as regards soil-formation, and the conclusions to be drawn therefrom.

The potent effects of water upon both the mechanical and chemical processes of rock decomposition being well understood, the relative scantiness of rainfall in the arid regions leads us at once to expect a slower rate of decomposition of rocks and of their component minerals under the arid régime. The old observation of the freshness of the surfaces of half-finished obelisks in the quarries of Syene, and the good conservation of the same in the obelisks of Lower Egypt under slightly more humid conditions, as compared with the fate of Cleopatra's Needle at New York, are familiar to all. It is not, of course, moisture alone, but very essentially the temperature conditions accompanying both its abundance and scarcity, that are concerned in the effects produced.

Aridity being intimately correlated with the existence of deserts, we are at once led to associate sand and dust with arid conditions. The dust storms of the arid regions are as proverbial as are the sands of the desert; and the latter are in the public mind the symbol of sterility. It is only of late that

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the almost invariable high productiveness of the desert sands under irrigation is becoming a somewhat familiar conception, yet accepted with difficulty because in the more familiar humid region, " poor sandy lands " are a well-authenticated fact, and a " strong " or " substantial " soil is one containing a more or less considerable proportion of clay.

The reasonableness of this popular idea is well illustrated in the investigation made years ago by Dr. R. H. Loughridge,* of a very generalized loam soil covering the uplands of Kentucky, of Tennessee, Mississippi, and Louisiana east of the Mississippi river. In this investigation it was shown that by far the greater portion of the recognized plant-food ingredients was contained within the impalpable portion, viz., the " clay " and finest silts, only an insignificant amount being found in the " sandy " portion of the soil. The extreme poverty of the sandy lands of Florida, as shown by analyses subsequently made by him, fully corroborated these points for the humid region of the cotton states at least. And in Europe, the sandy lands of the northern plain are equally sterile without fertilization.

How is it then that the sands and dust of the arid region are so highly productive so soon as irrigated?

A comparative microscopic examination of sands from Florida and that from the arid deserts at once reveals the difference, which is equally accentuated by their chemical analysis. While the Florida or Mississippi soil sand under the microscope shows almost wholly quartz grains with clean, polished surfaces, the typical desert sand shows a great variety of minerals in granular form, coated with half-decomposed, finely pulverulent mineral matter, which also constitutes the " dust " portion of the material. Analyses made of the coarse and fine portions of such soils by Mr. L. M. Tolman † and by E. C. Lea (unpublished), proved that the surface-covering of the coarse sand grains was practically of the same composition as the fine dust itself. The subjoined table shows that in the typical upland clay loam from Mississippi (a soil noted for its high product of cotton) dissolution of soil ingredients substantially ceased when a diameter of only $\cdot 036^{mm}$ of the soil granules was reached; while from that limit, in the coarser portions of the California soils, obtained by the same process of hydraulic eleutriation, and up to half a millimeter diameter, there was not only no diminution but an actual increase of acid-soluble matters.

It thus appears that while in the humid Mississippi soil, solubility of plant food practically ceased above a grain-diameter

* This Journal, Jan. 1874.
† Rep. Calif. Exper. Station for 1898–1901, p. 33.

of ·036^{mm}, in the arid California soils as large an amount was found in the sand-grain sizes between ·12 and ·50^{mm} as in the ·016 to ·025^{mm} silt of Mississippi.

How does this radical difference between the sands of the arid and humid regions come about? The pulverulent nature of the soils formed under arid conditions supplies the answer. The binding material, the " clay," that forms so important a character of the prevalently clayey and loamy soils of the humid region, is in the properly arid soils present in minute proportions only; except of course where clays from prexisting clay formations have taken part in soil formation, or where,

Sediments.	Per cent in Soil.	Potash.	Lime.	Magnesia.	Phosphoric Acid.	Soluble Silica.	Alumina.	Total soluble.
Colloidal clay, ? diameter.								
Mississippi	21·64	·32	·03	·29	·04	7·17	3·97	11·82
California (Chino)	7·60	·16	·14	·17	·04	1·70	1·35	3·56
California (Jackson)	16·43	·13	·12	·08	·05	2·83	2·13	5·34
Very fine silt, ·016^{mm} diam.								
Mississippi	35·10	·41	·15	·36	·07	2·87	1·36	5·22
California (Chino)	18·53	·24	·53	·29	·06	4·96	1·76	7·84
California (Jackson)	34·90	·10	·04	·08	·02	2·50	2·44	5·18
Fine silt, ·016–·025^{mm} diam.								
Mississippi	13·67	·12	·09	·10	·02	·32	·17	·82
California (Chino)	5·49	·05	·11	·02	·01	·80	·51	1·50
California (Jackson)	9·96	·08	·04	·10	·01	1·01	1·01	2·25
Silt, ·025–·036^{mm} diam.								
Mississippi	---	--	--	-- ·36 --		--	--	·36
California (Chino)	3·92	--	--	--	--	--	--	lost
California (Jackson)	7·68	·06	·02	·05	·01	·82	·74	1·70
Silt, ·036–·047^{mm} diam.								
California (Chino)	6·40	·05	·18	·07	·01	·80	·55	1·66
California (Jackson)	8·21	·04	·01	·003	·001	·43	·64	1·22
Coarse silt, ·047–072^{mm} diam.								
California (Chino)	7·92	·06	·20	·03	·02	·89	·59	1·79
California (Jackson)	5·91	·03	·01	·01	·003	·42	·30	·77
Fine sand, ·072–·120^{mm} diam.								
California (Chino)	11·87	·06	·26	·10	·03	·98	--	1·43+
California (Jackson)	4·03	·01	·01	·005	·003	·28	·09	·408
Coarser sand, ·120–·050^{mm} diam.								
California (Chino)	36·11	·11	·69	·12	·04	2·43	1·59	4·98,
California (Jackson)	10·10	--	--	--	--	--	--	not detd.

as in swamps or marshes, humid conditions exist in the arid region as well.

Since kaolinization, which must precede the formation of colloidal, plastic clay material, is essentially a process of hydration, the presumption is that it will progress more slowly in regions of deficient rainfall. That this is actually the case can hardly be questioned by any one who has studied comparatively the results of rock decay in both the arid and humid regions; the contrary assertion, lately made, cannot, so far as I know, be supported by any facts properly observed and interpreted. The contrasts between the condition of the granites and granodiorites on the upper portions and the lower slopes of the Sierra Nevada and of the Sierra Madre of southern California, and still more between the latter and the southern Alleghenies, are so strongly accentuated as hardly to require discussion. The enormous deposits of almost fresh granitic sand at the base of the southern arid ranges, so coarse that the trees and seeds must be planted far below the surface in order to maintain life, while in the Alleghenies a clay subsoil formed in place lies within a foot of the surface on which the planting is done, are a practical demonstration of the greater intensity of clay-formation in the humid regions.

These differences in characters of the regolith of the two regions may be schematically illustrated in a diagram. This would show that in the humid region the humous "soil" as a rule extends only from six to nine inches from the surface, these being the depths prescribed by the Eastern Experiment stations for the taking of samples of "surface soil"; beneath which follows almost invariably a more clayey subsoil, which as a rule is unadapted to the growth of crops, so that not more than half an inch of it is allowed to be plowed up to the surface at once, on pain of spoiling the seed-bed for the succeeding season at least. No such restriction applies to the typical arid soils, in which the "surface" or humous soil is rarely less than three feet in thickness, and frequently extends to a much greater depth even with a considerable humus-content. This state of things is illustrated by the columns of California soils, in two of which the humus has been determined as reaching to the depth of twelve feet, as shown in the table here presented; and doubtless to at least one foot beyond.

The root of a hop plant here before you illustrates one of the practically most important results of this great depth and pulverulent texture of soils in the arid region. This root at ten feet is still over a millimeter in diameter, and of course went at least two feet deeper than the specimen shows. Now

since a root cannot perform its functions in the absence of the oxygen of the air, it is clear that the air readily penetrates to the depth shown ; and in many cases observed, even to as much as twenty feet and more. And since both air, moisture and humus are found at these depths, this implies not only that the farmer in the arid region can fearlessly plow to any practicable depth, but also that the mass of his available soil is from three to five times as great as that of an equal area of land in the humid East. In other words, he has several farms one above another, instead of a single one with one or two feet of available soil and subsoil.

If this be so, then it might be allowable in the arid region to use the regolith materials thrown up from cellars directly as cultivable soils. Daily experience shows this to be the case. Except where heavy clay soils prevail, or where wet maceration has at some time consolidated the subsoil mass, the materials from eight or ten feet depth dug out of cellars or the foundations of houses can oftentimes be directly used as surface soils in garden and fields ; and the farmer in grading his land for irrigation ordinarily excavates it as deeply as may be necessary without fear of the " raw subsoil," as would be needful in the humid East. The prompt natural afforesting of the placer and even hydraulic mines in California teaches the same lesson.

Searching for the physical and chemical causes of this state of things, we see at once that it is mainly referrible to the pervious, pulverulent nature of the regolith, which is itself the result of the absence or great deficiency of plastic clay. It is immaterial whether or not this is concurrent with a slow rate of kaolinization, as the microscope seems to indicate. It is quite certain that the *plastic* clay substance, the "colloidal clay," is formed only in small amounts ; and this is quite consonant with what we know of the transformation of kaolin into plastic clay. Mere pulverization will not accomplish this; under wet trituration* it is certainly at least a physical hydration process, which does not occur in the case of other fine powders. It is true that the latter may be molded into shape when wetted ; but that shape is not retained after drying if any pressure is applied, while clay proper dries into a hard, resistant mass, such as in arid climates like that of Mesopotamia has not even required burning to retain the Assyrian inscriptions for thousands of years. These ancient nations understood the peculiar character of plastic clay better than those who to-day contend that its plasticity is simply due to the fineness of its particles ; for we nowhere find that chalk or

* See Johnson and Blake, this Journal, May, 1867.

other easily obtainable fine powders have been similarly used. Nor will the finest "slickens" of our quartz mills, which remains suspended indefinitely in distilled water, serve for modeling, any more than for pottery or porcelain. The utmost possible comminution of graphite or talc, so closely similar to kaolinite in softness and crystalline texture, will fail to impart to them anything resembling the adhesive plasticity of colloidal clay.

In the humid region the abundant and long-continued rains cause the plastic clay in the surface soil to diffuse in the soil water and to be carried into the subsoil, where much of it stops at a shallow depth and thus produces the clayey subsoils of humid regions. In the arid region, notwithstanding the extreme fineness of many soils which causes them to rise as dust at the slightest breath of wind, no such action occurs and thus opportunity is afforded for the deep penetration of roots, which allows much of the ordinary vegetation brought from the humid region to do without rain or irrigation during a six months drought.

The fact that in most parts of the arid regions, the scanty rains occur during the coldest portion of the year, probably accounts in a large measure for the retardation of rock decay; which, others things being equal, is probably in all cases accelerated by heat. On the other hand, the abrupt and constantly recurring changes of temperature account for a large part of the physical disintegration .which produces the great masses of pulverized rock or sand which we find in "desert" regions. The intense radiation of heat into space through the far undersaturated air of the arid climates, which occurs so soon as the sun disappears and often results in the violent disruption of cobbles from unequal contraction, naturally affects profoundly the macrocrystalline rocks especially; crumbling their surface and enabling the torrents to carry off almost fresh "sand" composed of all the mineral rock-constituents into the arid valleys; where under the influence of vegetation and increased moisture their chemical decomposition can progress more rapidly.

Not, however, rapidly as in the humid region, where the humus acids aid materially in mineral decomposition. For not only is the humus-content of arid soils usually very much less than in the humid, but so soon as formed such acids are neutralized by the carbonate of lime always present in far greater proportion than in the humid soils, save when the latter are directly derived from calcareous formations. This leads us to the consideration of chemical peculiarities of arid and humid soils respectively.

*Average Composition of Soils in the Humid and Arid Regions of the United States.**

	Humid.	Arid.
No. analyzed.	696	573
Insoluble residue	84·17	69·16
Soluble silica	4·04	6·71
Sum of insoluble residue and soluble silica	87·68	75·87
Potash	·21	·67
Soda	·14	·35
Lime	·19	1·43
Magnesia	·29	1·27
Br. ox. of manganese	·13	·11
Peroxide of iron	3·88	5·48
Alumina	3·66	7·21
Phosphoric acid	·12	·16
Sulphuric acid	·05	·06
Water and organic matter	4·40	5·15
Hygroscopic moisture	--	5·46
Humus	1·22	1·12
Nitrogen in humus	5·00	15·23
Nitrogen in soil	0·17	0·14

The table before you shows these peculiarities, which I have somewhat elaborately discussed elsewhere. A glance shows the main points of difference to lie just where they would be expected as resulting from a diminished rainfall, causing a corresponding diminution of the leaching-out process, which in the humid climates is the necessary consequence not only of a large rainfall, but especially of its occurrence during the warm season, when the concurrent effects of warmth and the consequent evolution of carbonic acid, both from the roots of vegetation, and from the oxidation or fermentation of dead vegetable matter, can be exerted. Hence we see that the lime which in the humid region is constantly and abundantly leached out into the drainage and streams, is in the arid retained to an extent amounting to from ten to thirteen times the average content found in humid soils not directly derived from calcareous formations. A similar condition is found as regards magnesia, through to a less degree. Potash averages the triple amount. It may seem strange that a similar relation is not shown here as regards soda; the reason is that for fairness of comparison, alkali soils are not included in the list. It is well known that in the case of zeolitic silicates, such as are known to exist in soils, potash is retained more tenaciously than soda. The latter is therefore washed down to the lower ground, and there gives

* Soils directly derived from calcareous formations have, equally in both regions, been excluded from this comparison.

rise to "alkali soils," which characterize the arid region to a greater or less extent all over the world. Their chief soluble salts are usually the *chloride, sulphate* and *carbonate* of sodium, varying in relative proportion from place to place at short distances. These differences are largely due to cross-reactions between the salts of the alkalies and alkaline earths under the influence of carbonic acid formed within the soil by the usual processes, resulting, e. g., in the formation of sodic carbonate and calcic sulphate from sodic sulphate and calcic carbonate. Magnesic sulphate is similarly formed. But on exposure of the soil to free diffusion of air, the process may go backward so far as to re-form the original compounds.

The peculiar effects of sodic carbonate upon clay, causing it to diffuse from the flocculent condition into single-grain structure, frequently results in the formation of " alkali hardpan " at the depth to which the annual rainfall usually reaches. This characteristic of " black alkali lands " is illustrated in the diagram before you, showing that at the depth of three feet there is a maximum of accumulation of carbonate, cementing the soil into a hard, tough mass which is quite inaccessible to ordinary means of disintegration, and yields reluctantly even to dynamite ; but is quickly and completely resolved into a pile of crumbs when subjected to the chemical action of gypsum and water. This affords a ready means of reclaiming " black alkali " lands, so far as the present price of land plaster will permit ; since the sodic sulphate thus formed is at least four times less injurious to vegetation than the carbonate.

Unfortunately there is no practically available chemical reaction by which the highly injurious common salt could be changed into sulphate. The same is true of the calcic and magnesic chlorids, which are occasionally, though fortunately not very frequently, found in the soluble salts of alkali lands.

The difficult solubility of calcic phosphate explains why the leaching process which causes such large differences in the other important plant-food ingredients, is not apparent in the average phosphoric acid-content of the two regions.

It goes without saying that so far as plant-food ingredients are concerned, alkali lands are from their very origin very rich in them, and when reclaimed by leaching or otherwise are profusely and lastingly productive. Aside from a high " reserve," they always contain *water-soluble* potash, and very commonly nitrates and phosphates also.

What action these salts exercise in the weathering process is not well established except as regards the sodic carbonate, which undoubtedly is active both in dissolving free silica and in decomposing silicates.* That common salt in presence of

* On the Geologic Efficacy of Alkali Carbonates. This Journal, August, 1897.

the humus acids of the soil might exert "aufschliessende" action also, seems at least probable from its effect in "rusting" metals, and from that of lactic acid in the animal stomach. The sulphate is probably very inert in this respect.

An interesting and important difference exists in the nitrogen-content of the arid and humid soils, respectively. The average humus-content of the properly arid soils is materially less than that of the humid, as might be expected from the much smaller amount of vegetable debris that finds its way into the soil. As a matter of fact, the leaves of all the spring vegetation of the arid region remain outside of the soil and are oxidized away during the hot summers, leaving little more than their ash behind. It follows that the humus of the arid soils is almost wholly derived from the decay of roots alone; and the deep penetration of the latter, already referred to, explains the occurrence of humus down to the great depths shown in the small table below, which gives the humus percentages found in a bench soil in which hop roots penetrated over twelve feet.

Humus in Russian River bench soil, from one to twelve feet depth.

Depth, feet	1	2	3	4	5	6	7	8	9	10	11	12
Humus %,	1·21	1·16	1·14	1·17	·74	·60	·47	·78	·54	·52	·53	·44

But the total humus percentage in arid soils is usually so small that in the humid region it would be considered wholly inadequate. So it would be, from two causes: first, that it is there among the first things needful for the maintenance of proper tilth in the clayey lands, while in the pulverulent soils of the arid region this is much less necessary; second, because we find the nitrogen-content of arid humus to be on the average three or more times higher than is the case in the humid. Hence the adequacy of the minute amounts of humus found in many of the most esteemed arid soils (·25 per cent and even less); to which may be added the at least probable greater intensity of nitrification when no great excess of carbon and hydrogen compounds is present to compete with the activity of the nitrifying organisms; an activity which, moreover, can evidently progress at much greater depths in the pulverulent, pervious arid soils.

The physical and chemical details of this subject are quite complex, so that a full discussion is necessarily lengthy. But the summary here given is probably enough to show its wide theoretical as well as practical interest, and the need of caution in applying the maxims of the humid region in arid climates.

ART. XX. — *The Colorimetric Determination of Small Amounts of Gold ;* by RALPH NELSON MAXSON.

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

APPLICATION of the colorimetric method for the estimation of small amounts of gold, based upon the purple of Cassius coloration, have been proposed by Carnot,[*] Rose,[†] Sonstadt,[‡] Cassel,[§] Prister,[||] Moir[¶] and others, but the use of this reaction for such a purpose is open to objection. According to the authority of other workers, the coloration thus produced is extremely variable, varying in intensity and shade according to the condition of the solution and precipitant. Moreover the substance is unstable, and artificial standard solutions are necessary if accurate results are to be obtained.

It has been suggested that the coloration of red colloidal gold suspensions might have a quantitative relation to the amount of metal present and a method of colorimetric estimation, free from the objections stated above, be based upon this relation. The following investigation was therefore undertaken in the hope of discovering whether such a relationship would not offer a suitable means for the estimation of small amounts of gold.

The preparation of the red colloidal suspensions was naturally the first object of interest. Blake[**] has shown that acetylene is the most suitable reagent for effecting the reduction of the auric salt, the treatment consisting in drying the chloride at 170°, dissolving in ether, and pouring the etheral solution into water also containing ether and saturated with acetylene gas. The use of ether was objectionable for the purpose of this investigation and the simpler procedure described below gave good results.

The measured quantity of a standard solution of the auric salt was drawn off into a calibrated flask and treated with a suitable amount of an aqueous solution of acetylene, made by dissolving the previously washed gas in water distilled and cooled in tin. The color having developed, the solution was shaken and the flask filled to the mark. The gold solutions used in these experiments were prepared from pure gold chloride, which contained hydrogen chloride in the usual amounts, and had not been subjected to a preliminary drying. The standard of these solutions was determined gravimetrically by means of magnesium ribbon, and by the electrolytic process with the

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[*] Compt. Rend., xcvii, 105 and 169. [†] Chem. News, lxvi, 271.
[‡] Chem. News, xxvi, 159. [§] Eng. and Min. Jour., 76, xviii, 661.
[||] Jour. Chem. Met. and Min. Soc. of South Africa, iv, 235, 1903.
[¶] Jour. Chem. Met. and Min. of South Africa, Sept. 1903.
[**] This Journal, xvi, 381 (1903).

revolving cathode. Solutions of less concentration were then obtained by suitable and accurate dilution.

A preliminary series of qualitative and quantitative experiments gave evidence that the coloration was of a quantitative nature and that the suspensions were sufficiently stable under suitable conditions.

The Gallenkamp colorimeter was used in the subsequent quantitative experiments immediately following. The delicacy of the readings was increased by placing the instrument in a light-tight box pierced with suitably situated holes; the influence of external colors was avoided by admitting light to the instrument from a ground glass plate, which was found to be very efficient.

It is a well known fact that small amounts of electrolyte will rapidly change " red " gold to the " blue " modification. It is necessary therefore to conduct the comparisons in a room reasonably free from fumes, and to have all containing vessels free from soluble material. It was found that flasks which had been treated with steam for a few minutes gave the best results. Red suspensions contained in such flasks gave no trace of blue after an interval of several weeks.

Using the precautions outlined above, the results shown in the following table were obtained. The error of the personal equation was determined by means of a series of comparisons conducted with different concentrations of the same suspension, and covering a range of amounts of material identical with the amounts handled in the experiments given below.

The forty-nine analyses given in the table were made under widely varying conditions. The age of the suspensions varied from a few minutes to several weeks. In order to avoid error of measurement, new standard suspensions were prepared from time to time, and their concentrations are shown in the last column of the table.

The analyses covered a wide range in amounts of gold and were conducted under varying conditions of light. The results are seen to run with fair regularity and the errors are approximately of the same order of magnitude.

The Gallenkamp colorimeter, used in the foregoing experiments, is not only expensive but cumbersome and complicated in construction; moreover, the instrument is not suitable for the correct estimation of the most minute amounts of gold, the color becoming too faint for accurate comparison because of the shortness of the columns of liquid. A modified form of the type of apparatus proposed by Penfield for the colorimetric estimation of titanium and consisting of comparison tubes set vertically in a dark box and illuminated from below, was therefore adopted. The tubes used in these comparisons had a

Table I.

No.	Strength of solution. per cent.	Gold taken. grm.	Gold found. grm.	Error. grm.	Gold in 1cm3 of standard. grm.
1	99·6	0·00080	0·00086	+ 0·00006	0·000086
2	95·5	0·00077	0·00082	+ 0·00005	
3	90·9	0·00075	0·00078	+ 0·00003	
4	85·7	0·00073	0·00074	+ 0·00001	
5	84·3	0·00071	0·00073	+ 0·00002	
6	67·6	0·00062	0·00058	— 0·00004	0·000086
7	63·4	0·00058	0·00055	— 0·00003	
8	56·0	0·00054	0·00048	— 0·00006	
9	52·0	0·00052	0·00045	— 0·00007	
10	47·9	0·00047	0·00041	— 0·00006	
11	98·6	0·00081	0·00085	+ 0·00004	
12	88·2	0·00075	0·00076	+ 0·00001	
13	78·8	0·00070	0·00068	— 0·00002	
14	71·6	0·00065	0·00062	— 0·00003	
15	66·1	0·00059	0·00057	— 0·00002	
16	60·4	0·00054	0·00052	— 0·00002	
17	57·8	0·00048	0·00050	+ 0·00002	
18	49·8	0·00043	0·00043	± 0·00000	
19	44·1	0·00038	0·00038	± 0·00000	
20	36·4	0·00032	0·00031	— 0·00001	
21	98·6	0·00081	0·00085	+ 0 00004	0·000086
22	88·2	0·00075	0·00076	± 0·00001	
23	78·8	0·00070	0·00068	— 0·00002	
24	71·6	0·00065	0·00062	— 0·00003	
25	66·1	0·00059	0·00057	— 0·00002	
26	60·4	0·00054	0·00052	— 0·00002	
27	57·8	0·00048	0·00050	+ 0·00002	
28	49·8	0·00043	0·00043	± 0·00000	
29	44·1	0·00038	0·00038	± 0·00000	
30	36·4	0·00032	0·00031	— 0·00001	
31	87·8	0·00030	0·00030	± 0·00000	0·000034
32	79 1	0·00028	0·00027	— 0·00001	
33	71·7	0·00026	0·00024	— 0·00002	
34	63·1	0·00024	0·00022	— 0·00002	
35	57·6	0·00022	0·00020	— 0·00002	
36	46·6	0·00019	0·00016	— 0·00003	0·000034
37	44·6	0·00017	0·00015	— 0·00002	
38	35·8	0·00015	0·00012	— 0·00003	
39	28·9	0·00013	0·00010	— 0·00003	
40	16·4	0·00004	0·00006	+ 0·00002	0·000034
41	21·9	0·00007	0·00007	± 0 00000	
42	25·9	0·00009	0·00009	± 0·00000	
43	36·9	0·00011	0·00013	+ 0·00002	
44	46·5	0·00013	0·00016	+ 0·00003	
45	38·3	0·00015	0·00013	— 0·00002	
46	47·3	0·00017	0·00016	— 0·00001	
47	Lost by accident				
48	56·8	0·00022	0·00019	— 0·00003	
49	66·1	0·00024	0·00023	— 0·00001	

diameter of 1^{cm} and a length of 13^{cm}, and were accurately graduated to hold 10$^{cm^3}$.

A mirror suitably situated beneath the box containing the tubes gave efficient illumination. Such an apparatus is not only cheaply and easily procured, but if tubes of these dimensions are used it is capable of accurately determining very small amounts of gold.

The method of comparison was carried out in the following manner. A measured amount of the suspension was drawn off into the left hand tube and diluted to the mark with water ; a suitable amount of water was then placed in the right hand tube and the standard suspension drawn into the tube until the colors were seen to be identical. The necessary amount of water to be used can be determined by preliminary experiment.

The positions of the tubes were always reversed before the final reading was taken.

The following experiments were made in order to determine the error and range of amounts of gold capable of accurate estimation in such an apparatus with tubes of the dimensions described above. The comparisons were made with a red suspension prepared by careful dilution of a more concentrated standard suspension which contained 0·000010175 grams of metal in one cm^3.

The results obtained with different concentrations of the standard suspension just described are given in the following table.

TABLE II.

No. Ana.	Gold sus. taken. cm³.	Gold sus. used. cm³.	Gold used. grm	Gold found. grm.	Error. grm.
1	9·50	9·05	0·000102	0·000097	—0·000005
2	8·00	7·59	0·000086	0·000082	—0·000004
3	7·00	6·89	0·000075	0·000074	—0·000001
4	6·00	5·83	0·000065	0·000063	—0·000002
5	5·00	4·84	0·000054	0·000052	—0·000002
6	4·00	3·88	0·000043	0·000042	—0·000001
7	3·00	2·47	0·000032	0·000027	—0·000005
8	2·00	1·82	0·000022	0·000020	—0·000002
9	1·00	0·93	0·000011	0·000010	—0·000001

The intensity of the color in the above experiments ranged from a deep red to a faint pink. Further comparisons made with suspensions more dilute than those described above gave errors of magnitude increasing with the dilution. The amounts handled here are, then, the minimum quantities that can be accurately estimated with the apparatus described. It is obvious that if larger amounts of the metal are to be determined, tubes of greater dimensions should be used.

The application of such a method for the determination of gold naturally starts with that element. The weighed amount of metal, contained in a clean porcelain crucible, can be readily brought into solution with the aid of chlorine water or aqua regia and the excess of the solvent evaporated off upon the water bath. Experiments have shown that a gentle preliminary heating of the solution of the auric salt hastens the rapidity of the reduction. Care must be taken not to reduce any of the gold chloride by such a procedure.

If traces of electrolyte are present the coagulation of the "red" gold may be sometimes avoided by the addition of a few drops of ether to the cold solution. When small amounts of the metal are handled the volume of the solution should not exceed a few cubic centimeters, and only a small amount of the aqueous solution of acetylene should be added; otherwise the coloration may be partially or totally inhibited.

In conclusion, it can be seen from the evidence of the experiments described above, that the colorimetic estimation of small amounts of gold is quantitatively possible if proper precautions are taken to ensure the maximum coloration and exclusion of electrolytes. The method is quick and simple in character, and for the amounts of gold used above, the results show it to possess suitable accuracy for the correct estimation of small amounts of the metal.

The author wishes to acknowledge his indebtedness for much helpful aid and advice in this, and in previous work, to Professor Gooch, at whose suggestion these experiments have been carried on.

Art. XXI.—*Cobaltite Occurring in Northern Ontario, Canada*; by Justin S. De Lury.

The vein containing the cobaltite described in this note is situated in the southeastern part of Coleman Township, on the claim owned by Mr. John Columbus, which is near the recently discovered cobalt-silver mines of Northern Ontario, The country rock, Huronian slate-conglomerate, contains most of the valuable deposits of the district. The bulk of the vein matter is quartz, which contains, besides the cobaltite, small quantities of chalcopyrite and pyrite. The part of the vein containing the cobaltite crystals varies from six to eight inches in width.

The mineral crystallizes in cubes and octahedra, but usually in combinations of these two forms. It is of a pure silvery white color, except on some weathered faces which have a red tarnish. The crystals are very brittle, and when broken show a rough uneven fracture.

Owing to the brittleness of the crystals, good specimens for examination can be obtained only from weathered portions of the vein. Some of these crystals were carefully cleaned and examined on a Goldschmidt two- circle goniometer. The cubic and octahedral faces, although giving sufficiently good reflections to determine them as such, were much pitted and striated (see fig. 1), thus giving a series of reflections. Several crystals were examined and of all the reflecting faces only one was found which did not correspond to the cubic or octahedral positions; it corresponded more closely to (342) than to any other form. However, since it was the only occurrence of this form,

it may be safer to assume that it is not a crystal face but a contact face.
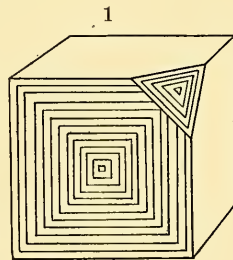
	I.	II.	III.
Co	29·10	29·17	35·54
Fe	4·55	4·72	----
Ni	0·97	1·68	----
As	44·55	44·77	45·18
S	20·73	20·23	19·28

An analysis was made of powder obtained from carefully cleaned crystals. The result of this analysis is presented in column I. For purposes of comparison an analysis of cobalt-

ite from Nordmark* is given in II, while in column III the percentage conposition corresponding to the formula, CoAsS, is appended.

Professor G. R. Mickle of the School of Practical Science, University of Toronto, obtained some of the vein-matter from Mr. Columbus' claim in October 1905, and presented it to Professor T. L. Walker of the University of Toronto, who kindly gave it to the writer for examination.

Chemically, physically and crystallographically, this note adds little to our knowledge of cobaltite. However, as this is the first authentic discovery of the mineral in North America, it is worthy of being recorded. Leonhard,† in 1843, describes its occurrence in Connecticut in a conglomerate, but Dana does not recognize this locality.

*Flink, Ak. H. Stockholm Bihang, xii (2), No. 2, 5, 1886.
† Top. Min., p. 321, 1843.

Art. XXII.— *Wasatch and Wind River Primates;* by F. B. Loomis.

The Amherst College expedition of 1904 made a considerable collection of Primates from the Wasatch and Wind River beds, especially from the latter, which are the basis of the following study, supplemented by reference to other collections from the same horizons.

Anaptomorphidae Cope.

The genus Anaptomorphus was established by Cope when he described the Bridger species, *A. aemulus,*[*] known by a single but nearly complete lower jaw. In 1882 the Wasatch species, *A. homunculus,* was added to the genus,[†] being an unusually complete skull. Later, lower jaws were found, and the lower dentition mostly made out. The type species has but eight teeth in the lower jaw, the formula being $i\frac{2}{2}$ $c\frac{1}{1}$ $pm\frac{2}{2}$ $m\frac{3}{3}$; while the lower jaw of *A. homunculus* is not so much shortened, having apparently nine teeth in the series, making a formula $i\frac{2}{2}$ $c\frac{1}{1}$ $pm\frac{2}{3}$ $m\frac{3}{3}$.[‡] Then while in *A. aemulus* the paraconid is wanting, in *A. homunculus* it is present though reduced. These two marked differences led Wortman to suggest[§] that these two species should be placed in different genera, but for lack of more abundant material, he did not propose a new one.

In the Wasatch the Amherst expedition found one new Anaptomorphus, little over half the size of *A. homunculus;* and nine specimens of a second new species in the Wind River beds. While these do not add to our knowledge of the generic features, their rarity and the interest in American Primates seems to require their description. They are both closely related to *A. homunculus* and should a new generic name be proposed would go along with that species.

The affinities of the family seem to the writer to be with the modern Tarsius, as pointed out by Cope (Tertiary Vert. 1884, p. 246) and Wortman. The latter authority has proposed the following classification of Primates,[‖] which is adopted in this paper.

[*] Proc. Amer. Phil. Soc. Phila., 1872, p. 554.
[†] Proc. Amer. Phil. Soc. Phila., 1882, p. 152.
[‡] See Osborn, Bull. Amer. Mus. Nat. Hist., vol, xvi, 1902, p. 200.
[§] This Journal, 1904, p. 213.
[‖] This Journal, 1904, p. 213.

Primates	{ Cheiromyoidea	Gnawing forms like Cheiromys, Mycrosyops, etc.

Primates {
  Cheiromyoidea — Gnawing forms like Cheiromys, Mycrosyops, etc.
  Lemuroidea — Lemurs
  Anthropoidea {
    Arctopithecini
    Palaeopithecini
    Neopithecini {
      Adapidae
      Cebidae
      Cercopithecidae
      Simiidae
      Hominidae

Anaptomorphus minimus sp. nov.

The type consists of a portion of the right mandibular ramus, containing molars 1 and 2, and a part of premolar 4, found in the lower Wasatch at the foot of Tatman Mt., Wyoming.
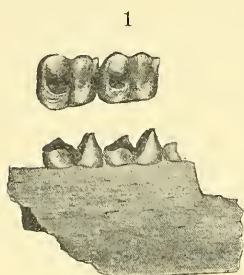
FIG. 1. *Anaptomorphus minimus*, type, ×5.

The teeth are wide and low with acute cusps, the talonid being slightly larger than the trigonid. The paraconid is distinct and stands close to the inner margin of the tooth. The protoconid is connected with the paraconid by a long low protolophid, and with the metaconid by a comparatively high metalophid. The hypoconid and entoconid are of about equal size. No hypoconulid is present.

Specific characters are found in the position and development of the paraconid, and the extreme small size of the animal. The two lower molars measure together $3·4^{mm}$ in length and $1·4^{mm}$ in width; the depth of the jaw under molar 2 is $3·2^{mm}$.

Anantomorphus homunculus Cope.

For excellent figures and description of this species, see Osborn, Bull. Amer. Mus. Nat. Hist., vol. xvi, p. 200, and comparisons in the table on the following page.

Anaptomorphus abbotti sp. nov.

The type consists of a right mandibular ramus containing premolars 3 and 4 and molars 1–3, found in the middle beds of the Wind River formation on Bridger Creek, Wyoming. The species is named for Mr. L. F. Abbot, to whose interest much of the success of the expedition was due.

The molar teeth are low with low cusps, but rise progressively to the fourth premolar, which has a prominent crown. All the teeth in the short jaw are compressed from front to back, making them proportionally wide. A distinct cingulum runs along the front and external side of each molar. On

ANAPTOMORPHIDAE.

	A. homunculus	*A. abbotti*	*A. minimus*
Premolar 3	Internal cingulum Posterior cingulum slightly raised medianly	No internal cingulum Posterior cingulum raised medianly	
Premolar 4	Posterior cingulum not raised	Posterior cingulum raised medianly	
Molar 1	Trace only of cingulum Protolophid short Metalophid low Talonid larger than trigonid	Strong cingulum in front and outside Protolophid very short Metalophid low Talonid larger than trigonid	No cingulum Protolophid long and low Metalophid high Talonid only slightly larger than trigonid
Molar 2	Trace only of cingulum Paraconid close to metaconid Protolophid low Metalophid low	Strong cingulum in front and outside Paraconid close to metaconid Protolophid low Metalophid moderate	No cingulum Paraconid very distinct Protolophid low and long Metalophid high
Molar 3	Trace only of cingulum Paraconid small but distinct Metalophid low and notched Talonid about equal to trigonid	Strong cingulum in front and outside Paraconid a mere rudiment Metalophid deeply notched Talonid longer than trigonid	
Horizon	Wasatch	Wind River	Wasatch
3 molars length	6·5^{mm}	7^{mm}	About 4·5^{mm}

molar 1 the paraconid is strong and well separated from the metaconid ; on molar 2 it is less independent ; and on molar 3 is barely distinguishable. The last molar is small, the talonid elongated and narrow with a strong hypoconulid ; the hypoconid and entoconid being merely indicated on the raised margins running from the hypoconulid forward. On molars 1 and 2 the hypoconid and entoconid are well developed, and the hypoconulid is wanting. The fourth premolar has a high protoconid over the front root, and the merest rudiment of a deuterconid beside it. The posterior cingulum is raised

medianly, suggesting a hypoconulid.   The third premolar is two-rooted, and has but a single cusp.   Its posterior cingulum is also raised medianly, suggesting a forming cusp.
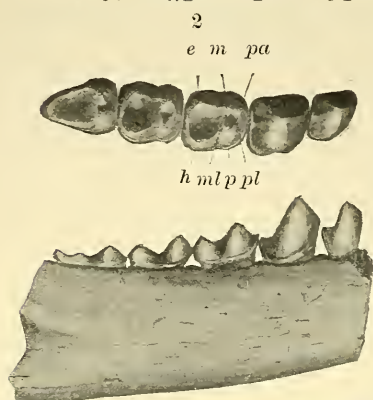
FIG. 2. *Anaptomorphus abbotti*, type, ×4.

Specific features are found in the external cingulum of the molars, the elongated talonid of molar three and in the raised posterior cingulum of the third and fourth premolars.

Nine specimens were found on Bridger Creek in the Wind River beds.

The three molars measure 7^{mm} in length and molar 2 is 2^{mm} wide.

Adapidae Schlosser.[*]

In this family the American genus Notharctus approaches the European genus Adapis closely, especially the new species *N. minutus* from the Wind River.   Two genera are represented in America, the simpler and apparently ancestral Pelycodus from the Wasatch, and the more advanced Notharctus of the Wind River and Bridger.

The family may be defined as follows ; dentition i$\frac{2}{2}$ c$\frac{1}{1}$ pm$\frac{4}{4}$ m$\frac{3}{3}$; molars low crowned and with low cusps ; paraconid reduced but present ; external cusps more or less crescentic ; hypoconid small ; the last lower molar with a weak and varying heel.

The family makes its appearance in Europe and America suddenly and at almost the same time, apparently migrating from some northern center of distribution onto the two continents ; the climate being a warm temperate or tropical one, as shown by the fauna[†] and flora collected in the basal beds of the Wasatch by the Amherst expedition.

The two genera are distinguished as follows :

Pelycodus	*Notharctus*
Outer cusps of lower teeth more or less conical :	Outer cusps of lower teeth more or less crescentic :
No mesostyle on upper teeth :	Mesostyle on upper teeth :
Hypocone weak :	Hypocone strong :
Heel of last lower molar large, tending to have two or more cusps :	Heel of last lower molar weak with a single cusp only :
Fourth lower premolar simple.	Fourth lower molar complex.

[*]Affer, Lemuren, Chiropteren, etc., 1887, Pt. 1, p. 21.
[†] Wortman, this Journal, 1903, p. 419.

Pelycodus Cope.

The genus is founded on *P. jarrovii* from the New Mexico Wasatch, the type among others from that region having disappeared. Specimens of the various species are abundant throughout the Wasatch of the Big Horn basin and run up into the Wind River, where they give place to the more specialized Notharctus. On Bridger Creek, Wyo., where a rich pocket of Wind River was found, Notharctus specimens were second in abundance to Hyposodus only. While several species occurred, the smaller sorts were the more abundant.

Pelycodus frugivorus Cope var.

This, the smallest and most abundant of the Wasatch species, was founded by Cope on a portion of a jaw from New Mexico; and, on account of the correspondence in size, the Big Horn specimens have been associated with it. While the two faunas closely resemble each other, and are doubtless closely related, the northern species differ slightly from the southern; for which reason the writer has used the variety designation. In this instance the last lower molar of the New Mexico form has fewer cusps on the less developed heel, than does the Big Horn.

The species is characterized by low chunky teeth; a moderate external cingulum on the lower molars; the last lower molar having an elongated heel with three small cusps occupying the position of the hypoconulid; the hypoconulid of molars 2 and 3 being small and situated close to the hypocone.

3

Fig. 3.   *Pelycodus frugivorus* Cope, var., × 2.

In the position of the hypoconulid and development of the cingulum, the species is closest to *P. tutus;* in the modifications of the heel it is nearer *P. nuniensis.* Specimens were collected from all levels in the Wasatch on Gray Bull River and in the Buffalo Basin. The last three lower molars measure very uniformly 15^{mm} in length and 4^{mm} in width.

Pelycodus tutus Cope var.

Like the foregoing, this species is based on a New Mexico fragmentary mandible, which carried only the third and fourth premolars and the first molar. Like the foregoing, the Big Horn specimens vary, especially in the premolars, the third premolar being simpler, and the fourth having the two principal cusps much closer together.

The species is marked by stout low teeth ; an external cingulum on the lower molars ; the hypoconulid of molars 1 and 2 being small and close to the hypocone ; the last lower molar being shortened and having but one cusp on the heel, the hypoconulid.

4

FIG. 4.   *Pelycodus tutus* Cope var., ×2.   The last molar is restored, the original being crushed.

The species is close to *P. frugivorus,* but differs especially in the larger size, and in the single cusp on the last lower molar.   The species is rather rare on Gray Bull River, only four specimens being found.   The last three lower molars measure 18^{mm} in length and 4$\frac{1}{2}$^{mm} in width.

Pelycodus jarrovii Cope.

See Final Rep. Surv. West of 100th Meridian, vol. iv, 1887, p. 137.

This large species from New Mexico has not been found elsewhere as yet.   It is marked by a simple heel on the last lower molar, on which is merely a wall without any cusps. The hypoconulid of molars 1 and 2 is barely perceptible.

The three lower molars measure 20^{mm} in length.

Pelycodus angulatus Cope.

Last cit., p. 144.

This is a dubious species founded on a single molar tooth from New Mexico.

Pelycodus nuniensis Cope.*

This is the only species of Pelycodus to carry over into the Wind River, and is by Osborn considered a transition to the Notharctus species.   However, on account of its stocky build it appears to the writer a typical Pelycodus.

The species is marked by low stout teeth ; the third lower molar having its heel elongated and carrying two cusps where the hypoconulid is usually situated ; the hypoconulid of molars 1 and 2 being small and central in position ; and the paraconid being weak.

While the last lower molar resembles *P. frugivorus,* the species is larger and chunkier, and has the hypoconulid placed

* See Bull. U. S. Geol. Surv. Terri., vol. vi, 1881, p. 187.

medianly. It is fairly common in the Bridger Creek beds,

5

FIG. 5. *Pelycodus nuniensis* Cope, × 2.

eight specimens being found. The last three molars measure 16^{mm} in length and 3½^{mm} in width.

Notharctus minutus sp. nov.

This, the smallest species of the family, is founded on a right mandibular ramus, containing the molars and the roots of the third and fourth premolars, found in the Wind River beds on Bridger Creek, Wyoming.

The low teeth have rather acute cusps, those on the trigonid being higher than those on the talonid. The external cusps are strongly crescentic. The paraconid is moderately strong, and stands well to the inner margin of the tooth. There is a strong protolophid but no metalophid, so that there is a basin on the trigonid as well as on the talonid. The heel of the last

6

FIG. 6. *Notharctus minutus*, type, × 5.

molar is surrounded by a raised rim on which there are no cusps. There is a strong external cingulum on all the molars. The form is a tiny one, and the jaw very slender.

The crescentic cusps, lack of a metalophid, and the basin on the trigonid causes the species to strongly resemble the European genus Adapis. Three specimens were found on Bridger Creek. The three lower molars together measure 5^{mm} in length.

Notharctus palmeri sp. nov.

This small form is abundant in the Wind River beds of the Bridger Creek exposure. The type is two fragments of the lower jaws of one individual, the one containing the left fourth premolar, the other carrying the second and third molars of the right side. The species is named for W. W. Palmer on account of his success in collecting in these beds.

The fourth premolar has but a trace of an external cingulum and a well developed posterior cingulum on which two cusps are developed, the larger to the outer side. On the molars there is also but a trace of an external cingulum. The last molar has the hypoconid and entoconid about equally developed and a small medianly placed heel on which there is a moderate hypoconulid.

The species differs from *N. cingulatus* in the lack of the cingulum and in the median position of the heel on molar 3. While eleven specimens were found, they are mostly very fragmentary, the jaws being extremely fragile. The three lower molars measure 11^{mm} in length and 2·7^{mm} in width.
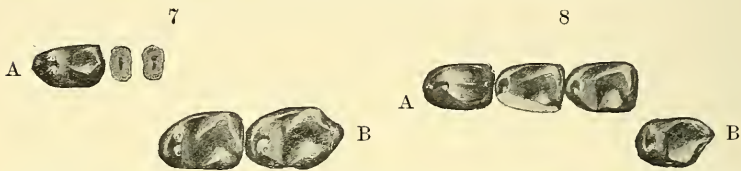
FIG. 7. *Notharctus palmeri*, type, × 3. A, the fourth premolar of the left side ; B, molars 2 and 3 of the right side.
FIG. 8. *Notharctus cingulatus*, type, × 3. A, premolar 4 and molars 2 and 3 of the right side ; B, molar 3 of the left side.

Notharctus cingulatus sp. nov.

This second small form is about equally abundant with the foregoing in the Wind River beds of Bridger Creek. The type is a right mandibular ramus containing the fourth premolar and molars 1 and 2. With it is associated a third molar of the left side which may belong to the same individual.

While similar to the foregoing, the species is distinctive in that the fourth premolar has a complete external cingulum, and the posterior cingulum is simply raised medianly into a cusp-like process. Molars 1 and 2 have an almost complete external cingulum. The last lower molar has the hypoconid larger than the entoconid ; and the small hypoconulid on a small heel, placed toward the inner side of the tooth.

Twelve specimens of this species were found on Bridger Creek. The three lower molars measure together 11^{mm} in length and 2·7^{mm} in width.

Notharctus venticolus Osborn.*

This is a larger species founded by Osborn on the Wind River specimens which Cope had associated with *P. tutus*. None were found in the Bridger Creek locality. The three lower molars measure 17^{mm} in length.

Amherst Biological Laboratory.

* Bull. Amer. Mus. Nat. Hist., vol. xvi, 1902, p. 195.

ADAPIDAE.

	P. frugivorus	P. tutus	P. vaniensis	N. minutus	N. palmeri	N. cingulatus
Premolar 3	Cingulum on front, inside, and rear	Cingulum on rear				
Premolar 4	Cingulum inside and rear not raised	Cingulum mostly in rear Rear cingulum raised medially	Cingulum in rear only, Rear cingulum raised medially		Cingulum behind only Rear cingulum with two cusps	Cingulum outside and rear Rear cingulum raised medially
Molar 1 and 2	External cingulum weak Protolophid weak Metalophid weak Hypoconulid small near hypoconid	External cingulum strong No protolophid Metalophid none Hypoconulid small near hypoconid	No external cingulum No protolophid Metalophid moderate Hypoconulid moderate median	External cingulum strong Protolophid strong Metalophid none Hypoconulid none cusps crescentic	External cingulum as a trace only Protolophid moderate Metalophid weak Hypoconulid moderate near hyoconid	External cingulum moderate Protolophid strong Metalophid strong Hypoconulid small near hypoconid
Molar 3	External cingulum weak Protolophid weak Metalophid weak Heel long with 3 cusps	External cingulum strong Protolophid none Metalophid none Heel short with 1 cusp	External cingulum none Protolophid none Metalophid weak Heel long with 2 cusps	External cingulum strong Protolophid weak Metalophid none Heel moderate with a rim only	External cingulum as a trace only Protolophid strong Metalophid weak Heel small central with 1 small cusp	External cingulum moderate Protolophid strong Metalophid weak Heel small to inner side with 1 small cusp
Horizon	Wasatch	Wasatch	Wind River	Wind River	Wind River	Wind River
Length of 3 last molars	15^{mm}	18^{mm}	16^{mm}	5^{mm}	11^{mm}	11^{mm}

Art. XXIII.—*A New Occurrence of Pseudo-Leucite;** by
C. W. Knight.

Through the kindness of Dr. A. E. Barlow of the Canadian
Geological Survey there came into the possession of the writer
two rock specimens whose characters are herewith described.
Mr. R. G. McConnell of this Survey collected the material
during the summer of 1904 and has sent this note regarding
the field relations :

"The leucite rock described in the following paper occurs
in the Ogilvie range on the upper part of Spotted Fawn creek,
a tributary of Twelve-mile river, Yukon Territory. It occurs
in a long dyke-like area about a mile wide where crossed. It
is bordered on the north by a reddish granitoid rock, probably
a syenite, and on the south by altered sedimentaries, mostly
quartzites and slates of Upper Palæozoic age. It has suffered
considerable deformation, the leucite crystals in places being
crushed into lines.

"The leucite rock is probably intrusive rather than effusive
in character, although the examination was too hurried to
obtain definite information on this point. It appeared to be
older than the syenite and younger than the sedimentaries."

The work was carried on in the geological laboratory of
Columbia University, New York, and the writer would express
his acknowledgments to Professor Kemp and Dr. Berkey
for advice and assistance.

Specimen A is of a medium gray color and perfectly fresh.
The ground-mass is very fine-grained and the constituent min-
erals cannot be distinguished with the naked eye. The prin-
cipal phenocryst occurs in well developed icositetrahedrons
usually less than 1^{cm} in diameter. Fig. 1 is a photograph
of two of these phenocrysts showing their crystal form. In
color they resemble the ground-mass of the rock so as not to be
distinguished from it. They, however, are readily separated
from the matrix. The crystal habit is that of the mineral leu-
cite, though in the microscopical examination given later on
no trace of an isometric mineral was found. A few sanidines
tabular in form and generally less than 5^{mm} in diameter are also
seen to play the part of phenocrysts.

Specimen B is quite similar to the one just described with
the exception that it has not as many of the icositetrahedral
crystals. Instead are seen grayish white, rounded areas 5^{mm} in
diameter with apparently no crystal form. Both specimens
show a striking resemblance to the pseudo-leucite tinguaite

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* Published by permission of the acting Director of the Canadian Geolog-
ical Survey.

from the Bearpaw mountains in Montana, described by Weed and Pirsson.*

Thin sections from specimens A and B when examined under the microscope showed the rock to be made up of the following minerals : orthoclase, pseudo-leucite, nephelite, scapolite and biotite. The first three minerals play the part of phenocrysts; orthoclase and nephelite also appear in the ground-mass and consequently occur in two generations.

Orthoclase :—The ground-mass consists largely of orthoclase laths, showing flow structures. They exhibit a tendency to flow around the pseudo-leucite. Wavy extinction is always observed with crossed nicols. These laths average about ·1^{mm}

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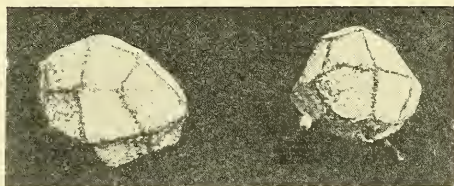
Fig. 1.   Pseudo-leucite crystals from Spotted Fawn Creek, Yukon Terri-tory, Can.   The crystal form (icositetrahedron) is that of the mineral leucite. Diameter of large pseudo-crystal is 1^{cm}.   The crystals have been very slightly flattened by pressure.

in length, while the phenocrysts, which often show the com-mon Carlsbad twins, average 5^{mm} in diameter.

Pseudo-leucite :—These extremely interesting and puzzling pseudomophs consist of the following minerals : orthoclase, scapolite, nephelite, biotite and a very little plagioclase. The *orthoclase* is most abundant and occurs under two conditions : first, in allotriomorphic grains, less than ·1^{mm} in diameter, generally concentrated in the more central portions of the pseudo-crystals; second, in lath-shaped individuals often con-centrated on the outer borders and oriented in such a way that their longer axes lie normal to the crystal faces of the pseudo-leucite (see fig. 2). It is a striking fact that this border arrangement appears to be a characteristic of the pseudo-leucites from Brazil, Magnet Cove, Arkansas, and the Bearpaw Moun-tains, Montana. Williams in his description of pseudo-leucites from Magnet Cove has referred to this arrangement of the orthoclase as a "palisade" structure.†   The allotriomorphic

* On some Phonolitic Rocks from Montana, this Journal, vol. i, p. 394, 1895, see also vol. ii, Aug. and Sept. 1896, p. 194.

† The Igneous Rocks of Arkansas—Annual Report Geol. Sur. Arkansas, vol. ii, 1890, p. 268.

grains of feldspar are almost always quite clear and fresh; the lath-shaped individuals around the borders, however, generally show incipient kaolinization and are in consequence cloudy when examined with one nicol. The *scapolite* is recognized by its low relief, high interference colors reaching the yellows and reds of the first order, cleavage cracks crossing at right angles, parallel extinction and the distinct unaxial cross of negative character which is readily observed in basal sections. It occurs in clear allotriomorphic individuals, generally irregularly

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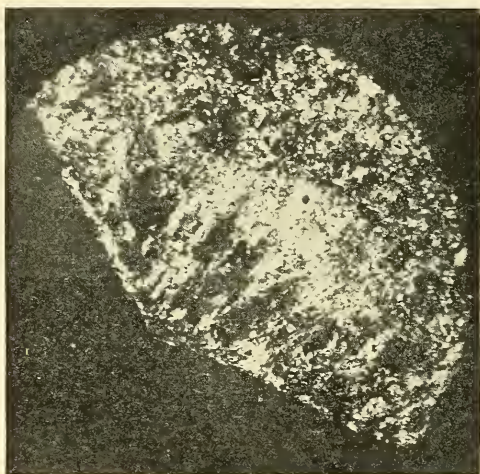
Fig. 2. Photo-micrograph of pseudo-leucite; crossed nicols; actual field 2·5^{mm}. Near the border the lath-like orthoclase individuals lie with their longer axes more or less normal to the faces (icositetrahedral) of the crystal. In the central portions the small allotriomorphic orthoclases are seen.

distributed throughout the pseudo-leucite, but sometimes also gathered together in little groups ·4^{mm} in diameter. In some instances the individual scapolites reach a diameter of nearly 1^{mm}, but it generally occurs in grains much smaller than this. It was observed in one case to have the appearance of being formed directly from nephelite; and further, the grains of scapolite sometimes occupy areas whose boundaries are distinctly quadratic—a characteristic form of nephelite. It should be noted here that scapolite has not been described before as occurring in pseudo-leucite.

The remaining three minerals which are seen in the pseudo-crystals are *nephelite, biotite* and an acid *plagioclase* feldspar. The first of these occurs in allotriomorphic and quadratic sections, showing low relief and low interference colors. Basal

sections give a distinct uniaxial cross, negative in character. The mineral does not seem to be abundant, but a more careful examination with high powers shows it to be present in greater amount than would at first appear. Wavy extinction, as observed in the orthoclase, is likewise seen in the nephelite. The *biotite* occurs in grains always less than ·05^{mm} in diameter. It is a greenish brown variety, strongly pleochroic. The tiny plates tend to arrange themselves along lines; again they are segregated into patches 1^{mm} or so in diameter, or are irregularly distributed throughout the pseudo-crystals. A very few individuals of an acid *plagioclase* feldspar were noted.

It has been already stated that the pseudo-leucites in specimen B do not appear to possess a crystal form when examined macroscopically. Under the microscope, however, some crystal faces are observed. It is possible that the absence of distinct crystal form may be due to the action of the magma on the original leucite crystals. Apart from the form of the crystals the microscopic description given above applies equally well to the pseudo-leucites of both specimens.

Nephelite:—A few crystals with quadratic cross-section and low interference colors give uniaxial interference figures negative in character. They occur in the ground-mass with one exception; in this instance a crystal 1·2^{mm} in diameter plays the part of a phenocryst; the mineral gelatinized easily in HCl. Nephelite is not an abundant mineral in the rock.

Scapolite:—Besides occurring as a constituent mineral of the pseudo-leucite, scapolite also forms part of the ground-mass. It is readily recognized by those characters already enumerated above. In size the grains will average less than ·05^{mm} in diameter.

Biotite:—The orthoclase laths and biotite make up the principal minerals in the ground-mass. The biotite occurs in plates, generally less than ·1^{mm} in diameter, lying in the interstices of the feldspar laths. It is a greenish brown variety, strongly pleochroic and appears to be similar to that found in the pseudo-leucite crystals.

Though nephelite does not play a prominent part, the rock is nevertheless here classified as a *pseudo-leucite phonolite.* It is highly probable, however, that nephelite was once present in greater amount than it is now, since the scapolite appears to be secondary after it.

The pseudo-leucites studied in this paper resemble very closely those from Brazil; from Magnet Cove, Arkansas; from the Bearpaw Mountains, Montana; from Beemerville, N. J.; and from the Highwood Mts., Montana. O. A. Derby* described the porphyritic types of foyaite from Brazil containing

* Quart. Jour. Geol. Society, May, 1891, p. 251.

"segregations" which present the aspect of crystals or groups of crystals. These consist of orthoclase, nephelite, augite, hornblende and titanite, with the crystal form of leucite. The marginal layer, rarely absent, is composed of lancet-shaped orthoclase (with nephelite) disposed normally to the faces of the pseudo-crystals. The peculiar masses were studied by Graeff and Hussak;* the former regarded them as inclusions of pre-existent foyaite; the latter looked upon them as true pseudo-crystals representing a tendency to the formation of leucite under physical conditions unfavorable to the complete development of that mineral. Derby suggested "that perhaps crystals of leucite exceedingly rich in inclusions (phenocrysts from the surrounding magma) were actually formed; but that before the complete consolidation of the magma, some change of conditions brought about, through magmatic action, a pseudomorphosis of the leucite molecule into orthoclase and nephelite."

As will be shown below, the pseudo-leucites from Spotted Fawn Creek, Yukon Territory, have about the same chemical composition as those from Magnet Cove, Arkansas, described by J. F. Williams.† At the latter locality they are found in leucite-syenite dikes and leucite-tinguaites. The pseudo-crystals occur in icositetrahedrons 5^{cm} in diameter and consist of a network of allotriomorphically bounded, tabular crystals which are generally arranged in radial forms and which are often interspersed with small allotriomorphic eleolite crystals and idiomorphic pyroxenes. The orthoclase crystals often lie with their symmetry-planes at right angles to the edge of the section and hence forming a sort of palisade about the edge. In the slide of this material examined by the writer it was at once noted that the minerals composing the pseudo-leucite were coarser in grain than in the pseudo-crystals from the Yukon territory. Wavy extinction was also noted in the crystals from Magnet Cove. Williams' hypothesis regarding their formation is similar to that of Derby. He says "they began to form under conditions favorable to the formation of leucite and, as is frequently the case with true leucite crystals, they included all sorts of foreign particles, such as magnetite and aegirite. The conditions then changed and instead of becoming true leucites their substance was recrystallized and the leucite molecule was broken up into eleolite and orthoclase."

The pseudo-leucites described by Weed and Pirsson‡ from the Bearpaw Mountains, Montana, occur in icositetrahedrons

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* Neues Jahrb. 1887, vol. ii, p. 255; and 1890, vol. i, p. 166.

† Annual Report Geol. Sur. Arkansas, 1890, vol. ii, "Igneous Rocks of Arkansas."

‡ This Journal, vol. i, p. 394, 1895, 4th series. See also vol. ii, 1896 (4), p. 194.

which average 1^{cm} in diameter. They consist of an allotrio-
morphic mosaic of orthoclase and nephelite. "In some cases
the outer edge of the section is composed of orthoclase crystals
with their longer axes perpendicular to the crystal faces of the
original leucite." A thin section of the Bearpaw pseudo-leu-
cite examined by the writer contains in its center an isotropic
kernel, whose outline resembles the figure 8. Part of the feld-
spar surrounding the kernel radiates out from this material,
giving a spherulitic structure to this part of the slide. It may
be that the orthoclase and nephelite have been formed directly
from the isometric kernel, or, in other words, this isometric
substance might be regarded as a remnant of the *original leu-
cite crystal*. Prof. Pirsson, however, has proved by chemical
tests that the material is either sodalite or analcite and not any
original unchanged leucite substance. The material examined
by the writer was too small to permit the use of microchemi-
cal tests.

Prof. Wolff[*] studied a leucite-tinguaite from Beemerville,
N. J., which contains pseudo-leucites similar to those described
above. They are made up "of an aggregate of orthoclase,
partly in irregular grains, more often in radiating prisms."
Between the orthoclase a comparatively small amount of
nephelite occurs. The centre of the pseudo-crystals contains
an isotropic mineral determined as analcite. Near the same
district Prof. Kemp[†] examined a basic dike consisting of
biotite and pyroxene set in a ground-mass that is chiefly
analcite. In portions some curious, spheroidal inclusions
appear having a diameter up to 10^{mm}; they are made up
chiefly of analcite and are always rounded and without
crystal form. In the fresh material Prof. Kemp was able
to show that the spheroids consisted partly of leucite. These
pseudo-crystals have, however, evidently been formed by
surface alteration and differ in this respect from the pseudo-
leucite from Yukon territory and the other localities men-
tioned above.

Prof. Pirsson[‡] described pseudo-leucites from the Highwood
mountains, Montana, consisting of alkali feldspars, nephelite
and small amounts of what is held to be analcite. They occur
in a "granular intrusive rock consisting of dominant leucite
with subordinate augite." These pseudo-crystals are similar
to those already described.

In order to study the chemical composition of the pseudo-
leucites from the Yukon territory, and also to compare them

[*] Harv. Coll. Mus. Comp. Zool. Bull., vol. xxxviii, p. 273–277, 1902.
[†] This Journal, 3d series, vol. xlv, p. 298–305, 1895; also vol. xlvii, May
1894.
[‡] Bull. 237, U. S. Geol. Surv. p. 83.

with other occurrences, two crystals were selected for analysis. The crystals, which were of a medium gray color with two or three white streaks running through them, broke away very readily from the ground-mass. This fact seems to indicate that the original leucite on breaking up into orthoclase, nephelite and plagioclase contracted so that it could be isolated easily from the ground-mass. It also goes to show that the breaking down of leucite probably occurred when the rock had entirely solidified, but was still at a temperature not far below its fusion point. Fig. 1 is a photograph of the two crystals analyzed; their actual diameters are about 1^{cm}.

	A.	B.	C.
	Spotted Fawn Creek, Yukon Territory.	Magnet Cove, Arkansas.	Mt. Vesuvius.
SiO_2	58·15	55·06	58·30
Al_2O_3	23·66 ⎫	25·26	23·80
Fe_2O_3	1·59 ⎭		
CaO	0·43	0·60	0·96
MgO	0·21	0·28	0·17
Na_2O	7·08	7·60	5·80
K_2O	8·49	10·34	10·94
H_2O-	0·10		
H_2O+	1·25	1·78 (ignition)	
Cl	trace*		
	100·96	100·92	99·97

* Present, but not determined.

A. Spotted Fawn Creek, Yukon territory, Canada; analyzed by C. W. Knight.

B. Magnet Cove, Arkansas, analyzed by J. F. Williams.

C. Mt. Vesuvius, analyzed by Ramelsberg.

For comparison two other analyses are given in the above table. The close resemblance which the pseudo-leucites from Magnet Cove bear to those from the Yukon territory is at once noted. From the high amounts of Na_2O which are shown by the above analyses it seems clear in each case that the original mineral was a *soda-leucite*. On the presumption that the scapolite in the pseudo-crystals from the Yukon territory is secondary after nephelite and that consequently the leucite broke down into feldspar and nephelite, we may find the proportions in which these minerals occurred by recasting the analysis. The biotite may be considered as inclusions (or as a secondary product from inclusions) in the original leucite. Since only a small per cent of biotite is present, the amount of K_2O required for this mineral is not great. To obtain, therefore, an idea of the relative amounts of orthoclase, nephelite

and anorthite all the K_2O may be calculated as present in the orthoclase; this gives: Orthoclase, $50·04\%$; nephelite, $32·38\%$; anorthite, $2·22\%$.

The small amount of lime is considered to belong to the plagioclase, which as previously stated occurs in very subordinate quantities. It is thus obvious that the scapolite is composed essentially of the marialite molecule $(Na_4Al_3Si_9O_{24}Cl)$.

The pseudo-leucites from the various localities previously enumerated have generally three common characteristics: (*a*) the crystal form of the icositetrahedron, (*b*) the "palisade" structure about the border, (*c*) the similarity of the constituent minerals.

Though the only specimen containing scapolite is that from the Yukon territory, still it seems highly probable that the scapolite in this case is secondary after nephelite and that consequently the original leucite broke down into orthoclase (with a small amount of plagioclase) and nephelite. The general resemblances just enumerated would appear to indicate that all these pseudo-crystals were formed under somewhat the same conditions. Just what those conditions were must still be a point open for discussion. It is believed by the writer that the mineral originally crystallized out, in the intra-telluric period of the magma, as a *soda*-leucite, that after the entire magma had solidified the leucite changed over into orthoclase, nephelite and subordinate plagioclase, and that still later the nephelite (both in the pseudo-leucite and in the ground-mass of the rock) changed partly into scapolite.

Leucite, which under any circumstances is a very unstable compound, is evidently rendered much more so by the large replacement of K_2O by Na_2O. It would seem that the presence of the latter in such large amount was responsible for the change of the *soda*-leucite into orthoclase, nephelite and very subordinate plagioclase.

Geological Laboratory, Columbia University.

Art. XXIV.—*The Re-formation of Soda-Leucite;* by T. T. Read and C. W. Knight.

In the case of a steel containing ·5 per cent carbon the molten mass on cooling first solidifies at 1225° C. as austenite, a solid solution of carbon in iron. This may for our purpose be regarded as a mineral, since it has a definite crystalline form and distinctive properties. If cooled slowly the austenite becomes metastable at a somewhat lower temperature and breaks down into two components, ferrite (Fe) and cementite (Fe_3C), using the former term in the metallographic and not the petrographic sense. The temperature at which this takes place is sharply defined (near 750° C.) and the process is marked by an evolution of heat. If, however, the cooling is accomplished rapidly (e. g., by quenching in water) this rearrangement does not have sufficient time to take place and austenite is preserved at ordinary temperatures. This is the familiar process for the hardening of steel. Under these conditions the austenite possesses a constant tendency toward rearrangement, which is restrained by the lack of molecular freedom at this temperature. On heating, this restraint is lessened and the austenite begins to effect the rearrangement, finally completing it at about the temperature at which it would have taken place with slow cooling. On raising the temperature slightly above this point austenite is again formed and may be preserved by quenching as before.

Following the line of thought suggested by these facts, it occurred to one of the authors[*] that if the crystals of pseudo-leucite could be heated to somewhat above the temperature at which the rearrangement to orthoclase and nephelite had taken place, soda-leucite would be yielded, which might then be preserved by rapid cooling. The slightest fusion of the crystal must, of course, be avoided. If the rearrangement in the pseudo-leucite is entirely analogous to that in the steel, then this change would be effected by temperature alone. But to make the analogy complete the heating should be effected at the pressure at which the rearrangement originally took place. Since this could not be ascertained, an attempt was made to cause the formation at atmospheric pressure of soda-leucite from the products resulting from the rearrangement.

In order to gain some idea as to the temperature required to produce this change, a small crystal of the pseudo-leucite, carefully freed from adhering groundmass, was placed in a platinum crucible provided with a closely fitting cover and sub-

[*] T. T. Read.

jected to the highest heat of a Bunsen burner for $5\frac{1}{2}$ hours. No noteworthy changes could be observed in a thin section made from the crystal thus treated.

Another specimen was then subjected to a constant temperature of 1225° C. in an electric furnace for ten hours. After cooling, a microscopic examination of the crystal in thin section showed parts to be isotropic. There still remained a considerable proportion of unalted orthoclase and nephelite. No traces of biotite or scapolite could be detected. The chlorine at this temperature would have been driven off, and with it perhaps some of the other constituents. The outer border was much darker in color and presented a glassy appearance. It was evident that the biotite had migrated to the border, forming a fused coating which had cemented the lower side of the crystal to the crucible. The shape of the crystal had not appreciably changed. The thin section showed the crystal to be full of globular holes about $\cdot 1^{mm}$ in diameter, due perhaps to the loss of volatile constituents and the passage of the biotite to the outer border.

Even granting that the isometric material which had formed was leucite, the difficulty of distinguishing it from glass is obvious. It was considered that the temperature employed was too high, since the edges of the crystal had a glassy and fused appearance, while the object of the experiment was to effect, if possible, the change of pseudo-leucite into soda-leucite in the solid.

Another crystal was therefore subjected to a constant temperature of 1100° for 8 hours. In this time a small area had become isotropic and showed a few bubbles, but otherwise was clear and colorless. The biotite had fused to a dark glass but had apparently not migrated from its original position. No scapolite could be detected (the chlorine had of course been driven off at this temperature), but otherwise than in these respects the appearance of the section had not been markedly changed beyond a distinct accentuation of the relief.

At this point it became necessary to discontinue the work for the present. If opportunity shall permit, it is the hope to continue it to more definite conclusions, but in the meanwhile it seemed wise to give an account of the preliminary work, as suggestive for discussion and perhaps research by others.

Both the authors are greatly indebted to Dr. M. N. Bolles of the Department of Metallurgy, who kindly conducted the heating in the electric furnace.

Department of Geology, Columbia University.

Art. XXV.—*Orotaxial Significance of Certain Unconformities ;* by Charles R. Keyes.

The unconformable relationships which some of the greater geological formations bear to one another in the Rocky Mountain region have been widely noted. Most of the observations bearing upon this theme have been made in Colorado and the states to the north and west. In this region, however, the full significance of the various unconformities which have been recognized cannot be measured. In each instance the values are qualitative and not quantitative.

The region mentioned has continued to be the theater of mountain-building from very early geological times. For this reason very largely the record of its geologic history is broken and obscured, and it is necessary to go into neighboring states to complete the account. To the southward in New Mexico conditions are quite different.

Soon after passing the south Colorado boundary the southern Rocky Mountains rapidly lose their imposing character and the last vestige is seen in the pitching anticline near the Glorietta pass, on the Atchison, Topeka and Santa Fe railroad, a few miles from the city of Santa Fe. Southward from this point, even to beyond the Mexican boundary 300 miles away, deposition has been more complete and continuous and repeated erosion less destructive than further northward.

In a given region it has been customary to write its geological history from the sediments alone. Gaps, even when recognized, have been passed over with little or no comment. Geologic history has, however, an erosional record that is about as long and fully important as the depositional record. The preserved erosional surfaces are the planes of unconformity. It is to some of the most important of these phenomena, as they have been recently made out beyond the southern Rocky Mountains, and to some of their depositional equivalents that attention is here called.

A decade and a half ago, S. F. Emmons, in a paper read before the Geological Society of America[*] on the Orographic Movements in the Rocky Mountains, mentioned the fact that from earliest Archean times this region has been one of upheaval. The author above mentioned, after reviewing the geological literature relating to this broad expanse of country, notes in the general geological column ten more or less marked unconformities.

In recent years, the same subject has been again broached, but from a somewhat different standpoint and in a neighboring province. More than double Emmons' number of great uncon-

[*] Bull. Geol. Soc. America, vol. i, pp. 245–286, 1890.

formities have been found, and the positions of these are indicated in the accompanying table of the major geological formations of New Mexico. For present consideration the chief value of the section lies in the surprising number of great unconformity horizons and in the presence of extensive formations which are represented by gaps in the rock-succession farther north in the Rocky Mountain region.

Since the time-value of the unconformity plane has been seldom measured quantitatively in sediments, and since every local geological section has an erosional as well as depositional record, the former is not measurable in the locality in which it is found, but finds expression in sediments in other and neighboring localities. One of the most remarkable instances of exact equivalency of this kind is found in the unconformity plane in the Upper Mississippi valley at the base of the productive Coal-measures. The depositional equivalent of this erosion plane is believed to be found on the south side of the Ozark dome in Arkansas, where the measurement is more than 18,000 feet. Southward beyond the end of the Rocky Mountains in New Mexico and the adjoining states conditions exist very similar to those in the Ozark region. Depositional equivalents of some of the gaps farther north are here found. Unconformities are also displayed in a way that enables the geological history to be made out with very much greater clearness than anywhere else. In this southern region, where mountain-making movements have not been so great as further northward, there has been recognized, as already noted, no less than a score of great unconformities, beside many of minor importance. The general geological section of this region, together with the horizons of unconformity, are given below.

Out of the 25 rock series which have been defined, there are only two (and possibly two other) exceptions in which these major formations are not separated by great planes of unconformity representing profound erosion intervals. The time-values of these various gaps in sedimentation no doubt differ very much among themselves; but they are all great. For instance, in central New Mexico, the Cimarronian Red Beds rest directly upon the Maderan limestones, with marked unconformable relationships. In southern New Mexico this interval is partially occupied by no less than 2,500 feet of sand stones and limestones. The relationships are indicated by diagram (fig. 1).

Little is known as yet of the unconformities of the Proterozoic within the boundaries of New Mexico. The presence of a pre-Cambrian clastic sequence has only been very recently recognized with certainty[*] and differentiated from the Archeozoic crystallines. There appear to have been several ero-

Great Unconformities in the New Mexican Succession.

Age.		Series.	Thickness.	Rocks.
CENOZOIC	Quaternary	(Not differentiated)	200	Gravels
	Tertiary	Llano Estacadan	200	Shales
		Arriban	500	Sandstones
		Wasatchan	1700	Sandstones
		Nacimientan	800	Shales
MESOZOIC	Cretaceous	Laramian	3600	Sandstones
		Montanan	1500	Shales
		Coloradan	1000	Shales
		Dakotan	500	Sandstones
		Comanchan	100	Sandstones
	Jurassic	Morrisonian	200	Shales
	Triassic	Zunian	1200	Shales
		Shinarumpan	1500	Shales
PALEOZOIC	Carboniferous	Cimarronian	1000	Shales
		Guadalupan	2500	Limestones
		Maderan	1000	Limestones
		Manzanan	1000	Limestones
		Ladronesian	100	Shales
		Socorran	300	Limestones
	Devonian	(Not differentiated)	400	Limestones
	Silurian	(Not differentiated)	100	Limestones
	Ordovician	El Pasan	1200	Limestones
	Cambrian	Tontoan	300	Sandstones
PROTEROZOIC		Chuarian	} 3000	Shales
		Grand Canyon		Sandstones
		Vishnuan		Quartzites
Archezoic		(Not differentiated)	5000	Schists

sion intervals. These may correspond to the three principal unconformities found farther west in Arizona. In northern New Mexico the three planes are believed to be superimposed.

The Paleozoic formations older than the Manzanan limestone (Mid-Carboniferous) are found only in the southwestern part of New Mexico, around the southern margin of the broad dome known as the Colorado High Plateau. To the north all

have been removed through erosion prior to the Manzanan period. In the south all of the series bear unconformable relationships to one another.

The thick Manzanan and Maderan limestones are widespread. They are found exposed in all of New Mexico west

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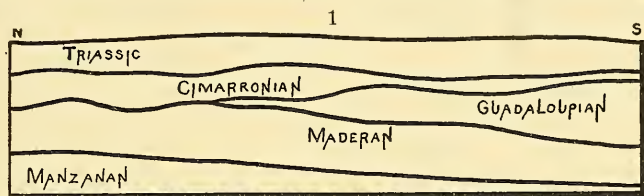
FIG. 1. Relationships of Late Carboniferous Formations south of the Rocky Mountains.

of the Pecos river and the Rocky Mountain front. They form the foundation of the entire High Plateau dome to the Grand Canyon. In all this vast region no trace has yet been discovered of any formation occupying the interval between the upper surface of the great limestone plate and the Red Beds. In southeastern New Mexico in the Guadalupe range there are over 2,500 feet of sandstones and limestones in this interval. This is the Guadalupan series and carries an extensive fauna, first made known by Shumard in 1858, but unknown elsewhere on the American continent.

The Red Beds are widespread. Very marked unconformities occur both at the base and at the top. Whether they are Permian or Triassic in age has long been a theme of discussion. A great unconformity lately determined in the very middle of the Red Beds succession appears to clearly separate the inferior Carboniferous part from the superior Triassic portion.*

Special interest centers in the probable existence of Jurassic deposits in the Morrisonian and Zunian formations. The general stratigraphic relationships are represented below (fig. 2).

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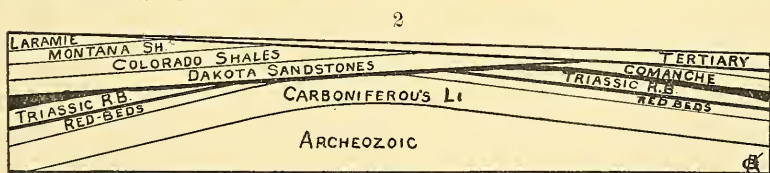
FIG. 2. Relationships of Mesozoic and Paleozoic Rocks of Northern New Mexico.

As for the other unconformities they may be passed over for the present.

In the course of the work of delimitating the formations composing the geological section of New Mexico, as set forth

* This Journal, vol. xx, pp. 423-429, 1905.

in this brief statement, the relative values of the biotic methods and a purely physical or orotaxial method have been strongly contrasted. For half a century the fossils of the region have been studied and the most that has come out of it has been only the geological age determined in the most general way. For the rock-succession few sharp lines have been developed and drawn by this means.

On the whole, recourse of late has been had only to the physical breaks in sedimentation. These bounding planes have given in the field both criteria for formational separation and precise data for quantitative correlation. The former have been surprisingly practical in their application. The latter are particularly instructive on account of furnishing many instances in which dependence upon fossils has been largely done away with. In fact, in the working out of the general scheme, aid from the contained organic remains of the different geological formations has been received only in a most general way, and frequently only as an independent check, among several other distinct methods. The paleontological conclusions usually lag so far behind the deductions derived from other sources in the field that in this as in other numberless cases they are almost useless as practical aids. They come in after the important questions have been already conclusively settled.

In several instances fossils have had to be neglected altogether, since the evidence afforded by them was so indecisive. Some of these cases present similar conditions to those described by McGee for the middle Atlantic slope, where he stated that "during the past two or three years more has been learned of the stratigraphy of the formations through physical means than through biotic methods in the previous 50 years."

One of the most instructive facts brought out by the present physical scheme has been the manifest necessity of complete revision of many conclusions arrived at through purely paleontological means. In such regions as the Rocky Mountains, where the rock formations are exposed on such a much grander scale than in more humid parts of the country, the fossils can never have the importance which they have in the last mentioned areas; in fact, their use may be largely done away with, and in actual practice they are very generally neglected. This fact the paleontologists have failed to take cognizance of, at least as far as published accounts indicate. Attention has been also called to this fact by Emmons, King, and others who have worked in the Rocky Mountain field, but who have not had to depend wholly upon the fossils in their stratigraphic efforts.

In the periods of mountain-building and in orogenic movement a quantitative measure of a regional geologic record is believed to be found.

New Mexico School of Mines,
  Socorro, New Mexico.

Art. XXVI.—*Some Phosphorescent Calcites from Fort Collins, Colo., and Joplin, Mo. ;* by Wm. P. Headden.

The calcites discussed in this article possess the property of becoming phosphorescent on being insolated and retain this property, in some cases, for a period of thirteen hours. Ordinary calcite under like conditions phosphoresces for one-third of a second and aragonite for twenty seconds. Many other minerals become phosphorescent on being insolated, but the duration of this phosphorescence is very brief.

The specimens described in this article are from two localities, Fort Collins, Colo. and Joplin, Mo. The Colorado specimens occur as a vein of calcite cutting through the Fort Benton shales. No distinct crystals have as yet been found at this locality. The specimens from this locality are inferior to the Missouri mineral in all respects, particularly in regard to the brilliancy of the phosphorescence. The best specimen from this locality was quite strongly phosphorescent after insolation, it was observed for two and one-half hours, when the observation was abandoned though the specimen was still phosphorescent.

The Missouri specimens occur in two forms, both in well defined crystals. One is the well-known dog-tooth spar, only slightly modified by a rhombohedron ; the other is a combination of two scalenohedrons. The crystals of dog-tooth spar are as a rule quite large, and have, exteriorly, a yellow color ; the crystals showing a combination of two scalenohedrons are smaller and their interior portion is yellow, while the outer portion is colorless or in some instances slightly violet. The change from the yellow to the colorless calcite in these crystals is sometimes shown very distinctly by a crop of chalcopyrite crystals which have formed on the surfaces of the more obtuse scalenohedron.

The Missouri specimens show a stronger phosphorescence and are in other respects better fitted for the purposes of this investigation than the Colorado ones. The following data, therefore, have been obtained from the Missouri mineral.

The occurrence of wine-colored crystals of calcite at the lead and zinc mines near Joplin, Mo., is well known, but I do not know the mine or mines from which my specimens were obtained. In the case of the dog-tooth spar, the wine-yellow color is due to the deposition of a yellow calcite in the last stages of their growth. The interior portions of these crystals are seldom if ever yellow, but are colorless or violet if transparent and white if opaque. The other type of crystals have yellow centers and a colorless or violet-tinged outer portion.

The yellow calcite alone possesses the property of phosphorescing in the sense that I use this term. The first sample which we found to possess this property had an irregular purple patch near its center, which appeared as a dark area in the mass of yellow light. Repeated observations on cleavage pieces which were partly yellow and partly of some other color fully justify the preceding statement. In such cases the phosphorescence was always limited by the line of growth which marked the change from the yellow to the other color, whatever it was, white, purple or colorless.

The duration of this phosphorescence in the yellow calcite was as much as thirteen hours, which was established by continuous observation. The duration actually exceeded this time, but one's eyes and judgment too become more or less unreliable after hours of watching, especially as this light not only becomes very feeble, but also assumes a ghastly whiteness before it fades out entirely. The phosphorescence was distinctly visible, however, in some specimens, for the time given, thirteen hours.

These experiments were made in both the summer and winter seasons. An insolation for any considerable time in the summer season produced a sensible increase in the temperature of the mass; this probably had some effect upon the intensity and duration of the phosphorescence in the samples observed at that time. I insolated a large specimen for thirty minutes at a temperature of $-3°$ C., when it was found to be strongly phosphorescent. I did not determine the duration of this phosphorescence, but I could not perceive any diminution in its intensity at the end of two hours. A variation of temperature from $-3°$ to $+25°$ C. does not, so far as our observation goes, materially affect the character and duration of the phosphorescence.

I endeavored to observe whether this phosphorescent light would give a spectrum or not; but the results were unsatisfactory. The action of this light on a photographic plate was tested by exposing a Seed's gilt edge dry plate to the action of the light emitted by a large, strongly phosphorescent crystal for 30 minutes. The portions of the plate intended to receive the action of the light were not protected in any way. There was no action at all on the plate, it was perfectly clear when developed.

Phosphorescence can be excited in the yellow calcite by the electric spark, also by the X-ray. The phosphorescence excited by the passage of the spark for a few seconds was observed for thirty minutes, but it had in this time become quite faint. A number of cleavage pieces of the Joplin mineral of different colors and a piece of Iceland spar were exposed to bombardment by the X-ray; they all became phosphorescent, but the

Iceland spar ceased to phosphoresce very quickly; so did the colorless, the white opaque and the purple pieces of the Joplin mineral, while the yellow was still phosphorescent at the end of an hour.

Burning magnesium provokes phosphorescence in the yellow but not in the other varieties, Iceland spar included. The duration of this phosphorescence was not determined, but it exceeded ten minutes.

The time of exposure to the action of these agents varied greatly, but it will be recognized that my object was to study the deportment of these calcites and not the relation of the intensity and duration of the phosphorescence to the intensity and time of action of the agents causing it. The shortest insolation timed was four minutes and it produced a strong phosphorescence. Our insolations were made at various times of the day, from early morning till after 5 o'clock in the evening, with apparently equally good results. The yellow calcite emits light when crushed or powdered : the light is yellow and there is no danger of mistaking it for the light emitted when an agate or porcelain mortar is rubbed with its pestle. The yellow calcite becomes phosphorescent when heated. Small pieces heated in an air bath began to phosphoresce when the thermometer indicated a temperature of 60° C., but the larger pieces introduced at the same time did not begin until the thermometer showed 75°. The phosphorescent light emitted by the heated pieces is reddish yellow, almost salmon-colored, and fades rapidly especially if the temperature has been raised to 180° or higher. If the temperature has been raised to 100° and the specimens removed, the phosphorescence fades rapidly at first but afterwards quite slowly.

Some of the samples burst when heated to 180°, possibly due to liquid inclusions ; the appearance of some of the pieces suggested the presence of such, but none were actually observed. Heating to 200° does not destroy the property of the calcite to become phosphorescent on subsequent insolation, but ignition does.

If a piece of insolated calcite be brought into a heated air bath, the character, intensity and duration of the phosphorescence is modified and deports itself as though the phosphorescence had been produced by heating alone.

The size of the pieces of calcite insolated has but little or no effect on the intensity or duration of the phosphorescence. In one instance a piece weighing less than two-tenths of a gram was the brightest one in the tray and was still recognizable as such at the end of one and a half hours.

In the large number of insolations made we met with but two exceptions to the statement that the yellow calcites become phosphorescent by insolation. I have not discovered the reason for these two exceptions. The cause was not due to

the calcites themselves, for they were subsequently insolated and phosphoresced brightly.

I have stated that ignition destroys the property of becoming phosphorescent by insolation, so does solution ; neither the solution itself nor the carbonates recovered from it by fractional precipitation show this property.

A yellow color in the Joplin calcite seems to be a sure indication that the sample will become phosphorescent upon insolation. Two things suggested themselves as possible explanations of these properties, the presence of sulphides and of organic matter, but I was unable to detect the presence of either of these. It, however, still seemed probable to me that this property was due to the chemical composition of the yellow portion : with this idea in view I submitted a carefully selected portion of the yellow calcite to analysis. This analysis gave but little promise that I might succeed by pursuing this method of investigation, as the percentages obtained for the calcic oxide and carbonic acid were almost exactly those required by theory. The precipitate, usually composed of ferric and aluminic oxide, amounted to less than 0·10 per cent, but it was the deportment of this precipitate that led me to repeat the analysis. The small amount missing in my first analysis, an amount less than 0·20 per cent, proved to be the interesting part of the mineral, whose analysis finally presented the following results :

Analyses of Yellow Calcite from Joplin, Mo.

SiO_2	0·032
CO_2	43·950*
SO_3	trace
H_2S	none
P_2O_5	trace
Cl	trace
CaO	55·740
SrO	trace
MgO	0·113
MnO	0·045
FeO	0·046
ZnO	0·014
Al_2O_3	trace
Cr_2O_3	trace
Ce_2O_3	0·007
$Di_2O_3, Sm_2O_2 . La_2O_3$	0·012
$Yt_2O_2 . Er_2O_3$	0·013
NH_3	trace
Na_2O	trace
Total	**99·975**

* One hundred grams of selected material gave 10^{cc} of gas not absorbed by KOH solution.

The analysis gives us no definite information relative to the cause of the phosphorescence, but merely an unusual though not an unknown fact relative to the composition of calcites. The presence of ceric oxide in certain limestones has been observed before; and Sir William Crookes has shown the presence of samaria and yttria in calcite, coral, etc.; but this is the first time, I believe, that these elements have been found in such notable quantities.

There are a few persistent peculiarities that have presented themselves in the course of this work which are worthy of an exhaustive investigation. The solution of the ceric oxides in hydrochloric acid shows, in addition to the lines of didymia, an extra line in the violet beyond the didymia line charted at 133–134. This line is easily observed by the aid of a small direct-vision spectroscope.

The ceric oxides obtained in this analysis have the following colors; the ceric oxide, CeO_2, has a pale rose-red color; this probably indicates the presence of a little didymia, though the cerous hydrate was suspended in a strong solution of potassic hydrate and treated with chlorine until the potassic hydrate was saturated, then gently heated, filtered, washed, etc.; and again submitted to the same treatment. This was repeated three times and still the ceric oxide appears to contain didymia.

The filtrates from the precipitate of ceric hydrate were precipitated by the addition of oxalic acid. All of these precipitates gave either a very light green oxide,—a greenish gray might be more descriptive of this oxide, or a green with a tinge of brown; this may be praseodidymia but it is more probably a mixture of didymia and samaria, which would account for the brown tinge in some of the portions and the light brown of two portions which no heat that I have been able to obtain with the blast lamp has changed in the least. There is no direct proof of the presence of lanthana; its presence has been taken as a matter of course.

The oxalates of the yttria group yielded on ignition a yellowish white oxide whose solution in hydrochloric acid gave an excellent spectrum for erbia. In working with this group I observed that there is an oxalate present which is quite insoluble in cold water and in oxalic acid, but is quite soluble in hot water. If the oxalates be first washed with cold water and then with boiling water, the oxalate will crystallize out of the hot wash water as it cools. According to the data that I find given, yttria oxalate is the most soluble oxalate in this group, and of it the statement is, that it is almost insoluble in pure water. This oxalate gives with ammonia a white precipitate similar to yttria and the other members of this group. I do not think that this is due to yttria because this oxalate can be completely

washed out of the oxalate precipitate, so that the boiling wash water will neither yield any crystals on cooling or give a precipitate with ammonia, even after concentration, though there is still yttrium in the precipitate. I have been compelled to postpone the further investigation of this precipitate until I may be able to command more material and greater resources than I have at the present time.

The presence of an oxide which is precipitated by ammonia in the presence of tartaric acid, and which is precipitated by oxalic acid from a solution containing free hydrochloric acid, but not by a saturated solution of potassic or sodic sulphate, is taken as conclusive proof of the presence of yttria. The characteristic absorption spectrum of erbia is relied upon as establishing its presence, but the question of the presence of the other members of the group is held in abeyance.

We have not as yet gained even a hint in regard to the cause of this property of the yellow calcite, i. e. of phosphorescing after insolation. I have not met with any statement which would lead one to infer that the presence of zinc or of any member of the yttrium or cerium group in the form of carbonate would impart this property to the calcium salt. The salts of the rare earths, the ignited yttria sulphate excepted, seem to show phosphorescence in a weak and rather unsatisfactory degree even when exposed to the action of the cathode ray in a radiant matter tube. When calcium is present the deportment of yttria and samaria is radically changed, especially in regard to the phosphorescent spectrum that they give. Some such fact may obtain in this case of phosphorescence after insolation.

A very large amount of work was done of which no record appears in this article, but the results of which serve as the basis for the following statements; the total amount of rare earths may be greater in a non-phosphorescent than in a phosphorescent calcite; the oxides of the yttria group are relatively more abundant in the phosphorescent than in the non-phosphorescent; the white, opaque calcite contains less zinc oxide and a much smaller amount of the rare earths than the yellow, phosphorescent portions.

The second of these statements is illustrated by the ratios found for the yttrium and cerium groups in the following four instances; in a sample of yellow, strongly phosphorescent calcite the ratio of the yttrium to the cerium oxides was $1\frac{1}{2}:1$, in another sample of yellow calcite this ratio was $1:1$, but in two samples of feebly or non-phosphorescent material this ratio was $1:2\cdot4$ and $1:2\cdot6$ respectively. The weight of calcite used in making these determinations was 500 grams in each case.

The white, opaque cleavage pieces, obtained by breaking up crystals of dog-tooth spar, have in no instance been observed

to be phosphorescent after insolation. Analysis shows that the rare earths are present in such pieces, but in less than one fifth of the maximum quantity found in other samples, while the zinc oxide was a little more than one half the amount found in the best material.

We are dealing with such small quantities and it is so difficult to select samples of 500 or even 50 grams that shall be uniform in their contents of these elements, that we should be careful to duly consider the possibility of variation in the samples selected, and further, the probability of error, for it is a delicate task to determine such small quantities of these elements.

If the question is one of chemical composition, it is evident that we are compelled to consider the unusual things, those which in this case are present in minute quantities, as imparting this remarkable property. If this view be correct, the common accidental constituents of calcite such as ferrous, ferric, manganous, magnesic and probably zinc oxide are eliminated from our consideration.

In describing this calcite I have mentioned purple as a rather common color in these samples or rather in portions of them. This is seemingly an insignificant fact, especially if we assume, as is usually done, that the pink, violet and purple is due to some manganese compound. The purple due to manganese, particularly as permanganate, gives a characteristic absorption spectrum; accordingly the purple portions of the cleavage pieces were examined with aid of the spectroscope. The light from an incandescent lamp gives an excellent continuous spectrum when viewed through the yellow or the colorless calcite, but a pronounced black line appears whenever a purple portion passes between the lamp and the slit of the spectroscope. If the purple color is intense enough two lines appear. No sample examined failed to give the stronger of these two lines very satisfactorily indeed. These two lines coincide with the α and β lines of didymia, which fact was ascertained by using a solution containing didymia, when the lines produced by the purple portions of the calcite were found to be coincident with the α and β lines of the solution and are, therefore, probably due to this earth.

The analytical results justify the inference that the yttrium group has a greater influence upon the phosphorescence of the calcite than the cerium group; and this inference is greatly strengthened by the spectroscopic proof that the didymia can readily be detected in portions of the crystals which have not, under any conditions, been observed to phosphoresce. As cerium, lanthanum and samarium are usually if not always associated with didymia, one is justified in assuming that the

other members of the group which occur in the mineral are
present in the purple portion also and probably play but a
small part, if any, in imparting this property of phosphor-
escing to the calcite.

The phosphorescence is confined to the yellow portions of
the mineral, and those having the deepest yellow color, such
as pass into a brownish yellow shade, show the strongest phos-
phorescence. Our failure to detect any organic coloring matter
suggests very strongly that we are to find the cause of the
phosphorescence in the presence of some element whose salts
are yellow. My interpretation of the facts is that they point
to the yttrium group or some member of it, whether it is at
present known to chemistry or not, as the cause of this property.
It may be only a coincidence, but it is a fact that the deeper
brownish yellow portions of the calcite are strongly suggestive
of the brownish yellow of xenotime, and had phosphoric acid
been present in this calcite in more than a very minute trace, we
might, with a fair show of reason, have inferred the presence
of the phosphate of yttria, but there is only a trace of phos-
phoric acid and the phosphate of yttria cannot be present. I
do not, however, intend to convey the impression that yttria
may not be the cause for which I have been searching, for at
the present time I am inclined to think that it is.

It may seem marvelous, even to the chemist, that an amount
of any substance so small as we are evidently dealing with in
this case, should be capable of producing such striking and
beautiful effects as I have endeavored to describe. It is
marvelous but not incredible. Sir William Crookes has been
able, by means of the phosphorescent spectrum, to detect one
part of yttria or samaria when diluted with one million parts
of lime, and the one part of samaria continued to cast its
shadow, so to speak, on the spectrum in the presence of two
millions five hundred thousand parts of lime.

The figures deducible from my analyses are scarcely sugges-
tive of such infinitesimal quantities as these, still it is possible
that the substance actually causing this wonderful sensitiveness
to sunlight and imparting the power to give it out again for
so long a time may be present in no greater quantity than one
part in two millions five hundred thousand.

The limit of my present progress is the establishment of a
probability that these calcites owe their property of becoming
phosphorescent on insolation to the presence of some member
of the yttrium group which is represented by 13 parts in each
100,000 parts of the calcite.

Colorado Agricultural College, Fort Collins, Colo.

Art. XXVII.—*On the Chromates of Cæsium;* by Frank Roy
Fraprie.

Of salts of cæsium and chromic acid, there have been
described a chromate and a bichromate, neither of which have
been thoroughly investigated. Cæsium chromate was appar-
ently first made by Retgers,[*] who studied its isomorphism
with the other alkaline chromates without describing the salt
itself. It was prepared in "beautiful clear yellow needles
several centimeters long" by Chabrié[†] in 1901, after the pre-
sent study was begun. The bichromate was first mentioned
in 1885 by Soret,[‡] who prepared cæsium chrome alum from
commercial bichromate, and was described by Chabrié (loc. cit.)
as "small crystals of a brilliant clear red."

In the present investigation the following salts have been
prepared :

Cs_2CrO_4 α (Rhombohedral-hemihedral)
Cs_2CrO_4 β (Orthorhombic)
$Cs_2Cr_2O_7$ (Triclinic)
$Cs_2Cr_3O_{10}$ (Rhombohedral-hemihedral)
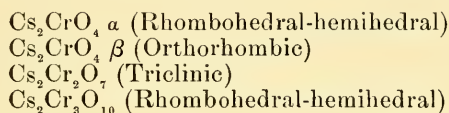
Cæsium Chromate α, Cs_2CrO_4.

This salt was prepared in Cambridge in 1901–2 by adding an
excess of silver chromate suspended in water to a solution of
cæsium chloride. The cæsium chloride used was prepared by
Mr. E. H. Archibald for the determination of the atomic
weight of cæsium, and was spectroscopically free from traces
of other alkali metals. The cæsium chromate was filtered by
suction and evaporated to small bulk, when a small quantity
of silver chromate separated. This was filtered off, and the
nearly saturated solution was allowed to crystallize in a desic-
cator. The crystals obtained at ordinary temperatures, instead
of being orthorhombic, like the potassium and ammonium salts,
were long hexagonal prisms, of a very pale yellow color, almost
colorless when transparent. They are perfectly stable in either
dry or moist air. They contain no water of crystallization.
An analysis for chromium gave the following result :

Salt taken.	Barium chromate.	% CrO_3 found.	Calculated.
0·2874 g.	0·1900 g.	26·12	26·22

A crystallographic examination of the crystals was made.
They consisted of a combination of the hexagonal prisms of
the first and second order equally developed, with a single

[*] Retgers, Ztschr. physikal. Chem., 1891, viii, 24–63.
[†] Chabrié, Comptes rendus, 1901, cxxxii, 678–681 ; Ann. chim. phys., 1902,
(7) xxvi, 212–228.
[‡] Soret, Arch. sci. phys. nat., 1885, (3) xiv, 96 ; Comptes rendus, 1885,
ci, 156–157.

pyramid the faces of which could not be measured on account of etching. Many crystallizations were made before well-terminated crystals were obtained, as the slightest rise in temperature of the solution caused etching, owing to the considerable change in solubility of the salt, and the pyramid faces were first attacked. By removing the crystals at a time when the temperature of the solution was falling, very perfect crystals were finally obtained and the pyramid measured on a two-circle goniometer. With the exception of some indeterminate line edges in the prism zone on one or two etched crystals, no other forms were observed on these crystals. The angle from the pole of the prism zone (corresponding to the absent basal pinacoid) to the pyramid was found to be 39° 23'.

Many attempts were now made to crystallize isothermally at from 50° to 70° in a thermostat. The solubility increases so markedly at high temperatures that the solution always got down to very small bulk before crystallization commenced, and crystals could only be got by allowing the solution to go to dryness. These crystals were naturally not ideal for measurement, and only one crop was obtained, at 70°, which gave crystals with measurable pyramids. These gave the same value as those crystallized at ordinary temperature.

The hypothesis of compressible atoms* suggested that crystals grown under pressure might exhibit a change of habit or angles due to unequal atomic compression,—a change which might be preserved by the viscosity of the solid after the pressure was removed. Such a change, if demonstrated, might be the cause of the irregularities to be observed in the angles of minerals. Accordingly experiments under pressure were next made in a Hempel bomb, to which could be attached an oxygen generator. As the manometer was graduated only to twenty-five atmospheres, the highest pressure used was about twenty-eight atmospheres, most of the runs being made at twenty-three or twenty-five. The bomb was tight enough so that the diminution in pressure during the course of an experiment rarely amounted to more than one atmosphere. About forty experiments were made, some at the room temperature, some at various temperatures in a thermostat. The method was as follows: the cæsium chromate was contained in a tall, narrow, flat-bottomed glass tube, the solution being saturated and in contact with some undissolved salt. This tube was placed in the bomb on a leaden tripod which stood in concentrated sulphuric acid, used as a desiccating agent. As this on one occasion got into the chromate, it was afterwards replaced by sticks of caustic potash packed into the spaces between the walls and a cardboard tube surrounding the chromate tube.

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* T. W. Richards, Proc. Amer. Acad. Arts and Sci., 1901, xxxvii, 1–17; 399–411.

The apparatus thus prepared was screwed up tight, connected with the oxygen generator, and heat applied to the latter until a sufficient pressure was reached, or until all the oxygen had come off. The generator was detached, and the bomb kept at the desired temperature in the thermostat for a period of from one to seven days. When opened, the crystals, if any were found, were removed from the liquid as hastily as possible, dried between filter papers, and examined. In the whole series of forty experiments not a single measurable crystal was obtained, the crystalline powder always consisting of irregular fragments mingled with very minute crystals. A microscopic examination often showed small perfect crystals.

Shortly before the end of the work in Cambridge, one crop of crystals was obtained at a pressure of twenty-eight atmospheres by heating the bomb in the thermostat at 70° for eight hours, and allowing it to cool slowly over night in the large tank of water. An excess of salt had been added to the solution, and a fair crop of crystals was obtained. While these was considerably etched, they gave readable signals, and from measurements of a number of crystals, it was found that the angles were the same, within the limits of error of reading, as on crystals grown under ordinary conditions.

The crystals of this crop differed in habit from those previously obtained, in that the predominant terminating plane was a rhombohedron, well developed on both ends of the crystals, and with its edges truncated by a pair of narrow faces of the pyramid ordinarily present. The faces of this rhombohedron were often slightly concave. For this reason, and because only ten faces could be measured, the axial ratio was calculated from the pyramid. The measurements follow :

$$Cs_2CrO_4a \text{ (Rhombohedral–hemihedral).}$$

$$a : c = 1 : 1·2314.$$

				Calculated.	Measured.	Readings.	Limits.
a	r	$10\bar{1}0$	$10\bar{1}1$	25° 7′	25° 0′	10	25° 19′–24° 21′
b	p	$11\bar{2}0$	$11\bar{2}3$		*50 37	34	50 42 –50 36
r	r	$10\bar{1}1$	$0\bar{1}\bar{1}1$	103 16			

Cleavage : basal, incomplete.

Forms : a ($10\bar{1}0$), b ($11\bar{2}0$), r ($10\bar{1}1$), p ($11\bar{2}3$).

The habit of the crystals is shown in figs. 1 and 2. Fig. 1 shows the crystals grown under ordinary pressure ; they were apparently holohedral, invariably fully developed, with the six pyramid faces on each end all nearly equal in size, and with no trace of any rhombohedral face. Fig. 2 shows the rhombohedral crystals grown under pressure.

The growth of crystals under pressure was undertaken with the idea of ascertaining whether any change in habit or crystallographic constants could be produced by mechanical stress during the crystal growth. The results thus far obtained are not
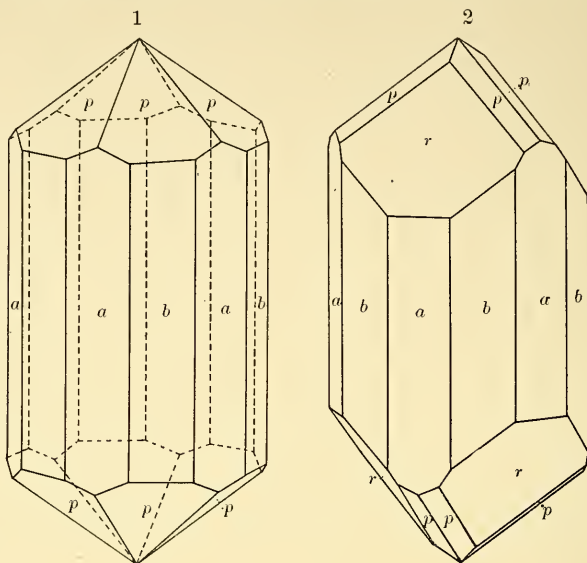
ready for publication, and it is proposed to continue this work in the near future in the Chemical Laboratory of Harvard University.

Cæsium Chromate β, $Cs_2 Cr O_4$.

On one occasion some of the crystal powder taken from the bomb, composed of extremely minute particles, showed under the microscope, besides a few dark red bichromate crystals and large numbers of the ill-formed long pale hexagonal needles, two or three well-formed crystals of a very much deeper yellow color and bounded by definite planes and angles. The whole mass of crystals which had been separated from the mother-liquor and dried, was searched in the hope of finding some crystals of this character large enough to measure, but in vain. The mother-liquor had been set aside, and the next day, when it was sought for the purpose of making another experiment, it was unexpectedly found to contain several large, deep yellow, apparently orthorhombic crystals. Although they had partly redissolved, a measurement showed that they were orthorhombic, isomorphous with and composed of the same forms as are found on potassium chromate, cæsium sulphate, and the other members of this group. No further crystals of

this kind were obtained at Cambridge, from lack of time. On resuming the work at Munich in the fall of 1902, using another preparation of cæsium, only the orthorhombic crystals were obtained. The cæsium chromate used, obtained from Merck, was recrystallized twice as dichloriodide, and then converted into chromate as before. The orthorhombic crystals were analysed and found to be of the same composition as hexagonal ones, as follows;

Salt taken.	Barium chromate.	%CrO$_3$, found.	Calculated.
0·3960 g.	0·2614 g.	26·12	26·22

Many attempts were now made to prepare the hexagonal crystals again, but absolutely in vain. Crystallization from either hot or cold solutions, quickly or slowly, always gave the same result, orthorhombic crystals. Only a small quantity of the formerly obtained hexagonal crystals was available, and repeated inoculations of solutions saturated and supersaturated with the orthorhombic salt had always the same result; the hexagonal crystals dissolved, and orthorhombic ones crystallized out. As the method of preparation in both places was the same, and the greatest care was taken in the purification of all materials used, and as the composition of the two salts is the same, it must be assumed that the hexagonal form is labile at ordinary temperature and pressure, and cannot exist in the presence of the orthorhombic form, although it may be possible to prepare it when no orthorhombic salt is present to start crystallization.

The measurements of the orthorhombic salt follow :

Cs_2CrO_4 β (Orthorhombic).

Axial ratio : 0·5640 : 1 : 0·7577.

Faces.	Symbols.	No.	Mean.	Limits.	Calculated.	Difference.
bp	010 110	50	*60° 35′	60° 24′–60° 51′		
ap	100 110	4	29 25	29 21 –29 29	29° 25′	±0′
pp	110 1$\bar{1}$0	13	58 50	58 36 –58 57	58 50	±0
bq	010 011	46	*52 51	52 26 –53 15		
cq	001 011	17	37 9	36 54 –37 25	37 9	±0
qq′	011 021	10	19 23	19 6 –19 35	19 16	+7
bq′	010 021	9	33 33	33 22 –33 42	33 25	+8
ao	100 111	10	43 7	43 2 –43 14	43 2	+5
oq	111 011	12	46 53	46 46 –47 3	46 58	—5
op	111 110	26	33 3	32 55 –33 12	32 57	+6
co	001 111	10	56 57	56 48 –57 13	57 3	—6
bo	010 111	3	65 41	65 37 –65 56	65 40	+1
	010 130				30 35	

Cleavage not observed.

Forms : *a* (100), *b* (010), *c* (001), *o* (111), *p* (110), *q* (011), *q′* (021).

The crystals vary much in habit. Often they are in the form of long yellow needles with no end faces, prismatic parallel to the *a* axis, and limited in length only by the width of the dish. Several crops were composed of prismatic crystals well developed on both ends, and once or twice the crop was composed almost entirely of interpenetration twins,
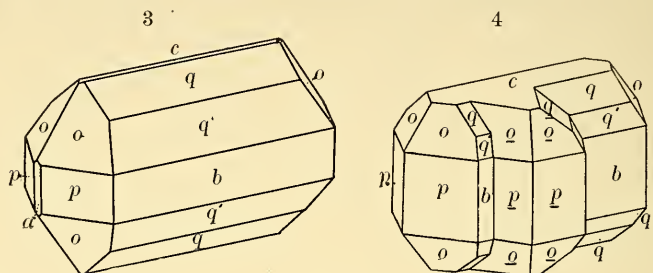
the twinning plane being 130, a face not observed on any crystal. The figures show a twin and a simple crystal. *a* (100) is rarely present and always very narrow, and the same may be said of *c* (001), except on the twins, where it is well developed. The other forms are always all present and of nearly equal development. The species is completely isomorphous with potassium sulphate and chromate.

Cæsium bichromate, $Cs_2 Cr_2 O_7$.

On one occasion when sulphuric acid got into the solution by the accidental breaking of a tube, the crop consisted wholly of microscopic red crystals of cæsium bichromate. These crystals seemed to be rhombohedra with apparently parallel extinction, but it was not possible to determine their system on account of their small size. An analysis for chromium resulted as follows :

Salt taken.	Barium chromate.	%CrO$_3$ found.	Calculated.
0·1370 g.	0·1437 g.	41·42	41·55

The salt is quite insoluble, and is precipitated by the addition of sulphuric acid to a cæsium chromate solution. It was later prepared by adding an equivalent or more of chromic acid to the solution of chromate. It is then precipitated as an orange red power, much more soluble in hot water than in cold. An attempt was made to crystallize it in the " Schwedischer Topf," an apparatus for crystallization by very slow and uniform cooling, but even when the fall in temperature from 100° to 20 extended over a period of seven days, the crystals were so stri-

ated as to be useless for measurement. A single crystal possessed a prism zone from which blurred signals could be read to within a degree or so, and this measurement and the cleavage are sufficient to establish the isomorphism with potassium bichromate.

$Cs_2Cr_2O_7$ (Triclinic).

Axial ratio unknown.
Cleavage parallel to 001, perfect.

				$Cs_2Cr_2O_7$	$K_2Cr_2O_7$
c	q'	001	0$\bar{1}$1	$66\frac{1}{2}°$	$67°\ 23'$
q	b	0$\bar{1}$1	010	25	26 57
b	q	010	011	$31\frac{1}{4}$	30 46
q	c	011	001	$58\frac{1}{2}$	54 54

An analysis of this salt gave the same result as the analysis made at Harvard of the salt precipitated by sulphuric acid.

Salt taken.	Barium chromate.	%CoO_3 found.	Calculated.
0·1592	0·1661	41·20	41·55

The occasional occurrence of orthorhombic crystals of entirely different form and color to those of the orthorhombic chromate, but not in sufficient quantity for investigation, suggests the probable existence of a second form of the bichromate. It is hoped that further investigation of this salt may be made in the near future.

$Cs_2Cr_3\ O_{10}$, *Cæsium trichromate.*

On further evaporation in the desiccator of the mother liquor from the bichromate, beautiful dark red rhombohedra of cæsium trichromate were deposited. An analysis resulted as follows :

Salt taken.	Barium chromate.	%CrO_3 found.	Calculated.
0·1845	0·2401	51·39	51·47

The habit of the crystals, which usually have one pair of rhombohedral faces very large, is apparently monoclinic, but a crystal with well-developed base showed the uniaxial cross very distinctly, and the measurements, although the crystals were not of the best, proved the hexagonal character. The trichromate is thus not isomorphous with any other trichromate. Mixtures of ammonium and rubidium trichromate crystallize in three systems, according to Wyrouboff,* monoclinic, orthorhombic, and hexagonal, but the present salt is of still a fourth form, trigonal.

* Wyrouboff, Bull. Soc. franc. min., 1881, iv, 120–135.

The measurements follow :

$$Cs_2Cr_3O_{10} \text{ (Rhombohedral–hemihedral).}$$

Axial ratio, $a : c = 1 : 1 \cdot 5549.$

Forms, r (10$\bar{1}$1), e (01$\bar{1}$2), b (11$\bar{2}$0), c (0001).

Cleavage not observed.

Faces.	Symbols.		No.	Mean.		Limits.			Calculated.	
cr	0001	10$\bar{1}$1	11	60° 58′		60° 49′–61° 29′			60° 53′	
ce	0001	01$\bar{1}$2	7	42	5	41 43 –42	9			
re	10$\bar{1}$1	01$\bar{1}$2	49	*49	10	48 9 –50	13			
re	10$\bar{1}$1	10$\bar{1}\bar{2}$	11	76	55	76 51 –77	3		77	2
rb	10$\bar{1}$1	11$\bar{2}$0	4	40	50	39 33 –41	17		40	50
rr	10$\bar{1}$1	01$\bar{1}\bar{1}$	24	81	41	80 51 –82	33		81	40
rr	10$\bar{1}$1	0$\bar{1}$11							98	20

5
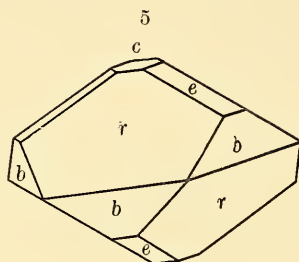
Summary.

This paper describes the preparation and crystallographic properties of two modifications of cæsium chromate, Cs_2CrO_4, of cæsium bichromate, $Cs_2Cr_2O_7$, and of cæsium trichromate, $Cs_2Cr_3O_{10}$, and leaves in doubt the existence of a second form of the bichromate.

It proves that a pressure of thirty atmospheres during the process of crystallization is not sufficient to produce any measurable difference of crystallographic axes or angles in hexagonal cæsium chromate, but makes it probable that it effects a change of habit in the crystals.

In conclusion I must express my thanks to Professor Theodore W. Richards and Dr. Charles Palache of Cambridge, and Professor Paul von Groth of München, for their encouragement and advice during the progress of this investigation.

Art. XXVIII.— *Descriptions of two remarkable new species of Goliath Beetles (Dynastes) from Dominica Island, Antilles—Brief Contributions to Zoology from the Museum of Yale University, No. LXVI;* by A. Hyatt Verrill.

Dynastes tricornis sp. nov.

Male.—Elytra, thorax, and head polished, deep purplish black with no hair except along the edges of the segments, where the hairs are short, sparse, and rusty or ferruginous red; ventral surface highly polished, deep brownish black with very few sparsely distributed reddish hairs along the edges of the segments. Legs stout, black, and smooth, except along the tibiæ of the anterior pair, which are deeply but minutely pitted; tarsi and tibiæ edged with fine reddish hairs; processes of tibiæ very similar in form to those of *D. Hercules*. Dorsal outline of elytra broad, obtuse, and slightly compressed laterally at a point about one-third the distance between the anterior and posterior extremities.

Thorax shield-shaped in a dorsal view; concave in a lateral view and bearing three slender, smooth, curved, processes or " horns." The three horns are arranged in a triangle with the two posterior ones forming its base and curving forward and inward toward the third process, which forms the apex of the triangle; the anterior processes rounded below and flattened above, somewhat thickened near the center and curved semicircularly upwards at the outer end. No hairs on any of the thoracic processes.

Head minutely pitted and without appendages of any sort, except a small, slightly raised, transverse ridge between the eyes. Lateral posterior edges of the thorax below appendages and upper surface of anterior appendage minutely pitted.

Length from anterior extremity to tip of abdomen (exclusive of thoracic process), 1·45 inches; width of thorax at posterior segment, 0·60; width of thorax at widest point (across two posterior processes), 0·70; width of thorax at anterior segment, 0·25; width of elytra at widest point, 0·85; length of two posterior thoracic processes, 0·35; length of single anterior process, 0·45.

Habitat.—Highest mountain slopes of the island of Dominica. Several specimens. Female unknown.

As will be seen by the foregoing description, this new *Dynastes* is very distinct from any other species of the genus. Its small size, three thoracic and no occipital appendages, as well as its polished and uniformly colored surface are characters which serve to identify it at a glance.

In the arrangement of thoracic horns it resembles *D. Neptunus* from South America, but from this species it differs very materially. It appears to be very rare in Dominica, for during two years collecting in the island I have procured but few specimens, and it is unknown to most of the natives, who, as a rule, are fairly familiar with the fauna of the island.

Dynastes Lagaii sp. nov.   Figure 1.

Male.—Much smaller than either *Dynastes Hercules* or *Vulcan* and averaging scarcely if any larger than *Dynastes tricornis.*

Elytra brownish olive, with a bright metallic luster in living specimens, sparsely and irregularly spotted with circular markings of deep brown, most numerous near the posterior extrem-

FIGURE 1.   *Dynastes Lagaii.*   Male, natural size.   Type ; phot. A. H. V.

ity and lateral and anterior edges.   Thorax, head, abdomen, legs, ventral surface, edges of elytra and a broad band across anterior portion of elytra, rich chestnut-brown.   Thorax with a short, cylindrical, slightly curved process.

Head with a stout, short, crescent-shaped process.   Thoracic " horn " with a minute, scarcely perceptible process on either side at base.   Occipital " horn " without protuberance of any sort except a very minute notch or tooth on the dorsal surface near the base.

Entire dorsal surface thickly and conspicuously pitted and everywhere covered with short, yellowish brown hair which becomes longer and conspicuous around the base of the occipital process, posterior portion of thorax, and along the median line of elytra.   Ventral surface of thoracic process

covered with thick, velvety, golden-yellow hair. Ventral surface of head, thorax, and abdomen finely but thickly pitted, and with scarcely any hair except along the edges of segments and posterior extremity of abdomen ; the latter with a long thick fringe of silky golden hair.

Female.—Scarcely distinguishable from female of *D. Hercules*, except by the much smaller size and abundant hair which completely covers the dorsal surface.

Length, exclusive of thoracic and occipital processes, 2·00 to 2·25 inches ; length of thoracic process, 0·45 to 0·60 ; length of occipital process, 0·20 to 0·25 ; width of thorax at posterior segment, 0·80 to 0·85.
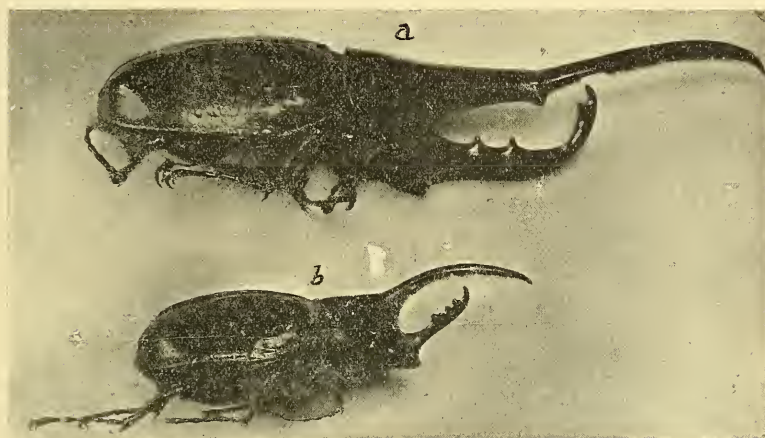
FIGURE 2, *a.* *Dynastes Hercules.* Male, ⅔ nat. size.
FIGURE 2, *b.* *Dynastes Vulcan.* Male, ⅔ nat. size. Type, phot. A. H. V.

Habitat.—Interior mountain ranges of Dominica I., from 2000 to 4000 feet above sea level. Several specimens.

To make this notice more complete, the description of a third rare species is here reproduced. It was originally described in a brochure published by A. H. Verrill at Rosseau, Dominica, April, 1905.*

Dynastes vulcan A. H. Verrill. Figure 2, *b.*

Male.—Much smaller and with much shorter and more slender thoracic and occipital processes than even the smallest and most undeveloped specimens of *Dynastes Hercules.*

* *Description of a new species of Dynastes (Hercules Beetle) from Dominica.* By A. Hyatt Verrill.

The thoracic " horn " is much more curved and has the two lateral projections much nearer base than in *D. Hercules.* Occipital horn slender near base but wide vertically from a point near middle to near the anterior end ; compressed laterally, broad in profile, but slender when viewed anteriorly, in marked contrast to the occipital appendage of *D. Hercules*, in which species the occipital " horn " is fully as wide anteriorly as laterally, and nearly circular in section.

Protuberances on occipital appendage three in number and of almost equal size and equally spaced between anterior extremity and middle of the " horn." No indication of a bifurcated tip to the occipital appendage, as is usually the case with *D. Hercules.* Anterior profile outline of occipital process almost straight, not convex as in *D. Hercules.* Thorax broader, more depressed, and less conical in dorsal outline than in *Hercules.* Elytra broader, more obtuse posteriorly, and more convex in profile than in *D. Hercules.* Color of elytra uniform, dark, sooty-brown, occasionally with indications of circular or lunate markings of a lighter, more yellowish shade. Lower parts lighter and more brownish than in *Hercules*, with more abundant and lighter colored hair ; especially on ventral surface of the head and thorax. Dorsal portion of thorax, especially posteriorly, much rougher and more deeply pitted than in *D. Hercules.*

Length, from anterior extremity to tip of abdomen, exclusive of thoracic appendage, 2·60 to 2·65 inches ; dorsal length of thoracic appendage, 1·40 to 1·50 ; anterior length of occipital appendage, 1·06 to 1·10 ; width of thorax at posterior segment, 1·15 to 1·20 inches.

Habitat.—Windward or Atlantic slopes of Dominica. Three specimens. Female unknown.

Professor SAMUEL PIERPONT LANGLEY.

In the death of the Secretary of the Smithsonian Institution, America loses its most prominent astronomer and physicist. Professor Langley was born in Roxbury, near Boston, August 22, 1834, and died February 27, 1906. In this interval of over seventy-one years he contributed immensely to the study of the physics of the solar atmosphere and of the earth's atmosphere, besides also taking a prominent part in practical work, such as the distribution of standard time, and development of the aeroplane, considered as a flying machine. His popular writings are distinguished by a beautiful diction, and the pleasure that he took in conversing with young students is proverbial.

After studying at the Boston High School, making a special preparation as architect and civil engineer, and filling temporary positions in the Observatory of Harvard College and the U. S. Naval Academy, he settled, in 1867, as director of the Allegheny Observatory; at the same time the present writer settled at Cincinnati Observatory, and from that to the present the close relationship of the subjects in which we were interested has produced a corresponding personal intimacy. Especially were we for many years first united in the effort to introduce a uniform system of time signals that should be controlled by local observatories, and be a means of support for these institutions in their straightened finances.

While devoting much thought to practical astronomy during 1867–1875, Professor Langley still found time to devote his equatorial to the study of the sun's surface and his drawings of the details of the spots have all the wonderful characteristics of the rarest and best of modern photographs. His attempts to measure the relative temperatures of the spot and the surface, by the thermo-electric method, led to his development of that form of the electric resistance thermometer, which he called the " bolometer." Each form of thermometer has its special troubles, and the bolometer is no exception. For twenty years we have been accustomed to receive pamphlets and memoirs, detailing the steady progress made by himself or his assistants in improving the sensitiveness and accuracy of the bolometer. Notwithstanding the rival apparatus of Ångström and the thermopile, the bolometer is still in favor; of course both instruments must be used side by side if we would attain results better than either one can give alone.

By applying the bolometer to the solar spectrum Langley was able to reach far beyond the limit before recognized and to measure the relative distribution of heat throughout the whole extent of the spectrum; he thus laid the foundation for all modern study of the special absorbing and radiating powers of atmospheres and gases for the individual wave lengths of light.

The last published memoirs by Langley and his assistant, Mr. C. G. Abbot, demonstrate beyond all peradventure the steady decrease of the absorption of the earth's atmosphere as the wave lengths increase.

From the measurement of the distribution of heat in the solar spectrum Langley then passed to the distribution of energy, and from this to the sum-total of energy in the spectrum. Now the sum total of energy was also supposed to be given by Pouillet's or some other form of pyrheliometer, and Langley at once began to experiment with every form or modification of this apparatus. He traveled extensively in this country and Europe in order to consult with all those who were working on these problems, and his progress, up to the end of 1883, was presented in his report on the Mount Whitney expedition, published as Professional Paper Number xv of the Signal Service, under the title, " Researches in Solar Heat." He had already observed from the summit of Mount Etna, and in 1878 from the summit of Pike's Peak, but these new observations were made from the still higher summit of Mount Whitney. In fact the study of the solar atmosphere forced him, first of all modern physicists, to undertake the greatest expense and labor in order to realize even a few days of work at the highest possible altitude. The general result of the expedition to Mount Whitney was to demonstrate that, in all probability, the universal opinion of physicists was in error in believing that the infra-red rays are more absorbed than the luminous and ultra-violet : as Langley himself states, considering the weight of authority against him, he felt bound to repeat his experiments in every manner, and with every precaution. It also followed that the accepted value of the heat radiated from the sun, as received at the outer surface of the earth's atmosphere, must be very greatly increased, and that its value could not be less than 2·6 calories, while it might be as high as 3·5, the most probable figure being 3·0 calories.* We believe that up to the last Professor Langley saw no reason to depart greatly from this result. He made this experience on Mount Whitney a strong argument as to the importance to meteorology of similar observations at other great elevations.

In 1887 Professor Langley was appointed Secretary of the Smithsonian Institution, succeeding Professor S. F. Baird. This necessitated his removal to Washington, where he was able to established the Astro-physical Observatory, and to continue the researches begun in Allegheny. Washington is unfortunate as regards the steadiness of the atmosphere, but its selection was forced upon Langley by circumstances over which

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* Namely small calories, or a gram of water heated from 0° Centigrade to 1° Centigrade per square minute per centimeter.

he had no control, and the great work that has been done there will undoubtedly prove an important preliminary experience, leading to the eventual establishment, in a favorable location, and under a competent physicist, of an astro-physical observatory that shall be worthy the name of the founder.

But a very different problem had also fascinated our colleague, namely the soaring flight of the condor, the buzzard, and the sea-gull. While at the Allegheny Observatory he had gathered a collection of aeroplanes and of well mounted birds' wings, had placed them on his whirling machine, and had endeavored to penetrate the secrets of flight. After his settlement at Washington a larger machine and more elaborate experiments were made, in which he was assisted by Mr. George E. Curtis, who had become familiar with the subject through his studies with me of problems treated in my " Meteorological Apparatus and Methods." Professor Langley's work, entitled "Aerodromics" and his incisive article, " The Internal Energy of the Wind," were but the beginning of the new series of studies that occupied his attention up to the beginning of his last illness. A large appropriation was made by Congress for researches and experiments in artificial flight. The best of physicists and mechanics were employed to perfect the powerful little motor. A detailed report on the results has not yet been published, but it is very important that it should be prepared, both in order to save others from the wasteful labor of going over the same ground again, and also in order to secure for America the credit for the great work that was accomplished by him. He was one of the pioneers in this class of work, and like all pioneers prepared the way for the success that we hope ultimately to obtain. A few years ago we spoke of the conquest of space by the railroad, and of time by electricity, or the conquest of the ocean by the steamship, without having the least idea that within the next decade wireless telegraphy and the steam turbine would give us a still more complete conquest. It is so also with the air ; we now have the balloon, the aeroplane and the kite, but eventually we shall have the flying machine in some practical form.

As administrative officer in charge of the Smithsonian Institution, Langley defended the principle that the secretary should not sacrifice his scientific work to routine office work, but by continuing it should confer the greater honor on the institution.

Personally Professor Langley was of the gentlest and kindest nature. Nothing but the conviction of duty ever drew a harsh word from him. He could be silent and suffer, but not quarrel. His tender care for his mother and his kindly sympathy for the children of his friends (he had none of his own) will ever endear him to the memory of those who knew him best.

Cleveland Abbe.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The Determination of Sulphur in Pyrites.*—This import-ant analytical operation has given much trouble to chemists, but there is hardly another process that has received so much study and has produced so much literature as this, so that it would seem that the methods in use must have been perfected in all of their details. Recent investigations by Hintz and Weber show, how-ever, that there is a serious source of error in Lunge's method as applied by many chemists. They find that when barium chloride solution is added slowly to the acidified solution containing ammonium sulphate the amount of barium sulphate obtained is decidedly less than when the reagent is added rapidly. They find that in the first case the barium sulphate contains ammonium sulphate which volatilizes upon ignition and leads to a loss of sulphur. This unexpected result recalls to the reviewer a variety of natural barite from Missouri in which Ludeking and Wheeler (this Journal III, xlii, 495) found 0·2 per cent of ammonium sulphate, a circumstance which shows the tendency of ammonium sulphate to crystallize with barium sulphate. Hintz and Weber give the following directions for determining sulphur in pyrites : Treat 0·5^g of pyrites with 10^{cc} of a mixture of 3 parts of nitric acid, 1·42 sp. gr., and 1 part of hydrochloric acid, 1·17 sp. gr., allow the action to go on in the cold at first, and finally complete the decomposition on a boiling water-bath. Then transfer the liquid to a porcelain dish, evaporate to dryness on the water-bath, moisten with 5^{cc} of concentrated hydrochloric acid, and evapor-ate again. Take up the residue with 1^{cc} of hydrochloric acid, 1·17 sp. gr., and about 100^{cc} of hot water, filter through a small filter and wash the residue at first with cold, finally with hot water. Add to the filtrate, of somewhat more than 150^{cc} volume, while warm, 20^{cc} of 10 per cent ammonia and heat about 15 min-utes to about 70°. Filter off the ferric hydroxide precipitate and wash it with hot water until the volume has reached about 450^{cc}. Add a little methyl orange, neutralize with hydrochloric acid and add 1^{cc} of hydrochloric acid, 1·17 sp. gr. in excess. Heat until boiling begins and precipitate with a boiling solution of 24^{cc} of 10 per cent barium chloride diluted to 100^{cc}, adding the reagent at one time as rapidly as possible with vigorous stirring. Rinse the iron precipitate from the filter, dissolve it in as little hydro-chloric acid as possible, precipitate warm with ammonia, filter, and wash the precipitate. Heat the filtrate and washings until the greater part of the ammonia has been driven off, acidify slightly with hydrochloric acid, and treat with some barium chlo-ride solution. If any barium sulphate is found here, add it to the main precipitate. Filter the barium sulphate precipitate, washing

at first by three decantations with boiling water, then with boiling water on the filter until the chlorine reaction has disappeared. Dry and weigh it.—*Zeitschr. analyt. Chem.*, xlv, 31.   H. L. W.

2. *The Determination of Grape Sugar.*—The present methods for the quantitative determination of glucose are not based upon definite chemical equations ; for instance, the amount of cuprous oxide produced by Fehling's method depends upon conditions of concentration, etc.   Glassmann has now worked out two modifications of Knapp's method, which appear to depend upon strict stochiometric principles, but only one of these, apparently the most convenient one, will be noticed here.   The grape sugar solution is poured into a boiling solution of mercuric cyanide and caustic potash, or a similar alkaline solution of potassium mercuric iodide, when metallic mercury is precipitated according to the following equations :

$$CH_2OH(CHOH)_4CHO + 3Hg(CN)_2 + 6KOH =$$
$$COOH(CHOH)_4COOH + 4H_2O + 6KCN + 3Hg,$$

and

$$CH_2OH(CHOH)_4CHO + 3HgI_2.2KI + 6KOH =$$
$$COOH(CHOH)_4COOH + 4H_2O + 8KI + 3Hg.$$
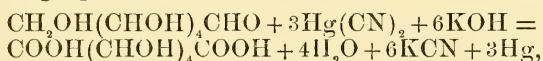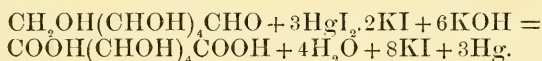
The precipitate is filtered and washed, dissolved by heating with strong nitric acid, and the mercury is determined with a standard thiocyanate solution, with ferric alum as an indicator, according to the method of Rupp and Krauss, which is carried out exactly like Volhardt's volumetric method for silver.   A tenth-normal NH_4SCN solution is equivalent to ·003009^g of $C_6H_{12}O_6$. (The author incorrectly gives this value for 1^{ccm} of $\frac{1}{100}$ normal solution.)   A number of test analyses carried out with pure grape sugar give very satisfactory results, but no statements are made in regard to substances which interfere with the process.— *Berichte*, xxxix, 503.   H. L. W.

3. *The Boiling of the Metals of the Platinum Group.*— MOISSAN has heated samples of 150^g each of osmium, ruthenium, platinum, palladium, iridium and rhodium, in his electric furnace, and has succeeded in bringing all of them to the point of ebullition and distillation by the use of currents of from 500 to 700 amperes and 110 volts.   Fusion took place in one or two minutes, and boiling was reached in less than four minutes.   The vapors were condensed upon a copper tube through which a rapid stream of cold water was passed, so that metallic spherules or microscopic crystals, usually in the form of felt, were produced.   All of the metals dissolved carbon from the crucible, which they gave up as graphite upon cooling.   The most difficult of all the metals to distil is osmium.   Palladium is more readily fusible than platinum, but it does not appear to be more readily volatile than platinum and rhodium.—*Comptes Rendus*, cxlii, 189.

H. L. W.

4. *Rapid Preparation of Hydriodic Acid.* — A convenient and rapid method for preparing this acid is described by BODROUX. He divides a certain weight of iodine into two equal parts. To the first barium peroxide is added in the presence of water :

$$BaO_2 + I_2 = BaI_2 + O_2.$$
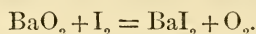
The remainder of the iodine is then dissolved in the filtered solution, and sulphur dioxide is passed in until decolorization takes place :

$$BaI_2 + I_2 + SO_2 + H_2O = BaSO_4 + 4HI.$$

The acid is then concentrated by distillation, for the reaction with sulphur dioxide does not take place normally in extremely concentrated solutions, so that it is recommended to use about 180^g of water for 100^g of iodine.— *Comptes Rendus,* cxlii, 279.

H. L. W.

5. *The Radio-activity of Polonium.*—MME. CURIE, who has obtained and described polonium as a radio-active element accompanying bismuth in pitchblende, finds that the material may be enriched by fractionally precipitating the oxychloride by means of water, when polonium is concentrated in the first precipitates. Having thus obtained poloniferous oxide of bismuth with an activity 250 times that of uranium, she measured its rate of decay and found that it loses one-half of its activity in 140 days. This corresponds very closely to the rate of decay of Marckwald's "radio-tellurium," so that it may be regarded as certain that the two substances are identical.— *Comptes Rendus,* clxii, 273.

H. L. W.

6. *The Electrochemical Equivalent of Silver.*—The importance of this constant is such that investigators still prosecute investigations to determine it with all possible accuracy. G. VAN DIJK, p. 286, in a very full paper, reviews the results of previous investigators and gives his own. The following table gives the values (corrected) obtained by various physicists :

Mascart	0·011155	Kahle	0·011181
F. and W. Kohlrausch	0·011182	Patterson and Guthe	0·01118
Rayleigh and Sidgwick	0·011176	Pellat and Leduc	0·011189
Pellat and Potier	0·011191	Van Dijk and Kunst	0·011180

Van Dijk devotes considerable space to a discussion of the corrections employed by Richards which led the latter to adopt the value 0·011175, and believes that his own result, $a = 0·011180$ is the true electrochemical equivalent of silver.—*Ann. der Physik,* No. 2, 1906, pp. 249–288.

J. T.

7. *The Electrolytic Coherer.*—Under the title of asymmetrical action of an alternating current on a polarizable electrode, Dr. GUNDRY discusses the reasons for the action of what is at present probably the most sensitive receiver employed in wireless telegraphy. This receiver consists of a very fine platinum point which forms the anode, in an electrolytic solution, of an E.M.F. of several volts. The current through this electrolytic cell is

greatly increased by the excitation of electric waves. Fessenden, to whom the priority of the discovery of this receiver has been awarded, believes that the action arises from an increase of heat in the immediate neighborhood of the small electrode ; this explanation has been found untenable. Later experiments of Rothmund and Lessing show a coherer and not an anticoherer effect when the electrolyte (phosphoric acid and hyperphosphorous acid at higher temperatures), has a negative resistance temperature coefficient. Reich believes that the action results from a depolarizing effect.

The object of Dr. Gundry's paper is to show that in a polarizable electrode, in general, as soon as we pass beyond the stage of initial capacity the alternating current gives rise to an asymmetry which appears as a coherer effect. His experiments were conducted only with mercury electrodes on account of the more definite conditions which can be obtained by their use. One electrode was very small in order that it might be considered unpolarizable, the other more than one thousand times greater. A galvanometer in the alternating circuit showed that the current, before symmetric, was rendered asymmetric by passage through the cell. In other words, there was superposed on the alternating current a direct current, and the production of this direct current involves the existence of an asymmetry in the E.M.F. of the polarization produced by the alternating current. This asymmetry, the author believes, is a natural consequence of the osmotic theory of electromotive force in general and its application to polarization in particular.

For the production of the alternating current the sine inductor of Kohlrausch alternated in use with the Dolezalek alternating current machine made by Siemens and Halske. An upper limit of 5000 alternations per second was obtained. Experiments with a platinum electrode both anodically and cathodically polarized, showed that the magnitude of the direct current value varied at high frequencies much less with the frequency than is the case with the mercury electrode.—*Phil. Mag.*, March, 1906, pp. 329–353.   J. T.

8. *Ionization by Röntgen and Cathode Rays.*—This is a study at Würzburg by J. Herweg of various unsolved points in regard to this subject. It is shown that the ionization produced by the X-rays up to a temperature of 400° is independent of the temperature ; in other words, the resulting ionization is not accompanied by a rise in temperature. It is also shown that simultaneous ionization of air by a glowing wire and the X-rays results in a simple superposition of both ionizations.

X-rays and also cathode rays produce a diminution of the discharge potential of the *Glimmentladung ;* the effect of the rays is dependent upon the volume of gas between the electrodes and the pressure.

A theoretical discussion of the movement of electrons in a combined electrostatic and magnetic field concludes the paper.—*Ann. der Physik*, No. 2, 1906, pp. 333–370.   J. T.

9. *Modern Theory of Physical Phenomena;* by AUGUSTO RIGHI. Authorized Translation by AUGUSTUS TROWBRIDGE. New York, 1905. (The Macmillan Co.)

La Théorie Moderne des Phénomenès Physique; par AUGUSTO RIGHI. Traduction libre sur la 2e edition italienne par EUGENE NECULCEA. Editions de "L'Eclairage Electrique."

These two translations bear witness to the richly deserved popularity of Professor Righi's little book. It is without question the best popular exposition that we have of the modern point of view which explains the phenomena of electricity, radio-activity and optics in terms of the electron. The translation is very well done and the book can be recommended unqualifiedly to the general reader who desires to get in a simple and non-technical form the gist of the epoch-making developments of the theory of electrons.   L. P. W.

II.   GEOLOGY AND MINERALOGY.

1. *Red Beds of Southwestern Colorado and their Correlation;* by WHITMAN CROSS and ERNEST HOWE. Bull. Geol. Soc. Amer., xvi, Dec., 1905, pp. 447–498, pls. 82–85.—This is the most important paper thus far published on the "Red Beds" of the Rocky Mountain region, and should be read in connection with Stanton's paper on the Morrison formation published in "The Journal of Geology," xiii, 1905, pp. 657–669. All of the Red Beds regions, from northeastern Arizona north to central Wyoming and east to the Front Range of Colorado, are reviewed by Dr. Cross. As his conclusions are of the first importance, his "summary" is repeated here in full. It is as follows:

"1. A marked angular unconformity is exhibited near Ouray, Colorado, between a well defined fossiliferous horizon of the Dolores Triassic formation and an extensive section of Paleozoic beds, including the Cutler Permian and the Hermosa Pennsylvanian formations.

"2. The Ouray unconformity is evidence of a stratigraphic break, of as yet unknown importance, in the midst of the Red beds of western Colorado. There are reasons to suppose that this hitherto unrecognized break is widespread and explains many discordant features of various Red bed sections, not only in Colorado, but in the adjacent Plateau province.

"3. The fossiliferous horizon of the Dolores formation, occurring above the unconformity noted, has been traced down the Dolores and San Juan valleys into the Plateau province. The sections of the mountain and plateau districts are comparable in many ways.

"4. A vertebrate fauna, similar to or identical with that of the Dolores formation, has been found at widely separated points in New Mexico, Arizona, Utah, Wyoming, and Colorado, and paleontologists regard it as clearly of upper Triassic characteristics.

" 5. Through the stratigraphic correspondence of the Red beds and associated formations in the Rocky Mountain and Plateau provinces and the evidence of the Triassic vertebrate fauna at numerous points, certain correlations are more or less clearly indicated.

" *a.* The Hermosa formation appears to occupy the same stratigraphic position as the Aubrey of Utah and Arizona. Further investigations are necessary, however, to explain certain faunal differences or dissimilarities noted by paleontologists between the formations.

" *b.* The Cutler formation, being older than the Ouray unconformity, is probably of Paleozoic age and corresponds more or less closely to the Permian portions of the stratigraphic sections of the Plateau and Mississippi Valley provinces.

" *c.* The Dolores formation includes diminished equivalents of the Shinarump and Vermilion Cliff formations of the Plateau. The Shinarump may include important divisions not represented in the Dolores.

" *d.* The La Plata formation is seemingly equivalent to the White Cliff sandstone. Its local assumption of red color has led to confusion with the Vermilion Cliff in certain districts and a reference to the Trias. Since the White Cliff sandstone underlies marine Jurassic beds, and the La Plata transgresses the Dolores and all older beds in marked unconformity, the Jurassic age of the lower division of the Gunnison group seems established.

" *e.* The McElmo formation appears to correspond closely to the Morrison and Como beds and the Flaming Gorge group of Powell. It is probable that the marine Jurassic horizon belongs between the La Plata and McElmo formations."   c. s.

2. *Annales de Paléontologie ;* published under the direction of Marcellin Boule, Professor of Paleontology at the National Museum of Natural History. Paris (Masson and Co.). Vol. I, Pts. I and II, Jan., 1906.—This new serial in quarto form is to appear four times a year, and will have at least 20 signatures and 20 plates. The price outside of Paris is 30 francs a year. The illustrations are heliotypes made directly from the fossils, while interpretations and explanatory drawings are to appear in the text. Each paper is independently paged, so that works of the same nature may be bound together or each may be bound separately ; a second pagination appears at the bottom of each page, which is that of the annual volume. The contents of the first part are as follows :

Fossiles de Patagonie. Les attitudes de quelques animaux ; par M. Albert Gaudry. Pp. 1-42.

Paléontologie de Madagascar. I. *Fossiles de la côte orientale ;* par Marcellin Boule et Armand Thevenin, avec la collaboration de J. Lambert. Pp. 1–17, pls. 1, 2. Describes Upper Cretaceous invertebrates. A new genus of echinoid was described as *Noetlingia* by Lambert, in 1898, and the name is used here, but

unfortunately it has been preoccupied by Hall and Clarke since 1893 for a Russian Ordovician brachiopod : *Part II. Sur quelques gisements nummulitiques de Madagascar ;* par Robert Douvillé, pp. 1–8, pl. 1.

Les grands chats des cavernes ; par Marcellin Boule. Pp. 1–27, pls. 1–3.

Types du Prodrome de Paléontologie stratigraphique universelle de d'Orbigny. Pp. 1–4, pls. 1, 2 (incomplete).—The original very brief descriptions of d'Orbigny are here republished with short observations by A. Thevenin ; no attempt, however, is made to indicate the present name for these fossils. The illustrations are of much value, as they are photographs of the originals. At least five of the species figured are American Paleozoic forms. Remarks on these are reserved until the work is completed.   c. s.

3. *Arthrophycus and Dædalus of Burrow Origin, and Preliminary Note on the Nature of Taonurus ;* by CLIFTON J. SARLE. Proc. Rochester Acad. Sci., iv, Feb., 1906, pp. 203–214. —The first article treats of the supposed fucoids usually known as *Arthrophycus.* An elaborate study has been made of a very extensive series of well-preserved specimens found in the Medina sandstones about Rochester, New York. From these researches, the author concludes that these bodies are not organic, but are the burrows of an animal, possibly a polychæte worm. These burrows and packings may be nearly horizontal with the sedimentation or vertically spiral either to the right or left. The generic term *Arthrophycus* is retained for the plumose forms found on the bedding planes, and *Dædalus* for the spiral burrows.

Taonurus treats of very similar burrows known to Americans as *Spirophyton,* and usually regarded as fucoid. These fossils are common in the eastern Hamilton formation and are undoubtedly made in the same general way as are *Arthrophycus* and *Dædalus.* The evidence and deductions on which the author bases these conclusions can not be presented here, and must be read in detail in order to appreciate these by no means simple fossils.   c. s.

4. *Echinoderma ;* by F. A. BATHER. Zool. Rec., xli, Dec., 1905, 96 pp.—This valuable annual record of the literature of Echinoderma, for 1904, continues the high standard set by the author. It lists 103 titles, and notes the contents of these papers in detail.

5. *The Osteology of Champsosaurus Cope ;* by BARNUM BROWN. Mem. Amer. Mus. Nat. Hist., ix, Dec., 1905, pp. 1–26, pls. i–v.—This memoir gives a detailed description of three more or less complete skeletons of the semiaquatic rhynchocephaloid reptile *Champsosaurus* from the lower strata of the lignite above the Ceratops beds of the Laramie, as exposed on Hell Creek, 130 miles northwest of Miles City, Montana. The material has been well worked out, and the memoir is handsomely illustrated by heliotype plates made in Germany.

6. *Maryland Geological Survey, Vol. V, 1905.* Wm. Bullock Clark, State Geologist, pp. 656, pls. 35, figs. 55.—The present volume is largely devoted to economic subjects and each of the parts have been issued separately at different times.

The Second Report on Magnetic work in Maryland by L. A. Bauer, now in charge of the magnetic work of the U. S. Coast and Geodetic Survey, forms Part I of the volume. This magnetic survey of Maryland is the most complete of any magnetic survey in the world except that of Holland, the magnetic declination, inclination and force having been determined in every portion of the State. The results have proved of both great practical value and scientific interest. The plate showing the lines of equal magnetic declination indicates their extreme irregularity, a pronounced focus of magnetic disturbance existing 19 miles northwest of Washington, a local variation of 7 degrees occurring within 7 miles. It is stated that a mathematical analysis of the forces producing the disturbances in this locality traces their source to parallel ridges running approximately in a northeast and southwest direction, agreeing with that of the serpentine beds, as mapped by the geologists.

The report also contains among other papers a report on the highways of Maryland and more than 400 pages on the distribution, value and geology of the Maryland coals.

This volume, like the preceding ones of the series, is handsomely printed, illustrated and bound.   j. b.

7. *Les Tremblements de Terre. Géographie Séismologique,* par F. de Montessus de Ballore. Préface par A. de Lapparent, pp. 500, pls 3, 89 page maps and figures; Paris, 1905 (Librairie Armand Colin).—The author of this volume has been known for many years as one who has patiently and laboriously collected all available statistics regarding earthquakes over the whole world, and he is one of the small group of men to whom the new science of seismology owes much. In this publication the whole subject of the geographic distribution of earthquakes is clearly and fully discussed. The numerous detailed maps occurring at intervals through the volume show graphically the location and frequency of recorded shocks. The method of representation has been to cover each town or center of seismic disturbance by a black circle, the length of the radius of the circle being proportional to the number of shocks. This method has been substituted in place of graded tints, bounded by curves of seismic frequency, the departure having been made on account of the essentially discontinuous and localized nature of earthquake centra. This has its advantages for the student of seismology, giving greater precision to the graphic representation of the data, but also possesses its disadvantages, especially for the casual reader. The *area* of a black disc impresses the eye rather than the *radius*, giving the impression of a greater concentration of shocks at certain centers than is actually the case. Again, as the time of observation grows longer the number of scattered shocks

in a region will presumably increase and the additional small circles will finally give something of the tinted effect. In addition, in the more sparsely settled districts there is a lack of complete record of small shocks away from the centers of population and a consequent tendency for the larger circles to cluster around the inhabited districts. For these reasons it might have been advantageous to have supplemented the present detailed maps with more comprehensive ones in which curves and tints should bring out the lines and places of greatest seismic disturbance. To a slight extent this has been done. The author reiterates his previous conclusions in regard to the independence of the great majority of shocks from volcanic centers, even in volcanic regions. The data also bring out the poverty of earthquakes over the geologically undisturbed portions of the crust and their association, on the contrary, with great fault zones, lines of folding, regions of great relief and geosynclines. They are evidence, in brief, of the internal forces of the world still at work.

In regard to the more highly inferential portions of the work; the author assumes the truth of the extreme views held chiefly by certain European geologists in regard to former land masses covering the greater portions of the present ocean basins and known as the Africano-Brazilian continent, the North Atlantic continent, etc., and discusses the relation of the earthquake zones to the fragmentation and foundering of these supposed land masses. It need hardly be said that much of this is highly hypothetical and that according to the charts in the back of the volume there was apparently no room for the ocean waters during Mesozoic time. On the whole, however, the volume is a most valuable contribution to that branch of geology which deals with earthquakes.   J. B.

8. *The Copper Deposits of the Clifton-Morenci District, Arizona;* by WALDEMAR LINDGREN. U. S. G. S. Professional Paper No. 43. 365 pp., 25 pls., 19 figs. in text.—The Clifton copper district is second only to Bisbee in rank among the copper districts of Arizona, its production for 1903 amounting to 53,400,000 pounds of copper. The present paper is a complete and detailed discussion of the ore deposits of this area and contains, particularly in its discussions of the contact metamorphism shown in the district and of the secondary enrichment of the ores, important contributions to the subject of economic geology.

The underlying rocks of the quadrangle are schists and a granite of pre-Cambrian age. Upon these rest unconformably a series of Paleozoic sediments, of nearly a thousand feet in thickness, composed chiefly of limestones, with some interbedded quartzites and shales. Above this series are found in certain sections several hundred feet of sandstones and shales which have been assigned to the Mesozoic. Intruded into all of these rock types in the form of stocks, dikes, sheets and laccoliths are a series of igneous rocks ranging in type from diorite-porphyries to granite-porphyries. These intrusions probably occurred in early Ter-

tiary time. Immense flows of later Tertiary lavas which lie unconformably upon the earlier rocks are found to the north of the district and in some places extend down into this quadrangle.

No great disturbance of the region occurred until the intrusions of the porphyries, which caused extensive breaking and dislocation of the sedimentary rocks. Subsequently folding must have taken place, and the uplifted area broke into fragments, which gradually settling down, formed the rocks into monoclinal blocks.

The ore deposits of the district are always found within or closely adjacent to the porphyry intrusions and are considered to have an intimate genetic relation with these rocks. They occur in two main forms; either as tabular bodies in strongly metamorphosed beds of limestone or shale, or as veins in fissures which traverse all of the rock types of the district. The intrusions of the porphyry produced in the adjoining limestones and shales important contact-metamorphic action which resulted in the metasomatic development of garnet, epidote, diopside and other silicates, accompanied by pyrite, magnetite, chalcopyrite and sphalerite. The sulphides were not later introductions but contemporaneous in their formation with the other contact minerals. The contact zone received large additions of oxide of iron, silica, sulphur, copper and zinc, which it is believed were given off by the intruded magma and forced through the adjoining sedimentary beds. These deposits when unaltered are everywhere of too low grade for profitable extraction, but have in many places been attacked by oxidizing surface waters and greatly enriched in value. Workable ores of this class are almost wholly oxidized, being made up chiefly of the two carbonates, malachite and azurite.

The vein deposits were formed somewhat later, but probably while the igneous rocks were still hot and giving off mineral-bearing waters which, circulating through the rocks, deposited the ore materials in the fissures, forming normal veins largely of the replacement type. The bulk of these deposits consist of pyrites with a copper content in the ore, usually below one per cent. But descending oxidizing waters have served to enrich these deposits also, forming in them a belt of chalcocite ore varying between 200 and 250 feet in thickness. During the earlier days the rich ores from the oxidized deposits in limestone and shale furnished the major part of the output, but at present the camp is depending chiefly on these large low-grade bodies of chalcocite ore.

W. E. F.

III. Miscellaneous Scientific Intelligence.

1. *A Contribution to the Oceanography of the Pacific*; by James M. Flint. Bull. U. S. National Museum No. 55, pp. 62, pls. 14, 1905. Compiled from data collected by the United States steamer Nero in 1899 while engaged in the survey of a route for a trans-Pacific cable.—The instructions regarding the

survey were to follow as nearly direct lines as practicable from Honolulu to Midway Island, thence to Guam, thence to Luzon, and also from Guam to Japan. Soundings were to be taken on the outward voyage at intervals of ten and two miles alternately, temperatures and nature of bottom being also observed. The return voyage was planned to cross the primary route zigzag at angles of 45°, the sides of the angle to be twenty miles in length: soundings to be taken at the apices of the angles. In this manner an examination was made of a belt of ocean about fourteen miles wide and over 6,000 miles in length, unequalled in thoroughness, so far at least as soundings are concerned, by any survey hitherto made of an ocean tract (p. 2).

Several submarine mountain ranges were encountered, the most noteworthy occurring east of Guam, with peaks rising to a maximum of 689 fathoms below the sea level, and valleys descending to a depth of more than 5000 fathoms. Four soundings below the 5000 fathom line were made in the abyss now known as the "Nero Deep." The deepest, 5269 fathoms, was about seventy-five miles east-southeast from the island of Guam and is the deepest sounding ever recorded, being only sixty-six feet less than six statute miles.

In computing the gradients from station to station serially on the outward voyage only, involving 1,100 soundings, sixty-nine localities only are found where the gradient exceeds 10 per cent. Of these fifty have an incline between 10 and 20 per cent, eleven between 20 and 30 per cent and six between 30 and 40 per cent. The steepest declivity was found on the slopes of the peak southwest of Midway Island, which rises to 82 fathoms beneath the surface of the water. Here there is a change in depth of 1,269 fathoms (7,614 feet) in a horizontal distance of 1·8 sea miles, a gradient of 70 per cent. With the few and localized exceptions, the bed of the Pacific Ocean, as developed by this survey, though rising here and there near to the sea level, and again descending to depths of five to six statute miles, follows easy gradients.

In commenting upon these results attention should first be called to their great value. The first reconnaissance of the ocean basins has already been completed and the results are embodied in the various charts showing the bathymetric contours. What is now most largely needed are detailed cross-sections such as this supplies of the Pacific Ocean and which the necessity of cable laying has fortunately secured. This has given some precision to the knowledge of submarine gradients along this line. That such is lacking in the Challenger and Albatross cross-sections may be seen by noting the distance apart of the stations except in the vicinity of land, and the resulting fact that the gradients given by connecting the stations are in nearly all cases comparatively flat lines, while the islands rise up with gradients in striking contrasts. For this to be true would imply that there were few or no submarine peaks of the same nature as those forming the oceanic islands but falling short of the surface, an assumption to be justly regarded as unwarranted and disproved along the line of the present cross-sections.

An important extension of the present line of work would be a detailed *areal* survey of chosen regions, one sounding being taken for every square mile, in order to determine the more detailed topography and possibly throw light on the question of the origin of the surface, whether from warping, faulting, folding, igneous extrusion or possibly in some cases from previous subaerial erosion.   On account of the slowness of sedimentation over the bottoms of the open oceans, it is doubtful if even geological aeons would suffice to mask the significant features of the broader structures.   Such a research might throw unexpected light upon such problems as that of the permanence of the continental platforms.   The difficulty and expense of the project, however, are such that it could only be undertaken by government enterprise.

J. B.

2. *The Microscopy of Vegetable Foods, with special reference to the Detection of Adulteration and the Diagnosis of Mixtures ;* by ANDREW L. WINTON, Ph.D., with the collaboration of Dr. JOSEF MOELLER.   Pp. 701, with 589 illustrations.   New York, 1906 (John Wiley and Sons).—" Turn about is fair play." Dr. Winton assisted Dr. Moeller in the preparation of a recent edition of the standard work, " Mikroskopie der Nahrungs- und Genussmittel," and now the favor is well returned.   The present volume is in part an excellent translation of the German treatise, but it is very much more.   It embodies the results of careful investigations by Dr. Winton, in a wide field of research, and is throughout characterized by clear statement.

Dr. Winton is wise in striking the happy mean between a too extensive presentation of the subject and the scanty hints hitherto accessible to students who read only English.   Physicians, analysts, and pharmacists will find this work sufficiently detailed to answer the more important questions which are now arising, and where the information falls short, suggestions as to further treatises are given.

In a concise preliminary chapter devoted to the equipment of a laboratory, the subjects of Histology and gross Morphology are succinctly given.   With this in hand, the investigator proceeds to consider the products of "Grain," and then to glance at sundry seeds which are among the many impurities.   The third part is devoted to Oil-seeds and Oil-cakes, and here one unfamiliar with the subject comes upon some interesting surprises : numerous unlooked-for species are referred to as accidentally mixed with the more common oilseeds of the mills.

Leguminous plants furnish material for an instructive chapter, the range being very wide.   Nuts have also a prominent place. To Fruits and Vegetables, the authors have given a large amount of most useful study.   Dr. Winton's examination of the " Jam " fruits is especially noteworthy.

In view of this volume, taken especially in conjunction with Dr. Leach's treatise on Food-Inspection, it may be unhesitatingly said that our Boards of Health are now well supplied with excellent counsel in English as to the best methods of investigating

intentional or "accidental" adulterations of foods. Both of the treatises are also desirable additions to the library of every practicing physician.   G. L. G.

3. *The Philippine Journal of Science.* Vol. I, No. 1; edited by P. C. FREER. Co-editors; R. P. STRONG and H. D. McCASKEY. Pp. 115, with 22 figures. Manila, 1906. Bureau of Printing. —For four years past the Bureau of Government Laboratories of the Philippine Islands has been active in research work, having published thirty-six bulletins dealing particularly with subjects in botany and zoology, and also with various tropical diseases. A new Bureau of Science has now been formed by the consolidation with it of the Bureau of Mines, and the *Philippine Journal of Science* has been begun under the editorship of Dr. Paul C. Freer, and with Richard P. Strong and H. D. McCaskey as co-editors, to contain the researches carried on under the auspices, as well as articles by others, in the Philippine Islands or adjacent countries of the Orient, who are carrying on related scientific work. The first number appeared in January, and contains articles by E. B. Copeland on the Water Relations of the Coconut Palm (Cocos nucifera), with introduction by Paul C. Freer; by H. S. Walker on the Coconut and its Relation to the Production of Coconut Oil; by P. G. Woolley on the Occurrence of Schistosoma Japonicum vel Cattoi in the Philippine Islands; and by R. P. Strong on a Study of Some Tropical Ulcerations of the Skin with Reference to their Etiology. Papers on systematic botany and monographs of various families and genera of Philippine plants will appear from time to time as supplements. The subscription price of the Journal is five dollars per year, and the supplements are supplied to regular subscribers without additional charge. This new Journal has a unique sphere and should prove of great value to science.

4. *Guide to the Invertebrates of the Synoptic Collection in the Boston Society of Natural History;* by J. M. ARMS SHELDON. Boston, 1905. (Published by the Society.)—The actual specimens of the fossil and living animals in the synoptic collection of invertebrates in the Museum of the Boston Society of Natural History are accompanied by numerous diagrams and drawings. These figures illustrate not only the microscopic forms but also such anatomical structures, developmental stages, and other features as are deemed of general interest and which are not distinctly shown in the specimens themselves. They are numbered consecutively with the specimens which they accompany, the whole series of 1264 numbers presenting a comprehensive view of the natural history of the invertebrates.

In this book of 505 pages, Mr. Sheldon gives a very interesting description of the important features illustrated by each of these 1264 specimens and drawings. It is in no sense a mere catalogue, however, but a connected account of the salient features in the whole field of invertebrate zoology. With this book in hand one would be able to study to the best possible advantage the collections displayed, for even without the collections the book is entirely readable, interesting, and instructive.   W. R. C.

5. *Monograph of the Isopods of North America. Bulletin of the U. S. National Museum, No. 54.* By HARRIET RICHARDSON. 8vo, 727 pp., 740 text cuts. 1905.— This is a complete monographic work on this group of Crustacea. All the genera and species, as well as the larger groups, are well described and nearly all the species are illustrated, most of the drawings having been made by the authoress. Analytical tables are given for the larger genera. The work is a very valuable contribution to American marine zoology. v.

6. *An Account of the Crustacea of Norway.* By G. O. SARS. Bergen. Published by the Bergen Museum.—We have received parts XI and XII of Vol. V of this extensive monograph, including parts of the families Thalestridæ and Diosaccidæ of the Copepoda. Like all the previous parts, it is profusely illustrated by autographic plates drawn by the author, whose skill and industry are truly marvelous. This work is of great importance to American naturalists, for large numbers of the species and genera are found also on the American coast. v.

7 *Birds of the Southern Lesser Antilles.* Proc. Boston Soc. Nat. History, Vol. XXXII, No. 7, pp. 203-312. 1905. By AUSTIN H. CLARK.—This includes a brief general account of the physical conditions of several of the islands, as related to the avifauna, and some facts relating to the recent destruction of many of the birds by hurricanes and volcanic eruptions. It gives a pretty full catalogue of the birds, especially of Barbados, St. Vincent and Grenada, but little is said of those of Dominica. v.

8. *Additions to the Avifauna of Dominica. Notes on species hitherto unrecorded, with descriptions of Three New Species and a list of all Birds now known to occur on the Island;* by A. HYATT VERRILL. Oct., 1905. Published by the author. Rosseau, Dominica.—In this brochure 72 species are added to the fauna of Dominica, making the total number now known 135. The greater number of additions are, of course, migrating species. The new species are *Thalurania belli* (a humming bird) ; *Buteo rivierei ;* and *Setophaga tropica*, a native redstart allied to *S. ruticilla.* This paper forms a useful supplement to that of Mr. Clark, previously noticed. v.

9. *Beiträge zur chemischen Physiologie*, herausgegeben von F. HOFMEISTER. VII. Band. Braunschweig, 1906 (Verlag von F. Vieweg und Sohn).—Of the forty-six communications included in the latest volume of the Beiträge a large number are devoted to studies of enzymes and their activities. A series of papers by Volhard's pupils in Giessen discusses lipolytic reactions, particularly their probable occurrence in the stomach. Special mention may be made of an interesting attempt (by Obermayer and Pick) to study digestive proteolysis by a new method involving a determination of the changes in the refractive power of solutions at various stages of hydrolysis. Several papers (by Becker, Reichel and Spiro) deal with the nature of the action of rennin. The rôle of colloids and their physico-chemical changes in certain biological processes also form subjects of investigation in papers by Meyer, Pauli, Mayr, and Reiss. In the domain of metabolism the fate of aliphatic amino-acids has been investi-

gated by Dr. G. Embden and co-workers, with the important conclusion, among others, that sugar may be formed from alanin in the intermediary nutritive exchanges. Dr. Wiechowsky has published a detailed review and report regarding the probable status of glycocoll in the synthesis of hippuric acid by animal organisms. Some features of growth are considered in a paper by Falta and Noeggerath, indicating their failure to maintain animals in continued health on so-called "artificial" food-mixtures. Babák has found marked differences in the relative size of the intestines of developing animal forms (frogs), this morphogenetic reaction depending on the kinds of foodstuffs furnished during the period of early growth. As may be expected, there is, further, no dearth of papers dealing with the chemical physiology of the proteids.   L. B. M.

10. *Life and Matter. An Answer to Haeckel's "Riddle of the Universe"*; by SIR OLIVER LODGE. Pp. 175. New York and London, 1905 (G. P. Putnam's Sons).—A discussion of the fundamental topics in philosophy by one trained to exact thinking in physics must necessarily be interesting, and this is markedly true of the little volume before us. The author states that his object is to make the book an antidote against the speculative and distinctive portions of Professor Haeckel's work entitled "Das Welträthsel." Furthermore he desires to confute two prevalent errors, viz: (1). The notion that because material energy is constant in quantity, therefore its transformations and transferences—which admittedly constitute terrestrial activity—are insusceptible to guidance or direct control. (2). The idea that the specific guiding power which we call "life" is one of the forms of material energy; so that, directly it relinquishes its connection with matter other equivalent forms of energy must arise to replace it.

11. *Joseph Leidy Memorial.*—At a meeting held recently in Philadelphia it was resolved to present to the city, for a place upon the City Hall Plaza, a statue of Dr. Joseph Leidy, in recognition of his memorable contributions to the natural sciences. Over one-half of the amount ($10,000) called for has been already subscribed and it is proposed to raise the balance as speedily as possible. Subscriptions may be sent to Edward B. Smith, Treasurer, 511 Chestnut st.

12. *Memorial to Professor Ernest Abbe.*—Contributions are being solicited in this country, as well as abroad, in behalf of the proposed memorial to Professor Ernest Abbe of Jena, whose invaluable work for optics and optical instruments has made his native town famous. This memorial is to take the form of a statue to be placed in Jena between the Volkshaus erected by him and the Zeiss Works.

The Bausch and Lomb Optical Company of Rochester will receive contributions for this important object; in a circular letter dated March 22 they remark that "this is a unique occasion, as Abbe was a unique man, and most of us who know anything at all about him will consider it a privilege to be able to contribute, be it ever so small a sum, to the statue that is to perpetuate his form to posterity."

MASTODON AMERICANUS, Cuvier.

(The "Shawangunk Skull")

A large public museum, for which we are now mounting a Mastodon skeleton, has asked us to find a sale for a cast of the head of this species which the actual skeleton will replace, as well as for another large cast which is crowded out through lack of floor-space. The former is figured above, and the latter is our restoration of the giant tortoise, Colossochelys atlas, from the Pliocene of the Siwalik Hills, India. Both of these casts we furnished to the museum a few years ago. They are to-day in excellent condition, but in order to effect an immediate sale are offered at a reduced price. Full details will be sent to anyone interested in their purchase.

Circular 59, just issued, lists casts of fossil mammals and birds, suitable for museums and colleges. Send for complete list of our circulars in all departments of natural history.

Ward's Natural Science Establishment,

76—104 COLLEGE AVENUE, ROCHESTER, N. Y.

CONTENTS.

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics—Determination of Sulphur in Pyrites, Hintz and Weber, 324.—Determination of Grape Sugar : Boiling of Metals of the Platinum Group, Moissan, 325.—Rapid Preparation of Hydriodic Acid, Bodroux : Radio-activity of Polonium, Curie : Electrochemical Equivalent of Silver, G. van Dijk ; Electrolytic Coherer, Gundry, 326.—Ionization by Röntgen and Cathode Rays, J. Herweg, 327.—Modern Theory of Physical Phenomena : La Théorie Moderne des Phénomenès Physique, A. Righi, 328.

Geology and Mineralogy—Red Beds of Southwestern Colorado and their Correlation, W. Cross and E. Howe, 328.—Annales de Paléontologie, 329.—Arthrophycus and Dædalus of Burrow Origin, and Preliminary Note on the Nature of Taonurus, C. J. Sarle : Echinoderma, F. A. Bather : Osteology of Champsosaurus Cope, B. Brown, 330.—Maryland Geological Survey, Vol. V, 1905, W. B. Clark : Les Tremblements de Terre ; Géographie Séismologique, F. de M. de Ballore, 331.—Copper Deposits of the Clifton-Morenci District, Arizona, W. Lindgren, 332.

Miscellaneous Scientific Intelligence—Contribution to the Oceanography of the Pacific, J. M. Flint, 333.—Microscopy of Vegetable Foods, A. L. Winton, 335.—Philippine Journal of Science, P. C. Freer : Guide to the Invertebrates of the Synoptic Collection in the Boston Society of Natural History, J. M. Arms Sheldon, 336.—Monograph of the Isopods of North America ; Bulletin of the U. S. National Museum, No. 54, H. Richardson: Account of the Crustacea of Norway, G. O. Sars : Birds of the Southern Lesser Antilles, A. H. Clark : Additions to the Avifauna of Dominica, A. H. Verrill : Beiträge zur chemischen Physiologie, F. Hofmeister, 337.—Life and Matter ; An Answer to Haeckel's "Riddle of the Universe," O. Lodge : Joseph Leidy Memorial : Memorial to Prof. Ernest Abbe, 338.

THE

AMERICAN

JOURNAL OF SCIENCE.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

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Art. XXIX.—*A Telephone Relay;* by John Trowbridge.

In histories of the invention of telegraphy much stress is placed upon the invention of the telegraphic relay; for it seemed doubtless to Joseph Henry and to Morse a complete apparatus for indefinite extension of the telegraph over land. In the progress of the telegraphic art, due to better lines and improved instruments, the telegraphic relay has lost the preeminent position it once occupied in men's minds; and the long discussions in the various treatises on the development of the art of telegraphy, in regard to the priority of the invention of the relay, have ceased to interest practical electricians.

It is natural, with the introduction of telephony, that attention should be directed to an analogous problem, that of the telephonic relay; a far more difficult problem than the telegraphic relay; and the future historian of the progress of telephony will find it difficult to analyze the work of hundreds of inventors who have sought to solve the problem.

When we consider that the telegraphic relay merely responds to one throb, so to speak, one inarticulate impulse, while a telephonic relay must reproduce the whole range of the human voice, we begin to realize the demand that the invention of such a relay must make upon both scientific knowledge of sound and of electricity and magnetism; and above all, upon mechanical skill. It does not, therefore, seem inappropriate to discuss in this Journal, which contains much of the work of Joseph Henry, some scientific points in connection with a telephonic relay.

The earlier inventors who attacked the problem naturally thought of the simple device of applying a microphonic contact immediately to the vibrating diaphragm of a telephone,

hoping to repeat the almost infinitesimal vibrations of this diaphragm, and to give them an increase of energy by a local battery. This attempt is an application pure and simple of the principle of the telegraphic relay and therefore marks no progress in the art; for it was not new in principle and furthermore it did not work. The application of the microphonic contact loaded the diaphragm at its most sensitive point and thus prevented the vibrations which one sought to repeat; moreover, the vibrations of the diaphragm are too minute to cause a sufficient agitation of the microphonic contact.

The next step in the mind of the inventor was to endeavor to increase the vibration of the center of the telephonic diaphragm by a lever. This arrangement was found to be inoperative, for the short arm of the lever exercised a prejudicial pressure on the vibrating diaphragm; moreover, the fundamental vibrations of the lever were superposed on the vibrations of the diaphragm, thus completely confusing speech.

It was perhaps natural to suppose that a number of microphonic contacts placed on a number of telephonic diaphragms, the telephones being arranged one after the other in tandem, might gather, so to speak, the slight vibrations of each and throw them in a united volume upon the relay line. This chorus arrangement, however, is also a failure; for the united speech is confused; much as if a number of persons singing the same note, some through the nose and others imperfectly, should undertake to transmit the note through a number of telephones. The imperfection of each microphonic contact disturbs the final result.

It must be remembered that the telephone is after all an imperfect instrument and its wonderful adaptiveness is greatly aided by the human brain, which catches at the connection of thought. This can be seen if individual words are transmitted without context. It will be found that the call girl will ask you to repeat such a collocation as " superstitious zoological veneration." Moreover the amount of energy utilized in the telephone is extremely small; most of the energy of the currents which actuate it and transmit speech is dissipated in heat. Some observers think that less than one per cent of the energy of such currents is transformed into sound waves. We see, therefore, that the problem of the telephone relay calls for all our electrical and mechanical aids to preserve and to transmit this small percentage.

Since mechanical enlargement of the vibration of the telephonic diaphragm by levers is out of the question, the next more promising step seemed to be the bringing in, so to speak, of electromagnetic energy, and it has been proposed to cause the telephonic currents on the circuit to be relayed, to react by

induction on a neighboring circuit at several points. This method gets rid of mechanical pressure on the vibrating diaphragm of the telephone, and substitutes an electrical pressure without any visible connection between the circuits. This method also is ineffective. It has, however, a certain analogy in another and more successful attempt to utilize an invisible and intangible magnetic effect without bringing a mechanical pressure on the telephonic diaphragm; this method consists in causing the telephonic currents to disturb a piece of iron, a balanced magnet, or a suspended coil in a strong magnetic field such as is found at the center of an electromagnet or between the poles of a strong permanent magnet.

The principle of this method is that of the siphon recorder, the invention of Lord Kelvin, which is used on ocean cables. Since the current on the cable is very feeble, and cannot work ordinary telegraphic instruments, some method must be used to magnify or to record the signals. The method adopted by Lord Kelvin was that of a delicately suspended coil so placed between the poles of a powerful magnet that when the feeble currents passed through this coil it oscillated; for the feeble currents animated the coil making it an electromagnet, the poles of which sought the poles of the powerful stationary magnet. Thus a very feeble electrical current could be detected by the powerful magnetic influence to which it was subjected. Here we have a mechanical movement, the movement of a vibrating system, produced without the intermediation of visible connecting parts. The same principle has been adopted in many forms of instruments for detecting and measuring electrical currents, both in laboratories and in commercial electrical installations.

It has, therefore, occurred to many minds that by the use of this principle of magnifying the vibration of moving parts by the reaction between the feeble currents in such parts and the environment about these parts, one should be able to strengthen or repeat such vibrations. The mechanical difficulties, however, are very great if one endeavors to apply this principle to the problem of the telephonic relay. A delicate suspension such as is used in the siphon recorder or the D'Arsonval galvanometer is out of the question; and a rigid suspension prevents the turning movement, the seeking of the poles of the powerful magnet by the little coil which conveys the feeble currents. A certain measure of success, however, can be obtained by careful adjustments in a laboratory; but the utilization of the turning movement of a little coil in a magnetic field has not yet proved of commercial use in telephony.

We are apparently brought back to some modification of the simple principle of the disturbance of a powerful magnetic

field by the effect of feeble currents circulating around coils placed in such fields. Suppose, for instance, that we have a hollow electromagnet with another electromagnet suspended above it, the iron core of the suspended magnet forming a part of the core of the stationary more powerful electromagnet. The system can evidently be balanced, in various ways; for instance, the suspended magnetic core can be maintained in a definite position by connection with a telephone diaphragm; and when a feeble current circulates through the coil of such a suspended electromagnet its position with respect to the stationary coil is changed. Instead of the diaphragm of a telephone, it is evident that a diaphragm connected to a microphonic contact can be employed. This idea can be found in the efforts of many inventors to construct a relay. Professor Dolbear has described a telephone which works upon this principle; a non-magnetic diaphragm placed close to the pole of a permanent magnet carries a little electromagnet which is balanced under the influence of the elasticity of the diaphragm and the magnetism of the permanent magnet. When the voice causes the diaphragm to vibrate, the movements of the little electromagnet disturb the magnetic field, producing feeble currents of induction in the little moving coil which transmit speech to a similar piece of apparatus. If this similar receiving apparatus of Professor Dolbear had been employed to modify a microphonic contact, it would have been the precursor of many subsequent inventions.

Instead, therefore, of the turning or torsional effect relied upon to actuate Lord Kelvin's siphon recorder,—called "Siphon" because a siphonic pen records the oscillations of the vibrating coil,—we have efforts to utilize the to and fro thrust of a vibrating core of an electromagnet whose position in a powerful field is modified by the strength of the feeble telephonic currents which circulate around the core of such a magnet.

At first sight it would seem that the inertia of the suspended electromagnet, or that of its core or plunger if the coil of the electromagnet is fixed, would be so great that the motion of the microphonic contacts would be seriously impeded. It is true that the weight of the vibrating parts in this form of relay must be small, and there must not be any subsidiary vibrations of the moving parts which might be superposed upon the vibrations due to the telephonic currents. It is evident that such subsidiary vibrations can arise if the moving parts are long and of considerable size. With a loaded microphonic contact we can have feeble effects or roaring sounds, as if the membrane of the ear is loaded by an obstruction.

In this form of telephonic relay we, therefore, have a micro-phonic contact connected with what may be called an iron plunger, the position of which in a magnetic field is modified by changes in its magnetism by surrounding feeble telephonic currents. The only mechanical connection is that of this moving plunger with the microphonic contact.

The magnetic part of a relay embodying the above ideas can be suitably constructed so as to perform their part to a commercial degree of perfection ; the principal imperfection of the relay arises from the microphonic part. Among such imperfections the most notable one is the roaring or "growling" of the microphone when a strong battery is used to get the greatest degree of sensitiveness from it. This noise, which arises in great part from crepitations produced by heat, can completely overpower telephonic transmission of speech. This crepitation is greatly enhanced by the direct connection of the plunger or moving electromagnetic coil with the microphonic contact; for the movements in the magnetic field and the crepitations in the microphone get into a swing together, mutually aiding each other. This mutual action is one of the greatest barriers to the perfection of a telephonic relay in which a close connection exists between the parts moving in the magnetic field and the microphonic contacts. To overcome this defect would be a great service to the art of telephony.

It is thought by some that this crepitation noise is analogous to that of the singing electric light arc ; it can be started in any transmitter either by too strong a current or by a suitable reaction between the vibratory motions in the transmitter and the current in the telephone circuit of which the microphone is a part, for instance the roaring can be started by holding a telephone connected with the circuit directly in front of the transmitter.

With the view of accomplishing two results, I have constructed the following form of telephonic relay. These results to be attained are as follows : First, the prevention of the reaction of the magnetic parts on the crepitation of the microphone to obviate the excessive roaring or "growling" ; secondly, to provide means for a separate adjustment of the magnetic moving parts and the transmitter. This separate adjustment is evidently highly desirable ; for the part moving in the magnetic field may be in a suitable position for the greatest sensitiveness, while the microphonic contact has not a suitable contact pressure ; and any disturbance of adjustment of one of these parts of the apparatus disturbs the other. In accomplishing these results, the fact came out with great clearness that the separation of the microphonic contact by means of an air

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D

F 4

E

D

F 3

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F 1

N   S

B   C   A   D   T

S   N   E
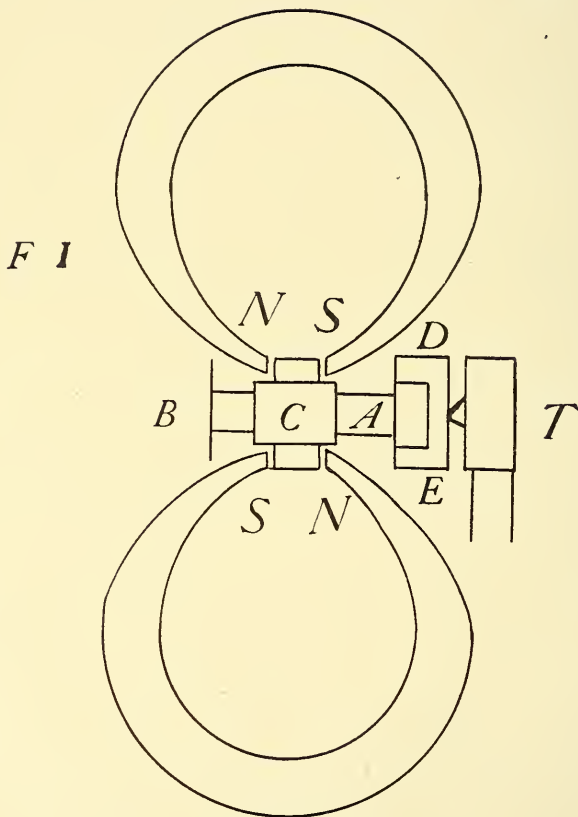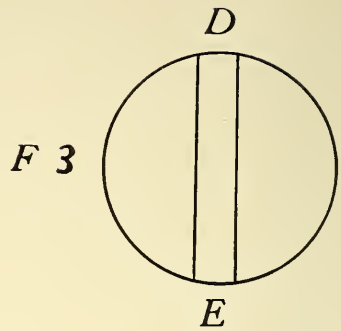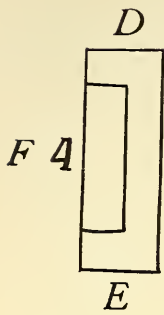
chamber from the magnetically moving parts, a separation
claimed by many inventors, is inoperative unless there is a
better sound-conducting medium between the microphonic
contact and the vibrating part in the magnetic field than the

layer of air. In fact, the layer of separating air is incapable of transmitting the feeble vibrations of a telephone diaphragm sufficiently for relaying; while a suitable solid sound-transmitting support to the microphone in contact with the edges of a diaphragm actuated by the movements in the magnetic field transmits such vibrations very efficiently. This is an exemplification of the fact that a person partially deaf can hear if the vibrations are conveyed to the ear by contact with the supports of the ear.

Considering thus the principles involved in the construction of a practicable telephonic relay, I have invented the relay

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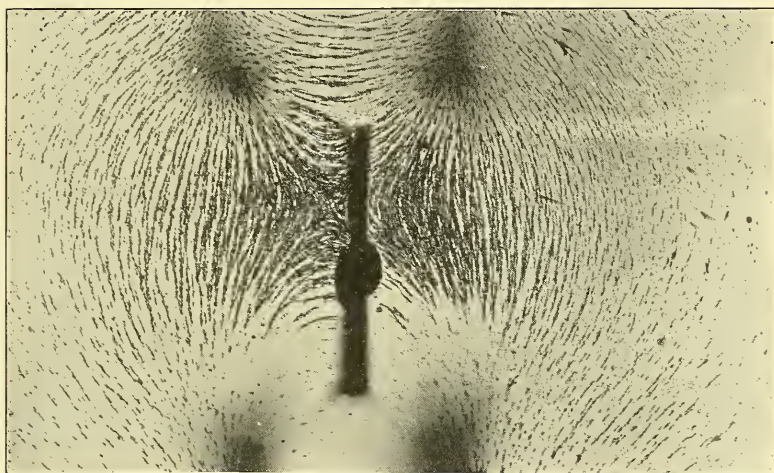
described below; a relay in which the barrier of undesirable "growling or roaring" is obviated; and a relay which permits of the desirable separate adjustment of magnetic parts and microphonic parts.

The relay consists of a small coil with a laminated iron core, which is balanced by two small diaphragms in a balanced magnetic field : the telephonic currents to be repeated or relayed enter the little coil and disturb the magnetic balance in the magnetic field.

In fig. 1, NS (diagrammatic) represent the poles of the magnetic field, C the moving coil actuated by the telephonic currents to be relayed, A and B the supporting diaphragms, DE sound-communicating support of the microphonic contacts or transmitter. This can be a heavy disc : in some experiments I have used a brass disc one half an inch thick and

have relayed loud and articulate speech. The main features of this relay are these: the magnetic field acts both in the direction towards B as well as toward A.

Fig. 2 shows by the lines of magnetic filings the character of this magnetic field. This arrangement may be considered a modification of the principle of the siphon recorder of Lord Kelvin, in which a to and fro thrust or vibration takes the place of the rotating or turning effect of feeble currents actuating a small coil suspended in a strong magnetic field.

The second important principle is the freedom of the central portion of the diaphragm A from the pressure of the transmitter T. The third point is the transmission of the vibrations of this diaphragm A by means of the sound-transmitting support of the transmitter to the transmitter T. As I have already said, the air enclosed in the chamber DE plays a very small part in the transmission of the vibrations of the diaphragm A. A proof of this important fact is as follows.

Fig. 3 represents a front view of the support DE of the transmitter, which in this case consisted merely of a metallic bar. Fig. 4 is a side view of this case. Here the air space between the transmitter and the diaphragm A is not enclosed, being open on both sides of the bar, which is connected at its edges with the diaphragm A. The transmission of speech in this case is loud, while if the connection at D and E with the diaphragm are removed and the bar upon which the transmitter rests in the same position parallel to the diaphragm A, a very feeble sound is transmitted through the intervening air.

One can, therefore, adjust the transmitter without bringing a pressure upon the most sensitive portion of the diaphragm A, its center, and without disturbing the adjustment of the moving coil C. The relay is very sensitive; it is loud, and the articulation good. Moreover it is free from the objectionable growling or enhancing effect of the crepitation of the microphonic contacts on the vibrations of the magnetic portion of the relay. I have been much indebted to the suggestiveness and mechanical skill of the mechanician of the laboratory, Mr. George W. Thompson.

The engineering problems connected with loading telephone lines are most interesting, and when completely solved may obviate the use of relays, and telephonic engineering may go through a phase analogous to that of the Morse telegraph, in which as I have said the telegraphic relay is subordinate in importance to good conducting lines. Nevertheless we have not reached this point yet, and the cost of a relay is practically nothing in comparison with the enormous expense of a loaded line. The relay, described in this article, seems to me to be an important solution of the problem of the telephonic relay.

Jefferson Physical Laboratory,
    Harvard University.

Art. XXX.—*A Stony Meteorite from Coon Butte, Arizona;*
by J. W. Mallet, University of Virginia.

I was told of the existence of the aërolite described in this
paper by Mr. D. Moreau Barringer of Philadelphia, who found
and owns the specimen, and has permitted me to examine and
describe it.

Mr. Barringer and Mr. Benjamin C. Tilghman, members of
the Academy of Natural Sciences of Philadelphia, have for
some time been engaged in exploration at the locality known
as Coon Butte in Coconino County, Arizona, whence large
quantities of meteoric iron—commonly called Canyon Diablo
iron—have been brought, and these gentlemen have recently
sent a paper to the Philadelphia Academy on the subject of
this exploration and their conclusions from the results they
have thus far reached.

Mr. Barringer has sent me the following account of the cir-
cumstances under which he himself found the meteorite I
have examined :

" On June 24th, 1905, while riding with Mr. S. J. Holsin-
ger in a general northwest direction from the crater to our
reservoirs in Canyon Diablo gorge, my attention was attracted
by a rather curiously shaped stone lying on the surface of the
thin soil which covers the level limestone plain extending for
many miles in every direction in this region. The rather
sharply pointed protuberance was what particularly attracted
my observation and made me realize that it could not be a
water-worn bowlder such as are frequently found in this
region." "Upon getting off from our horses and examining
the stone I at once suspected that it might prove to be an aëro-
lite, and of course became much interested in the discovery.
The greater portion of it was exposed to view, it being
imbedded in the loose soil only to about an inch in depth.
Two of the broken corners, as I remember, were exposed to
view, and the fractures exhibited seemed to be quite fresh.
I infer that these corners were broken off at the time of the
fall. The locality at which it was found is typical of the
region, namely a nearly bare or naked plain covered by loose
soil and dotted here and there with bunches of sage brush,
grease wood, etc. As I remember, the exact spot at which
the stone was discovered is between a mile and a mile and a
half distant from the crater in a general western direction,
and about ten and a half miles in a southeast direction
from Canyon Diablo station." "We made a thorough search
for the fragments which had been broken off from this stone,
but failed to find them. I infer that the stone struck the earth
at some distance from the spot where it was found, and

rebounded to this spot by reason of the force with which it struck."

Mr. Barringer thinks it highly probable that this aërolite was *seen* to fall about a year and a half before he found it, and has sent me the following statement of facts in support of this opinion.

"About the middle of January, 1904—on the 15th of the month, as nearly as the date can now be fixed—while two of our employees at Coon Butte were watching the camp (we had suspended operations during the winter), they were awakened, so they told us, by a loud hissing noise and looking northward saw that the heavens were brilliantly lighted, and while rushing out of their tent saw a meteor fall somewhere west or northwest of the butte between them and the railroad. We paid no special attention to the story, and supposed that although they might have seen a meteor fall, it had come to the earth, if it came to the earth at all, many miles distant. However on the same evening and at the same moment, a few minutes before nine o'clock, the hour being fixed by the train schedule, Dr. A. Rounsville and Dr. G. F. Manning were travelling together from Williams, Arizona, to Canyon Diablo station, Dr. Rounsville sitting next to the window on the south side of the car, and just before the train stopped they saw a brilliant light outside of the train, which Dr. Rounsville described just as our men did—i. e. as being lighter than daylight. He could see the mountains twenty miles away, and distinctly every shrub and rock for hundreds of yards from the train. As he exclaimed to Dr. Manning, who occupied the same seat, concerning this light, he caught a glimpse of a fireball dropping to the horizon in the direction of Coon Butte. The light and the fireball were both seen by Dr. Manning also. It seems from the coincidence of time almost certain that this was the same meteor as that seen by our employees at Coon Butte, the observers being about twelve miles apart. It was very near a spot at the intersection of the two lines of sight, the direction of which they of course could not determine with exactness, that I found the stony meteorite."*

The specimen as received by me was pyriform, with a roughly triangular cross-section, bounded by two approximately flat surfaces (one larger than the other) inclined at about 60° or 65° to each other and united by a third, irregularly curved convex surface. It was a good deal larger at one end than at the other. The general surface was smooth, but indented at places with the characteristic shallow pittings, like thumb prints on a lump of sculptor's modelling clay, which

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*Further correspondence, sent me by Mr. Barringer, shows that there is some doubt as to the date, but the preponderance of evidence is in favor of its having been *the same* in respect to both sets of observers.

are seen on so many meteorites. One, presumably rather large, piece had been broken off from the smaller end, and two other, much smaller, fractures appeared at and near the larger, end. Measuring the mass as it lay on the larger approximately flat face, the maximum length was about 14.5^{cm}, maximum width about 11.8^{cm} and maximum thickness about 8.9^{cm}. Fig. 1 is a reproduction of a photograph showing the general appearance. The weight of the specimen as it reached

1

me was 2789 grams. There is an external oxidized crust, generally of dark, blackish brown color, with patches of redder brown—for the most part very thin, not exceeding $.5^{mm}$ in thickness; at some points the oxidized material runs in to a depth of 7 or 8^{mm}. A surface of fracture shows a gray mass of (not very well defined) chondritic and brecciated structure, with numerous little spots of iron-stained yellowish brown color, including lustrous points of metallic iron—the general appearance like that of the Pultusk meteorites of Jan. 30, 1868 (but without the glossy black crust of these stones). There is a still closer resemblance, both of crust and fractured surface, to the meteorites from Ness Co., Kansas. From the general appearance of the surface of fracture I am inclined to class this specimen as Brezina's breccialike gray chondrite, Cgb. The specific gravity of the whole mass taken by suspension in water at 15° C. was found to be 3·471, which is sensibly less than the results of calculation from the constituent materials as found by analysis, indicating some lack of compactness in structure.

Dr. George P. Merrill, Head Curator of Geology at the U. S. National Museum, who has given much attention to the

petrographic study of meteorites, very kindly undertook to have thin sections made of some fragments I sent him, to examine these under the microscope, and to secure photo-micrographs of some of them. The notes with which he has favored me are as follows, and in figs. 2, 3 and 4 the accompanying photo-micrographs are reproduced.

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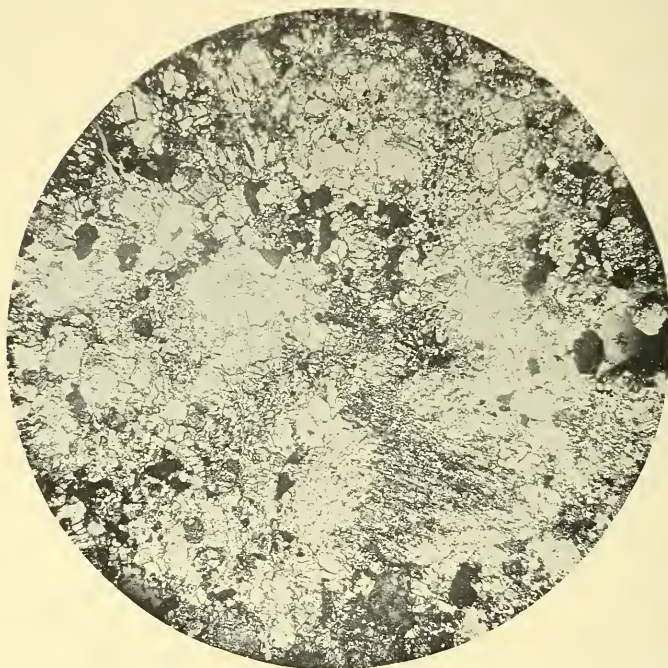
Section showing structure. The black areas are nickel-iron and metallic sulphides ; the light areas are olivine and enstatite.

"Aside from its metallic constituents, the stone consists mainly of enstatite and olivine. The enstatite, which is largely in excess, occurs in granular forms, without distinct crystal outlines and also in chondrules of the usual fan-shaped radiating and granular structures (figs. 2 and 4). In the larger forms of the single crystals a condition of molecular strain is manifested by the manner in which, between crossed nicols, the dark wave sweeps over the surface. Such a condition, it may be stated, is not uncommon in stony meteorites, through its full significance seems not to have been realized.

The olivine likewise occurs in granular form and in that of chondrules with the characteristic barred or grate-like and,

more rarely, porphyritic, structures. Except where stained
by a recent oxidation of the ferruginous constituents, both
minerals are colorless or but slightly gray.

In addition to the mineral above described is a completely
colorless isotropic substance occurring, as a rule, with no crystal
outlines, but rather filling interspaces as would an interstitial
glass. It is sometimes quite free from enclosures or, again,
includes numerous silicate granules and opaque metallic par-
ticles. Rarely does it show anything suggestive of cleavage

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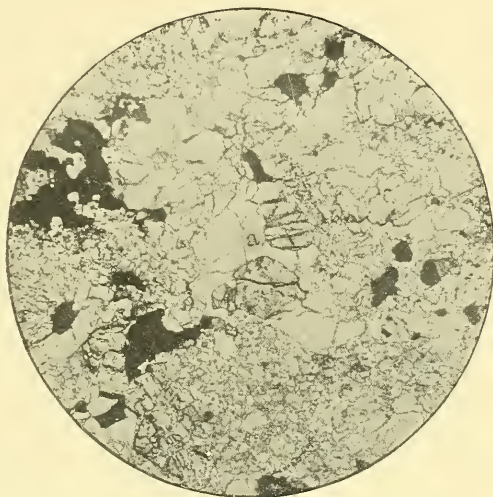
Section showing supposed maskelynite at *a*.

(see fig. 3 *a*). Excepting in its lack of crystallographic out-
lines, the mineral is similar in all respects, as far as appearance
goes, to the maskelynite of the Shergotty (India) meteorite,
and such I shall have to assume it to be. It is altogether too
small in amount to permit a satisfactory chemical determina-
tion, though with more material a micro-chemical test might
be made which would go a long way towards settling the prob-
lem.

The chondritic structure of the stone is not strongly marked,
and the individual chondrules are themselves almost invariably
of a fragmental nature. The one shown in fig. 4 is the most
perfect exhibited in any of the slides. The structure, as a
whole, is not unlike that of the Ness County, Kansas, stone,
and hence, if we follow Brezina, would be placed in the group
of intermediate chondrites, brecciated (Cib). As, however, I
have examined this stone only in thin sections, none of which

include an area of above 10^{mm} square, it is possible that fur-
ther study might relegate it to the Cgb group, of which the
Pultusk stone is a well known representative.

For the photo-micrographic illustrations accompanying these
notes I am indebted to the U. S. Geological Survey."

The chemical analysis was found to be somewhat trouble-
some, particularly in regard to the distribution of the iron pres-
ent in several different chemical conditions. The greater
part of the metallic nickel-iron, accompanied by some schrei-

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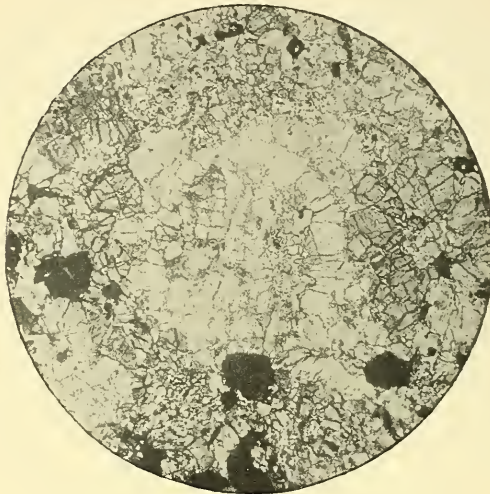
Section showing enstatite chondrule.

bersite and pyrrhotite, was separated from a pulverized sample
of about fifty grams, free from crust, by means of a magnet,
but it was not possible to obtain complete separation in this
way, so that a small proportion of silicates had to be deducted
from the magnetically separated part, and a small proportion
of the constituents of the nickel-iron, schreibersite and pyrrh-
otite to be in like manner deducted from the siliceous part of
the mass dissolved by acid. The part left by the magnet was
digested with hydrochloric acid of 15 per cent strength for
three days at a moderate heat, and thus a general separation of the
decomposable from the undecomposable silicates was effected,
but several determinations of particular constituents had to be
made on individual portions. Hydrofluoric acid was used to
obtain the alkalies, and the same reagent, with exclusion of
air, to secure a determination of ferrous iron.

The following statement gives the general results reached,
with an appended account of how they were obtained.

Enstatite	44·73
Olivine	33·48
Maskelynite (?)	6·87
Nickel-Iron	8·63
Iron rust	3·03
Schreibersite	·76
Pyrrhotite	2·14
Chromite	·08
	99·72

The minute amount of chromite was recovered from the silica of the portion undissolved by hydrochloric acid. There being but a few milligrams, no attempt was made at any analysis of it beyond fully establishing the presence of chromium.

Pyrrhotite was calculated from the amount of sulphur found, assuming the ratio S : Fe = 39 : 61. The sulphide was taken as pyrrhotite, rather than troilite, as the former is believed to occur more commonly in meteoric stones, the latter in meteoric iron. It may of course be troilite, and it may perhaps contain a little nickel.

Schreibersite was calculated from the amount of phosphorus found (partly in the magnetically separated portion, partly in the residue left by the magnet) on the assumption of the ratio, P : Fe : Ni = 15 : 56 : 29.

Iron rust was calculated from the amount of iron found in the ferric state and the amount of water driven off by heating and *collected,* assuming the composition to be that of most ordinary rust, namely, $Fe_2O_2(HO)_2$.

The nickel-iron was obtained by analysis of the magnetically collected portion, deducting mechanically adhering silicates and small amounts of sulphur and phosphorus found in this portion, and adding a small amount of nickel found in the portion left by the magnet (in excess of that accounted for as phosphide in schreibersite) and a quantity of iron from the same portion equivalent to the metallic copper thrown down from a solution of cupric sulphate.

The percentage composition of the nickel-iron, as thus obtained, is

Fe	88.81
Ni	10·72
Co	·15
Cu	trace
Sn	·01
Mn	trace
C	trace
	99·69

I was interested in again finding in iron of meteoric origin minute amounts of both copper and tin, having in former years identified both these metals as constituents of the Augusta Co., Va., and Wichita Co., Texas, meteoric irons. In the case of the Coon Butte meteoric stone none of the granules of nickel-iron exceeded ·5 or ·6^{mm} in diameter.

The feldspathic mineral supposed to be maskelynite was calculated from the alumina found, assuming (on the basis of Tschermak's analyses) that this forms 25 per cent of the mineral so named, assigning to this (on the same basis) silica in the ratio $Al_2O_3 : SiO_2 = 25 : 55$, and adding lime and the oxides of the alkaline metals as actually found. Lithium was tested for, but could not be detected. With these assumptions the percentage composition of the mineral in question is

SiO_2	55.00	} assumed
Al_2O_3	25·00	
CaO	14·17	
Na_2O	5·93	
K_2O	1·72	
	101 82	

As most of these constituents were found partly in the portion soluble and partly (to a larger extent) in that insoluble in hydrochloric acid, it is probable that the feldspathic mineral is attacked, though not readily, by that acid. But it is of course quite possible that some of these constituents may belong to the other silicates present. The supposition of Tschermak that maskelynite is simply a feldspar that has cooled from fusion in an amorphous state seems quite reasonable and likely.

Olivine was calculated from the remaining constituents of the portion left by the magnet and decomposed by hydrochloric acid, after deduction of the small quantities of iron, nickel and other minor constituents already disposed of as above, and also those of the maskelynite (?) to the extent indicated by the alumina, etc., found in this portion decomposed by hydrochloric acid. Thus calculated, the olivine gives the following percentage figures—

SiO_2	42·29
TiO_2	·01*
MgO	42·44
FeO	13·57
	98·31

* More exactly ·006.

This shows an excess of silica over that required for the orthosilicate of between 4 and 5 per cent, suggesting the possibility of a little free silica being present, perhaps as the asmanite (tridymite) of Maskelyne. That form of silica, it is stated, is soluble in a boiling solution of sodium carbonate in water, and as such a solution was used to take up the silica set free by the action of hydrochloric acid, it would be found and counted in with that of the olivine.

Enstatite was calculated from the results of analysis of the portion left by the magnet and not decomposed by hydrochloric acid, deducting the minute quantity of chromite and such of the constituents of the so-called maskelynite as occurred in this portion. The figures so obtained give the following percentage composition for the enstatite—

$$
\begin{array}{ll}
SiO_2 & 53\cdot87 \\
MgO & 26\cdot55 \\
FeO & 18\cdot35 \\
\hline
 & 98\cdot77
\end{array}
$$

showing a very fair accordance with the results of calculation from the formula of the mineral.

University of Virginia,
    Feb. 3, 1906.

Art. XXXI.—*On a New Stony Meteorite from Modoc, Scott County, Kansas;* by George P. Merrill, with analyses by Wirt Tassin.

The meteoric stone described below was received at the National Museum from Mr. J. K. Freed, to whom we are indebted for the facts given relative to its fall and the privilege of describing it.

The stone fell on the night of September 2, 1905, about 10 p. m., and seems to have come from the west or southwest. When about six miles due west of Scott City it exploded with what is described as a terrific roar, plainly heard for a distance of 25 miles, awakening those who had already gone to sleep and frightening people for miles around. Its appearance when exploding was variously described as like the "headlight of a locomotive," and a "white light as big as a haystack afire." Eighteen miles south of Scott City it is stated to have been light enough to "pick up a pin." Following the explosion, was a noise compared with the discharge of a heavy battery of artillery or of a heavy wagon running rapidly over the frozen ground, the noise gradually dying away like rolling thunder in the distance. Some claim to have heard the whistling of rocks through the air like bullets or heavy hail. Mr. Freed himself compares the sound to that of "a mighty swish-h-h, resembling the sound of a sky rocket."

After a search extending over a period of more than a year, fourteen pieces have been reported as found, scattered over an area some two miles by seven in the vicinity of Modoc, a small town on the Missouri Pacific Railroad. These were mostly complete individuals. Three and a fragment received at the National Museum weighed, respectively, 4640, 1170, 490, and 110 grams. Two others obtained by Dr. O. C. Farrington for the Field Columbian Museum are reported as weighing about 5400 grams. An individual of approximately 2000 grams weight is reported as in the hands of a collector in Kansas. This accounts for seven out of the fourteen reported finds. It seems safe to assume that the weight of the entire fall could not have been less than 15 kilograms.

The 4·64 kilo individual received at the Museum was the largest thus far reported. Its dimensions are: Height over all, 21^{cm}; maximum width, 15·5^{cm}; thickness, 10·65^{cm}. This was found several miles east of the others and was imbedded but four or five inches in the hard buffalo grass sod, inclining slightly to the west. It is a complete individual, with the exception of a small fragment of about an ounce weight, which

had been broken away to send to the Museum previously for examination.

This and the others examined are covered with a dull brown-black, slightly rough crust of approximately a millimeter in thickness, showing no traces of flow structure nor perceptible thickening in any part such as would indicate the position of the block in its flight through the air. The surfaces are, on the whole, rather free from pittings. Sundry darker streaks running parallel with the broader faces suggest a lack of homogeneity or a possible fissuring of the mass.

The broken surface shows the stone to be very indistinctly chondritic and of a color even lighter gray than the Möcs or Drake Creek, Tennessee stone, which it closely resembles. With a pocket lens abundant metallic points are visible.

Under the microscope the stone is found to consist essentially of olivine and enstatite in characteristic jumbled, granular crystalline forms, interspersed with larger irregular granules and indistinctly outlined chondrules of the same material, together with blebs of metallic iron and troilite. As already noted, the chondritic structure is quite inconspicuous on a broken surface, the individual chondrules consisting of irregularly rounded, oval and sometimes angular aggregates of olivines in granular and grate-like forms, or enstatites in eccentric radiating masses, in either instance the interstices being often occupied by a colorless mineral identified as feldspar. In a single instance a chondrule was noted consisting of a coal-black dust-like material interspersed with a few blebs of troilite, the whole being nearly surrounded · by the colorless zone of feldspar (?), the appearance in an ordinary light being practically identical with the black chondrule from the meteorite of Chateau Renard, as figured by Tschermak.* The mineral identified as a plagioclase feldspar occurs in small, perfectly clear and colorless interstitial forms, so lacking in crystalline outline and cleavage as at first to suggest a residual glass. Extinction angles are quite unsatisfactory, the dark waves sweeping across the face of the crystals in a manner indicative of a condition of strain; and, were it not for an occasional particle with inconspicuous twin bands, the real nature of the mineral would be in doubt. It was, unquestionably, the last mineral to crystallize, is quite free from enclosures, and occupies the interstices of the olivines and enstatites, often partially enwrapping them, very like a glass, but between crossed nicols polarizing faintly in light and dark colors and breaking up into granular masses comparable with the secondary feldspars in the drusy cavities of metamorphic rocks. Aside from occurring between the bars and radiating columns of the chondrules, as already mentioned, it is scat-

---

* Die mikroskopische Beschaffenheit der Meteoriten, pl. 17, fig. 3.

tered throughout the ground in a manner closely identical
with that of the Milena meteorite, as also figured by Tscher-
mak.*

As noted above, the stone is traversed by fine, thread-like
black veins, though how abundant such may be it is impossible
to tell without breaking the specimen, and this the writer has
not been able to obtain permission to do.

The fall adds one more—the twelfth—to the remarkable list
for which Kansas has become noted.†

As will be seen from the description, the stone belongs to
Brezina's group of veined chondritic meteorites (Cwa). It will
be known as the Modoc, Scott County, meteorite.

Chemical analysis, by Wirt Tassin.

The native metal was determined in 2·0255 grams of the
crust-free meteorite as follows: The finely pulverized mate-
rial was treated in the cold with a solution of mercuric ammo-
nium chloride, in an atmosphere of hydrogen. The results were:

Fe	6·56
Ni	0·68
Co	0·034

The sulphur was determined in 1·0300 grams of the meteor-
ite, after fusion with $Na_2CO_3 + KNO_3$. This yielded:

S	1·38

The phosphorus was estimated in 1·0450 grams, and the per-
centage found was:

P	0·051

The soluble silicates were determined by treatment with
HCl, sp. 1·06. The action was allowed to take place on the
water-bath and continued but two hours. The acid then
decanted off and the operation twice repeated. This treatment
gave:

SiO_2	17·38
FeO	10·95
Al_2O_3	0·20
CaO	0·14
MgO	17·73

The insoluble silicates were determined after fusion with
Na_2CO_3. The alkalies were necessarily determined in a sepa-
rate portion. Chromite was not present:

* Die mikroskopische Beschaffenheit der Meteoriten, pl. 16, fig. 3.
† For an enumeration of these see "A Newly Found Meteorite from
Admire, Lyon County, Kansas," Proc. U. S. National Museum, vol. xxiv,
1902, pp. 907–913.

SiO$_2$ .... 26·75
FeO .... 4·42
MnO....................... 0·10 (?)
Al$_2$O$_3$ .... 2·27
CaO .... 1·60
MgO .... 8·72
K$_2$O .... present but not determinable
Na$_2$O .... 0·44

The general composition of the portions of the meteorite analyzed, as derived from the combination of the several determinations, is :

Fe .... 6·56
Ni....................... 0·68
Co....................... 0·034
S .... 1·38
P....................... 0·051
SiO$_2$ .... 44·13
FeO .... 15·37
MnO....................... 0·10 (?)
CaO .... 1·74
MgO .... 26·45
Al$_2$O$_3$ .... 2·47
K$_2$O .... trace
Na$_2$O .... 0·44
                                   ————
                                   99·40

The mineralogical composition of the meteorite may be approximately calculated from the above summation. The amount of nickel-iron is determined directly ; troilite and schreibersite are calculated from the amounts of sulphur and phosphorus found, assuming that schreibersite has the formula Fe$_2$NiP. The soluble silicate is olivine. The insoluble silicates are regarded as enstatite and the feldspathic mineral noted, the amount of alumina found furnishing the basis for the calculation :

Nickel iron .... 4·59
Troilite .... 3·79
Schreibersite................... 0·34
Olivine .... 46·40
Enstatite .... 29·94
Other insoluble silicates .... 14·36
                                   ————
                                   99·42

It must be confessed that the last item in the calculation is not wholly satisfactory, the 14·36 per cent of other insoluble silicates not being accounted for in the microscopic examination. It undoubtedly includes the feldspathic constituent and

presumably also a portion of the irresolvable matter of the chondrules. A like condition of affairs was noted by Borgström in his description of the Shelburne meteorite,* which, from a chemical standpoint, this closely resembles.

The specific gravity of the Modoc stone was determined on two complete individuals, weighing 1110 and 490 grams, respectively, by a large apparatus constructed on the plan of the beam balance recommended by Penfield in the latest edition of his Brush Determinative Mineralogy. No attempt was made to exhaust the air from the pores, the stone being immersed in water and, with frequent agitations, allowed to remain until no more bubbles were given off. The average of two determinations was 3·54.

Addenda.

Together with the samples of Modoc meteorite forwarded, Mr. Freed included two small pebble-like masses, which had been found by his boy and which it was thought might possibly be also of meteoric origin. One of these was of ferruginous quartzite. The other, some 40 by 60 millimeters in greatest diameter, and weighing 135 grams, proved to be meteoric. This, although weathered to a dull rusty brown on the surface, still showed distinctly the usual pittings, and on a polished surface presented a dull dark-gray ground thickly spotted with small points of metallic iron and occasional rounded areas recognized with the unaided eye as chondrules. Under the microscope this is found to consist of an extremely fine tufaceous ground carrying large clear olivines in single crystals and scattered aggregates and numerous chondrules of both olivine and enstatite. The olivine chondrules are in part polysomatic and in part of the common barred or grate-like character. The enstatite chondrules are most commonly in radiate forms. The entire structure and even the identity of some of the mineral constituents are much obscured by iron oxides which have stained the mass an ocherous red throughout. The metallic constituents are much more abundant than in the Modoc stone named above.

Although differing somewhat from Washington's description and my own studies on the meteorite of Jerome in the adjoining county of Gove, the differences are so slight as to be seemingly non-essential, and I am inclined to regard this as a straggler from the Jerome fall, which, it will be remembered, was found on April 10, 1894, on the Smoky Hill River and has been described in detail by Dr. Washington, in this Journal for June, 1898, vol. v, p. 447. There is, however, a chance for a difference of opinion on this subject.

* Trans. Royal Soc. of Canada, 1904.

Art. XXXII.—*The Determination of the Feldspars by Means of their Refractive Indices;* by Fred. Eugene Wright.

Of the many methods which have been suggested for the discrimination of the feldspars, perhaps none has received less actual attention from petrologists than those based on the refractive indices, notwithstanding the fact that the refractive power of a mineral is one of its fundamental properties and can be determined approximately with comparative ease. The application of the refractive index methods to the feldspars was tested in detail by F. Wallérant,* who determined their refractive indices directly on a total refractometer attachment to his microscope. His particular method is applicable to all minerals except those of the highest refracting power, and would be in general use at the present time were it not for the special apparatus demanded and the fact that thin sections for his purposes require special preparation.

The method which is described below has proved serviceable in actual practice, and is based on the ability to determine the average refractive indices of the feldspars under the microscope by applying the principles developed by Schroeder van der Kolk some years ago.† The conception of the method is therefore not novel, and the following paragraphs are intended solely to suggest a modus operandi which has been found convenient.

Small mineral fragments when observed in obliquely incident light show, on immersion in liquids of higher or lower or equal refractive index, characteristic phenomena which are extremely sensitive and can well be used to distinguish minerals whose average refractive indices vary only five points in the third decimal place. As the theory of these phenomena, however, is given in full in the papers cited, only the practical application of the method to the study of the feldspars will be considered below.

Equipment.—Seven liquids are required whose refractive indices for yellow light are equal respectively to the refractive indices β for

Orthoclase	(Or)	1·523
Albite	$(Ab_{12}An_1)$	1·536
Oligoclase	(Ab_3An_1)	1·545
Andesine	(Ab_3An_2)	1·554
Labradorite	(Ab_2An_3)	1·563
Bytownite	(Ab_1An_3)	1·572
Anorthite	(Ab_1An_{12})	1·582

* Bull. Soc. Min. Fr., pp. 268–271, 1898.

† Tabellen zur mikroskopischen Bestimmung der Mineralien nach ihrem Brechungsindex. Wiesbaden, 1900. Compare also Rosenbusch-Wülfing, Mikroskopische Physiographie, 1904, I, 1, 259–261, also II, 345 ; and Fred. E. Wright, Tschermak Miner. Petr. Mittheil., xx, 239, 1901 and this Journal, xvii, 385–387, 1904.

and can be prepared by mixing oil of cedar ($n_{na}=1\cdot516$) and clove oil ($n_{na}=1\cdot532$) for orthoclase and albite; and clove oil ($n_{na}=1\cdot532$) with cinnamon oil ($n_{na}=1\cdot601$) in the requisite proportions for the remaining members. These liquids are miscible in all proportions, evaporate at nearly equal rates and are well adapted for the method. They can be kept in small glass stoppered dropping bottles, mounted on a square wooden block and labelled with the name of the feldspar to which their refractive index corresponds. Another series consisting of monochlorated benzene ($1\cdot523$), oil of cloves ($1\cdot532$), aethylene bromide ($1\cdot544$), nitrobenzene ($1\cdot554$), mono-bromated benzene ($1\cdot562$), and mixtures of the latter with bromoform ($1\cdot595$), has been found to give equally good results, but cannot be procured so readily. Dilute Thoulet solutions might also be employed, but are not to be recommended since a slight evaporation of the water changes their refractive index rapidly. The solutions can be standardized either by measuring their refractive indices directly on a refractometer or by using fragments of typical feldspars as test objects in the method described below.

Manipulation.—In the actual determination of the feldspar, small grains of the substance $0\cdot1$ to $0\cdot004^{mm}$ in diameter are used and can readily be obtained by breaking up, in an agate mortar, larger fragments of the mineral which have been chipped off the hand specimen. After immersion in a drop of one of the liquids between object glass and cover slip, the grains are observed in obliquely incident light under a microscope fitted with a medium power objective and condenser lens slightly lowered.* The nicols should not be crossed. The simplest way to produce oblique rays of light is to cast a shadow on part of the microscopic field by placing the forefinger between the reflector and lower nicol tube on the microscope. In place of the finger a piece of cardboard or a movable iris or stop diagram can be substituted to advantage.†

* In actual practice, it will be found that the phenomena on which this method depends can be reversed by raising or lowering the condenser lens. If a medium power objective be used, and the condenser lens be raised from its lowest possible position to direct contact with the object glass, it will be noted that the edge of the shadow, cast over part of the field, becomes more distinct on elevation, until at a certain point it is in sharp focus, after which it again becomes less clearly marked. It is in the lower and higher positions of the condenser lens and within the transition zone of the indistinct edge of the shadow that the phenomena are most clearly defined. On passing the focus point, we pass from divergent to convergent rays and the phenomena. which appear, are reversed. In the description below the condenser lens is considered to be in its lower position below the point of sharp focus. As a check on the observations, it is often advisable to raise the condenser lens and observe the reversed phenomena. By placing the condenser lens in suitable position, the highest power objectives can be used equally well and minute particles thus be studied.

† Compare Tscherm. Min. Petr. Mittheil., xx, 238–239.

By shading half the microscopic field in this manner, the edges of the small grains on the object glass will appear to be unequally lighted near the dark shadow. If the mineral grain be more highly refracting than the liquid, its edge next the shadow will appear brighter than the edge opposite; on the other hand, if the liquid have higher refracting power, the phenomena are reversed and the light band appears on the farther side from the shadow, while the adjacent edge appears darker than the rest of the grain. In case both mineral and liquid have equal refractive indices for light waves of medium length, the opposite edges of the mineral grain appear brilliantly colored—bright red on one side and blue along the farther side. The occurrence of the red and blue bands along opposite edges of the mineral is, therefore, a sufficient criterion that the refractive indices of mineral and liquid are equal for light waves of medium length. The dispersive power of liquids is often strong, and care should be taken that the colors which appear are actually red and blue and that both edges of the grain are equally bright.

By trial, the approximate refractive index of the feldspar fragment is thus found and the variety determined.

Since in this method cleavage fragments alone are used, extinction angles on (001) P and (010) M can be measured in the same powder preparation and a still more accurate determination made. The determination of the refractive index, moreover, relieves the ambiguity which exists in the angles obtained from certain members of the feldspar series.

In practice, this method has proved particularly valuable in the study of rocks containing both plagioclase and orthoclase. In the thin section it is not always a simple matter to recognize small amounts of orthoclase when abundant acid plagioclase is present, while by the refractive index method the two can be distinguished readily and accurately. Similar conditions obtain in specimens containing both orthoclase and nephelite, in which case the method applies to equal advantage.

Geophysical Laboratory, Carnegie Institute, Washington, D. C.

ART. XXXIII.—*Siderite and Barite from Maryland;* by
WALDEMAR T. SCHALLER.*

Siderite.

A NUMBER of specimens of small splendent crystals of siderite were obtained through the courtesy of the Foote Mineral Company of Philadelphia, who give as the locality, " within two miles of Frostburg, Maryland." The crystals are very small and are deposited in great numbers on a gray massive siderite rock. A very striking feature of the crystals of siderite is the splendent play of colors that they show. They are very iridescent, and while their color is brown, the light reflected from the surfaces of the crystals is in all colors. Associated with the siderites and intermingled with them are numerous small barite crystals. The matrix is a compact impure iron carbonate having a specific gravity of 3·7. In this are imbedded occasional masses of white, opaque barite showing good cleavage. In the rock are numerous cavities which are lined with siderite and barite crystals, the specimens forming geodes, the crystals having been derived from the massive rock.

The crystals vary in size from those which are very minute to those a millimeter in size. They are mostly attached to the matrix by one end, though double terminated crystals are by no means rare, these being irregularly scattered through the mass. The entire layer of crystals is about a millimeter thick.

Chemical Properties.—A number of the crystals were broken from the specimens and very carefully selected from the matrix by hand. The crystals were freed from a small amount of barite by the electromagnet and finally about one-tenth of a gram of pure crystals was obtained, of which each crystal had been picked out and shown to be free from any foreign matter. It was noted that the crystals did not possess a uniform color, some of them being a much lighter brown than others. It was at first thought that the lighter colored ones contained calcium or magnesium, but such was found not to be the case. The change in the intensity of the brown color of the crystals cannot be solely due to the amount of iron in the crystals. The selected crystals were dissolved in hydrochloric acid and the iron precipitated with ammonia and weighed. Tests made for maganese, calcium and magnesium showed them to be absent. The weighed iron oxide was fused with sodium bisulphate, reduced and titrated with potassium permanganate, giving practically the same figure.

* Published by permission of the Director of the U. S. Geol. Survey.

$$FeO \ldots\ldots\ldots 62\cdot01 \text{ (calc.} -62\cdot07\% \text{ FeO)}$$
MnO .... none
CaO .... none
MgO .... none

The crystals are therefore pure iron carbonate and well suited for obtaining crystallographic constants for siderite.

Crystallographic Properties.—The siderite crystals have a rather unusual habit for that mineral, as the dominant form is the scalenohedron $v=\{21\bar{3}1\}$, the common form for calcite. A number of other forms are present, and a very marked feature of these crystals is that in approximately the places where the a-face would come there are rounded hollows. The crystals are highly polished and seemed likely to give perfect reflections, but on examination on the two-circle goniometer, it was found that the faces were not as perfect as was at first expected. This is due chiefly to the fact that some of the large scalenohedral faces appear broken and the parts slightly displaced, yielding more than one signal, several minutes apart. The crystals were mounted in polar position, and so adjusted that on turning the vertical circle (the horizontal one being clamped) the reflections from the several faces of each form fell, respectively, in a vertical line coinciding with the vertical cross hair. After the crystal was adjusted as perfectly as possible, the reading on the horizontal circle was taken for each face, the signal being brought to the exact center of the field in each case. The forms present are shown in the following table, those forms which are new for siderite being marked with an asterisk.

r	$10\bar{1}1$
*l	$70\bar{7}5$
*k	$50\bar{5}2$
f	$02\bar{2}1$
v	$21\bar{3}1$
*y	$32\bar{5}1$

The new form $l=\{70\bar{7}5\}$ occurs but once as a small face below $\{10\bar{1}1\}$ but larger than that face. The reflection was fair.

	ϕ	ρ
meas.	$0°\ 14'$	$52°\ 49'$
calc.*	$0°\ 00'$	$53°\ 07'$

The form $k=\{50\bar{5}2\}$ occurs as a minute line face somewhat rounded, and truncating the edges of the scalenohedron $v=\{21\bar{3}1\}$. The measurements show that the ρ angle is about 68°, though no accurate measurement could be obtained.

calc. $(\rho) = 67°\ 12'$.

* From element derived by writer.

The unit rhombohedron r occurs on nearly all of the crystals as small faces truncating the apex of the crystals. The new scalenohedron $y = \{32\bar{5}1\}$ occurs on all the crystals and is a characteristic form for this locality. Though it varies in size, becoming relatively wide and short or narrow and long, its general form is shown in figure 1.

The zone $v\ y\ y^{\mathrm{VI}} v^{\mathrm{VI}}$ is sometimes somewhat striated between y and y^{VI}, and using the dot signal, it was seen that there was a maximum of brightness in the position required for the faces $\{7.6.\bar{13}.1\}$ and $\{11\bar{2}0\}$. It could not be shown, however, that these faces were actually present.

1
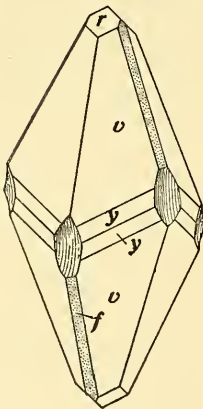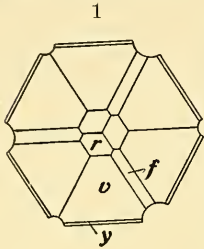
The form $f = \{02\bar{2}1\}$ occurs as broad dull faces giving no reflection and only an almost imperceptible haze of light. Measurements of the ρ-angle gave values from 59° to 62°, calc. 62° 17′.

The concavities give an indefinite blaze of light in the zone of the negative rhombohedrons, about 80° from the base, so that they do not reach down to the prism zone. A study of these hollows on the goniometer, using the dot signal, showed that they consisted of vertical striations approximating in the center of the form $\{06\bar{6}1\}$, and at the extreme edge to $\{11\bar{2}0\}$, with many forms in between these.

Fig. 1 is an attempt to illustrate the actual appearance of these crystals, showing, particularly, the concavities described. The indentations in the orthographic projection are somewhat exaggerated. With the exception of these and the broad dull faces of $\{02\bar{2}1\}$, the faces of the crystals are highly polished, and do not show any etching. It seems probable that these hollows should be regarded as the result of an incomplete or skeletal growth rather than as the result of etching. They are, in a way, analogous to the hopper-shaped crystals of sodium chloride, where the two faces 001 and 100 (in one zone) alternate and the resultant hollow has, in cross section, a V-shape. In the case of the siderites, however, instead of an alternation of the two faces, $06\bar{6}1$ and $11\bar{2}0$, there is a gradation from the prism to the rhombohedron and the result is a rounded hollow instead of a sharply angular one, as in the case of sodium chloride.

Siderite.

Etch Figures.—A cleavage piece was left standing in cold dilute hydrochloric acid for several days and then examined under the microscope, when well-defined etch figures could be observed. These are triangular in shape and possess a plane of symmetry parallel with the shorter diagonal of the cleavage rhomb of siderite, and are shown in figure 2. They resemble in symmetry the figures shown in Miers' Mineralogy (page 112) for calcite and not those given for dolomite. The symmetry of siderite is, therefore, the same as that of calcite and not that of dolomite, a conclusion sustained by the forms of the crystals.
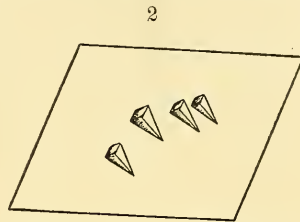
Etch figures on cleavage surface of siderite.

Value for c-axis.—Although siderite is a common mineral, good crystals are rare and the literature on siderite is poor in crystallographic data. The only value for the axial ratio given and which is adopted in all books is one obtained in 1812 by Wollaston. His statement in regard to siderite is as follows :* "I have examined various specimens of this substance, some pure white, others brown, some transparent, others opake. That which gives the most distinct image by reflection is of a brownish hue, with the semi-transparency of horn. It was obtained from a tin mine, called Maudlin Mine, near Lostwithiel in Cornwall. By repeated measurements of small fragments of this specimen, the angle appears to be so nearly 107°, that I cannot form any judgment whether in perfect crystals it will prove to be greater or less than that angle.

In this instance the carbonate of iron is nearly pure, and so perfectly free from carbonate of lime . . . . . ."

The measurements of the faces giving good reflections were used for calculating a value for the *c*-axis. The angles for the same form varied somewhat on different crystals, though the values obtained from the measurements of different forms agree very well with each other. From the average reading, the following values were calculated :

$$\text{From 10 meas. of } r = \{10\bar{1}1\}, c = \cdot82352$$
$$\text{'' } 27 \text{ '' '' } v = \{21\bar{3}1\}, c = \cdot82463$$
$$\text{'' } 16 \text{ '' '' } y = \{32\bar{5}1\}, c = \cdot82311$$

Average, $c = \cdot8240$

An attempt was made to measure the cleavage angle directly, but it was found that the resultant cleavage faces were never

* Phil. Trans., 159, 1812.

perfectly plane, with the result that each face gave several signals.

After this value for c was obtained and found to be different from the commonly accepted value, 10 more crystals were measured and after the greatest care in so adjusting each crystal that the reflections from the scalenohedral faces of v fell as nearly as possible in a straight line, each reflection was carefully measured. In the case of more than one signal, the extremes were measured and the average taken. The average value for the ρ angle for each crystal (six faces) is:

$$
\begin{array}{ll}
68^\circ\ 14' & 21' \\
26 & 27 \\
18 & 20 \\
15 & 19 \\
16 & 29 \\
\end{array}
$$

Av. $68^\circ 20\frac{1}{2}'$, $\therefore c = \cdot 8243$

The values for the two extremes, $68^\circ\ 14'$ and $68^\circ\ 29'$, are:

$$c = \cdot 8197 \text{ and } c = \cdot 8302$$

Taking the average of the values found from r, v, y, namely, $\cdot 8240$, and that found from the 10 crystals, namely, $\cdot 8243$, we get as a value for the c-axis for siderite of known purity,

$$c = \cdot 8241$$

As however, this value differs considerably from that adopted for siderite and as the crystal faces were at times uneven and the angular measurements showed considerable variation, the writer is rather hesitant in urging this new value. It, at least, serves to throw some question over the commonly accepted value and shows the need of additional measurement of material shown by chemical analysis to be pure.

The complete lists of forms so far observed on siderite is as follows:

$$
\begin{array}{lll}
c = 0001 & k\dagger = 50\bar{5}2 & d = 08\bar{8}1 \\
m = 10\bar{1}0 & M = 40\bar{4}1 & \delta = 44\bar{8}6 \\
a = 11\bar{2}0 & e = 01\bar{1}2 & a = 44\bar{8}3 \\
g^* = 10\bar{1}2 & h^* = 03\bar{3}2 & v = 21\bar{3}1 \\
z^* = 30\bar{3}4 & f = 02\bar{2}1 & \beta = 24\bar{6}1 \\
r = 10\bar{1}1 & \omega = 07\bar{7}3 & y\dagger = 32\bar{5}1 \\
l\dagger = 70\bar{7}5 & s = 05\bar{5}1 & i\ddagger = 41\bar{5}9 \\
\end{array}
$$

Those with no reference mark are found in Dana's Mineralogy.

* Gonnard, Bull. Soc. Min., xviii, 382, 1895; also 1st supplement, Dana.
† The present paper.
‡ Cesàro, Ann. Soc. G. Belg., xviii, 1891; also 1st supplement Dana.

Barite.

The barite occurs in three different forms on the specimens seen by the writer. The first is the white massive form which is often imbedded in the matrix. It is usually opaque and shows good cleavage. The second form occurs as an opaque white efflorescence which is composed of an aggregate of minute crystals. The third form is present in transparent colorless crystals which often reach a length of several millimeters, though usually they are rather smaller. The largest ones seen were about a centimeter long and 1 to 2^{mm} thick. On some specimens these transparent crystals are attached by one end to the massive barite and form a fringe, as it were, around it, the crystals standing normal. This occurrence is very suggestive of a secondary formation of the crystals, they being derived from the massive barite in the matrix. The large clear crystals are probably a more perfect development than the white efflorescence and both are doubtless derived from the massive barite. In the massive barite there are no siderite crystals, though small fragments of the matrix are included therein, and in the efflorescence there are frequently found enclosed crystals of siderite, and the clear large barite crystals are intermingled with those of siderite.

The crystals of barite are of especial interest as they are of an uncommon habit; they are prismatic, elongated parallel to the vertical axis. Such crystals have been noticed several times but are not the common form for barite.

The faces of the crystals are highly polished and gave excellent signals. The prism zone is occasionally striated, especially the macropinacoid, though for the most part the zone is not striated and each face is distinct and plane. The forms present are:

$c = 001$	$m = 110$	$q = 114$
$b = 010$	$\eta = 320$	$f = 113$
$a = 100$	$\lambda = 210$	$r = 112$
$\chi = 130$	$o = 011$	$R = 223$
$B = 370$	$d = 102$	$z = 111$
$n = 120$	$l = 104$	$*N = 551$
$N = 230$	$v = 115$	$y = 122$

The prism $B = \{370\}$ occurs twice on two crystals as small faces, usually giving a fair reflection. The angles measured are as follows:

$$28°\ 09',\ 27°\ 52',\ 27°\ 45',\ 27°\ 41'\quad \text{calc. } 27°\ 45'$$

The form was first noted by Düsing* and classed as doubtful by Dana and is not included in Goldschmidt's Winkeltabellen.

* Zeitschr. f. Kryst. xiv, 481, 1888.

The pyramid $N = \{551\}$ is new for barite,

meas. (ρ), 84° 55', 84° 58', 84° 08,' 84° 45'   calc. (ρ) 84° 45'

It occurs as very small faces.

3
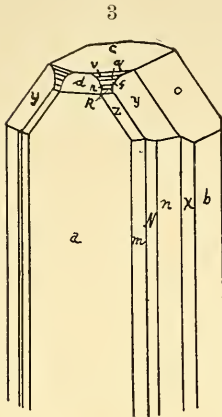
Barite.

The general ideal view of these crystals is shown in figure 3, though in detail the size of the various forms varies considerably even on the same crystal. There are, also, unusually more faces (line faces) in the prism zone than are shown in the figure. Occasionally the crystals are flat, parallel to the macropinacoid, but they are usually of equal diameter, horizontally. At times, too, one side of the terminated end is much larger than the other.

On account of the excellence of the signals, an axial ratio was calculated from the measurements. From the prism faces values for $\grave{a}$ were obtained and values for p_0 and q_0 were obtained from the pyramids and domes (the crystals being measured on the two-circle goniometer). From 44 values for $\grave{a}$ and 70 values for c, the following are obtained which come very close to the accepted value:

$$\grave{a} = \cdot 8146$$
$$c = 1 \cdot 3126.$$

Art. XXXIV.—*Pre-Cambrian Rocks of the Georgetown Quadrangle, Colorado ;*[*] by Sydney H. Ball.

Introduction.

In the summer of 1904 a geological survey of the George-town (Colo.) quadrangle was made by the writer under the supervision of Mr. J. E. Spurr and with the assistance of Mr. O. H. Hershey. To each the writer gratefully acknowledges great indebtedness. The present paper is a preliminary description of the pre-Cambrian formations exposed in this region.

The Georgetown quadrangle is situated in the center of the north half of Colorado and lies between the meridians 105° 30′ and 105° 45′ west longitude, and the parallels 39° 30′ and 39° 45′ north latitude. The northeast corner of the quadrangle is 26·5 miles west of Denver. Idaho Springs and Georgetown are the principal towns.

Topography.

Relief.—Situated upon the east slope of the Colorado or Front Range, the region is one of high elevation and of great relief. Massive Mount Evans (14,260 feet) is the highest peak in the quadrangle and is the center from which the main ridges radiate. The lowest elevation is 7,450 feet, in the valley of Clear Creek at the eastern edge of the quadrangle.

Drainage.— The streams are all mountain torrents of steep grade. The northern and central portions of the quadrangle are drained by tributaries of the South Platte River, including Clear Creek, its affluents, and the headwaters of Bear Creek. The southern portion of the quadrangle is drained by tributaries of the North Fork of the South Platte.

Evolution of topographic forms.—From a point commanding a wide view of this portion of the Colorado Range, three distinct topographic forms are recognizable; first, an ancient, mature mountainous upland ; second, V-shaped valleys incised in this upland ; and third, glacial cirques developed at the heads of some of the valleys, passing below into U-shaped valleys.

The mountainous upland over considerable areas in the east central and southeastern portions of the quadrangle has been but little modified by recent erosion, and remnants of the old surface are preserved on the crests of ridges throughout the quadrangle. The mountainous upland was an ancient land surface with about the same differences in altitude as those of the present surface. Dome-shaped mountains and smooth

ridges, however, existed where sharp peaks now are, and the valleys between were broader and less steep than those of the present streams. The drainage was dendritic and mature, the surface being adjusted to the structure of the underlying rocks and to the varying resistances to erosion of the different formations. Lakes did not then exist. The period at which this mountainous surface reached maturity is unknown, but it was probably in late Tertiary or early Pleistocene time.

After the old upland had been formed, deformation increased the gradient of the streams and they cut the present canyons, straight-walled and beset with pinnacles and rugged ribs of rock, in the old broad valleys. The valley-heads of these revived streams were afterward occupied by alpine glaciers of two distinct epochs. The glaciers eroded cirques, arêtes, U-shaped valleys, hanging valleys and lake basins, and by the deposition of lateral, terminal and ground moraines further modified the topography of the upper portions of the valleys.

General Geology.

Preliminary outline.—The rocks of the Georgetown quadrangle, with the exception of Pleistocene deposits and intrusive igneous rocks possibly of Tertiary age, belong to the pre-Cambrian complex of the Colorado Range. The oldest rocks, named in this article the Idaho Springs formation, are crystallines probably of sedimentary origin. These rocks have been most intricately injected by a series of holocrystalline igneous rocks, presumbly of pre-Cambrian age. So intense is injection that the rocks of the quadrangle may be considered an immense igneous breccia, exposure after exposure being encountered in which it is difficult to decide whether to map it as the older rock intruded by the younger, or as the younger rock with inclusions of the older. Some idea of the complexity of injection may be gained from the fact that in a distance of one mile, on the ridge between Silver Creek and Clear Creek, six formations alternate seventy-six times, or at the rate of one alternation to 70 feet. This is exclusive of a number of minor injections and inclusions.

That the injections of the pre-Cambrian igneous rocks took place at widely separated periods is shown by the different degrees of schistosity developed in the different formations. The granitoid habit of the igneous rocks and the character of their metamorphism indicate that the present surface during the whole period of pre-Cambrian intrusion was buried beneath deep masses of overlying rocks.

At three points near Chicago Creek, at elevations of from 9,200 to 10,100 feet, residual bowlders of red or brown silicified sandstone are rather abundant. Pebbles of the pre-Cambrian granites are contained. Outcrops of lithologically similar

sandstone occur on the North Fork of the South Platte one mile above Shawnee and at Pine Post Office on the same stream, both localities being south of the Georgetown quadrangle. The sandstone is lithologically like certain facies of the lower Wyoming of the foothills of the Front Range. It is possible that in Mesozoic time the quadrangle or a portion of it was submerged beneath the sea. In comparatively late, probably Tertiary time, dikes, sheets and stocks of siliceous and intermediate igneous rocks intrude the pre-Cambrian complex. Within the quadrangle there is no evidence that these ever reached the surface and formed flows, although they may have done so. Certain of these rocks are somewhat like some of the andesitic pebbles in the Denver formation* of the Denver Basin and others are somewhat similar to dikes which cut the Lower Wyoming formation near Boulder, Colorado. The evolution of the land surface and the two periods of Pleistocene alpine glaciation have already been mentioned.

The stratigraphic succession of the formations of the Georgetown quadrangle from the top down follows :—

Recent.—Alluvium
> Alluvial fan deposits
> Landslides
> Talus
> Travertine.

Pleistocene.—High Basin debris sheets (sheets of rock debris at the heads of non-glaciated streams ; indicating pre-glacial downcutting and late glacial filling).
> Later glacial deposits, including lateral, terminal and ground morainal deposits and overwash gravels.
> Gravels of terrace 25 feet above present stream channels.
> Gravels of terrace 55 feet above present stream channels (possibly pre-Glacial).
> Earlier glacial deposits, lateral and ground morainal deposits, and terminal morainal deposits in the adjoining Central City (Colo.) quadrangle to the north.
> Gravels of terrace 180 feet above present stream channels.

Tertiary.—? Intrusive igneous rocks of widely varying character in dikes, sheets and stocks.

Mesozoic.—? Sandstone residuals.

Pre-Cambrian.—Pegmatites and contemporaneous granite and granite-porphyry.
> Silver Plume granite.
> Rosalie granite.
> Quartz-monzonite. } Probably contemporaneous.
> Quartz-bearing diorite. }
> Gneissoid granite.
> Quartz monzonite gneiss.
> Idaho Springs formation (biotite-sillimanite-schists, biotite-schist and quartz-gneiss with lenses of silicate rocks).

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* Cross, W., U. S. Geol. Survey. Monograph XXVII, pp. 315-6.

Pre-Cambrian Rocks.

The Idaho Springs Formation.

Name.—The name Idaho Springs formation is applied to a series of interbedded, metamorphic, crystalline rocks, presumably of sedimentary origin, which are typically exposed in the hills surrounding Idaho Springs.

Distribution.—The formation is widely distributed over the quadrangle and there is scarcely a square mile in which it does not occur in areas of some size injected by igneous rocks or as shattered fragments included in them.

Petrography.—The Idaho Springs formation includes four intensely metamorphosed crystalline members, three of which, the biotite-sillimanite schist, the biotite-schist, and the quartz-gneiss, are interbedded with and grade into one another, while the fourth, the lime-silicate rocks, although interbedded with the others, appears only to grade into the quartz gneiss.

The biotite-sillimanite-schist is a foliated and often intensely crenulated, normally fine-grained black rock which on weathered outcrops has a rusty appearance. Biotite, quartz, feldspar and sillimanite are always recognizable megascopically, and muscovite, garnet, tourmaline and corundum are sometimes prominent. Sillimanite occurs in single rods and bundles of rods elongated in the plane of schistosity and these are cut by transverse fractures whose interstices are filled by biotite flakes. The biotite-sillimanite-schist is injected lit-par-lit by an ancient pegmatitic rock and it also often contains "eyes" of a more modern pegmatite, which will be referred to later.

Microscopic examination shows the texture to be that of a typical schist, the constituents all having a common parallel alignment, that of the biotite and muscovite plates and the sillimanite rods and bundles being very pronounced. The feldspars prove to be orthoclase and microcline with some plagioclase (albite or an acid oligoclase, rarely andesine) whose twinning is notably uneven. Quartz and orthoclase are often micropegmatically intergrown and in a rock which has suffered such profound metamorphism it seems probable that this texture originated during recrystallization. Sillimanite was produced largely at the expense of feldspar, and to a less extent of biotite. Sillimanite, in turn, sometimes alters to a kaolinitic material. Zircon, apatite and magnetite, rather constant accessory minerals, are only of interest from the fact that the last two often show a distinct orientation parallel to the plane of schistosity. Corundum, andalusite, and in part garnet, muscovite and tourmaline are clearly later than the major recrystallization of the rock, and from field relations are considered products of contact metamorphism.

The biotite-schist is differentiated from the type just described by a finer grain, a less perfect schistosity (continuous films of biotite being absent), by a medium or light gray color, and by the almost total absence of muscovite and sillimanite. Small segregations of magnetite surrounded by white halos from which they have abstracted all the ferromagnesian minerals are rather common.

The quartz-gneiss is a well banded, dense, vitreous rock varying in color from gray to brown, red or black. Quartz greatly predominates over all other constituents, which include most of those present in the biotite-sillimanite-schist. Under the microscope the gneiss is composed of intricately interlocking quartz lenses elongated parallel to the banding, the darker color of certain bands being due to magnetite cubes in discontinuous rows. The quartz-gneiss is exposed for a distance of one-half of a mile on Sugarloaf Peak.

Distributed in bands in the three types of the Idaho Springs formation already described, but particularly characteristic of the biotite-schist, are white ellipsoidal masses from one-half to four inches in length. These sharply bounded masses are flattened parallel to the plane of schistosity and in some instances are mashed to paper-thin sheets. They are composed of quartz and sillimanite, other minerals being present only in small amounts. The ellipsoidal masses occur widely over the area, but are particularly well developed on Chief and Pendleton mountains.

The silicate rocks of the Idaho Springs formation, which include many intergrading facies of widely varying composition and texture, grade into the quartz-gneiss. The facies are hornblende-augite-feldspar-gneiss, quartz-magnetite-gneiss, and several kinds of massive rocks. These massive rocks include coarse-grained aggregates of quartz, epidote and brown garnet in varying proportions with texture of a miarolitic pegmatite, and lime-silicate rocks composed of dominant calcite with smaller amounts of scapolite, grossular garnet, bottle-green pyroxene and quartz. The microscope shows calcite to be rather widely distributed and titanite to be a common accessory mineral in the silicate rocks of the Idaho Springs formation. Perhaps the most striking textural peculiarity is the presence of micropegmatitic intergrowths of epidote and zoisite, epidote and garnet and calcite and garnet, all clearly the products of recrystallization. The silicate rocks are well exposed in the vicinity of Alpine Peak.

Origin of the Idaho Springs Formation.—The Idaho Springs formation has been so greatly metamorphosed that all original textures have been destroyed. The lithologic variation across apparently bedded bands suggests a sedimentary

series, while the bands containing the ellipsoidal masses are most naturally regarded as conglomerates. The quartz-gneiss is present in such thick masses that it can scarcely be of pegmatitic or vein origin and probably represents intensely metamorphosed sandstone. The silicate rocks would in this interpretation of the origin of the formation represent calcareous sandstones and impure limestones, while the biotite-sillimanite-schist and biotite-schist would be metamorphosed shales and arkoses. The abundance of aluminum silicates in the series and the similarity to metamorphic rocks of known sedimentary origin strengthens the view of the supposed sedimentary origin of the Idaho Springs formation. This formation then may be regarded as an intensely metamorphosed series of shales, arkoses, sandstones, conglomerates and impure limestones.

Age.—The Idaho Springs formation is the oldest member of the pre-Cambrian series in the Georgetown quadrangle, and it forms the network into which the other formations were injected. The pre-Cambrian quartzite of South Boulder Creek (Colorado), described by Dr. C. R. Van Hise,[*] lies unconformably upon a granite which in the amount of mashing suffered and in lithological character somewhat resembles the Silver Plume granite later to be described. While the gap of 18 miles between Idaho Springs and South Boulder Creek has not been traversed, it is believed that the Idaho Springs formation is vastly older than Van Hise's pre-Cambrian quartzite.

Hornblende-Gneiss.

Distribution.—The hornblende gneiss has a wide distribution, especially in the southern portion of the quadrangle. It occurs in sheets and dikes in the Idaho Springs formation and may have formed surface flows.

Petrography.—The hornblende-gneiss is typically a rather fine-grained, well-banded rock in which white laminae of quartz and feldspar alternate with black or greenish-black layers of hornblende. Biotite is developed at the expense of hornblende where maximum movement has occurred, and along shear planes the rock passes to a biotite-hornblende-schist. Aggregates of hornblende or biotite, or both, give a porphyritic aspect to certain facies. Rather massive, fine-grained facies occur but are rare.

The microscope shows the banding to be partially a segregation into laminae of like minerals during recrystallization and partially a result of lit-par-lit pegmatitic injections. The parting parallel to the banding is largely due to the common

[*] U. S. Geol. Surv. Bull. 86, p. 325.

elongation of the ragged hornblende prisms, and to a some-what imperfect orientation of the hornblende cleavage. Horn-blende and biotite together form over one-half the rock, while plagioclase, usually labradorite, and smaller amounts of ortho-clase and quartz are the other essential constituents. Titanite, apatite, zircon and ilmenite or magnetite are accessories, and augite, epidote and pyrite are sometimes present. The more massive facies show traces of igneous texture, one rock from the west bank of Soda Creek, .8 of a mile south of Idaho Springs, being a metadiabase of ophitic texture in which the ferromagnesian mineral is hornblende.

Age.—The hornblende-gneiss cuts the Idaho Springs forma-tion and is therefore younger. The gneiss itself is cut by the other igneous rocks of the quadrangle. From the excellent schistosity developed over wide areas in this much meta-morphosed basic igneous rock, it is probably almost as ancient as the Idaho Springs formation.

Quartz-Monzonite-Gneiss.

Distribution.—The quartz-monzonite-gneiss is widely dis-tributed, particularly in the central and southern portions of the quadrangle. The largest area is on Paines Mountain.

Petrography. — The quartz-monzonite-gneiss is a gray, medium-grained gneissic rock which is normally porphyritic. The gneissic structure is due to the segregation in alternating bands of quartz and feldspar and of biotite and hornblende. The parting parallel to the gneissic structure is seen, under the microscope, to be due to the parallel orientation of biotite blades through recrystallization and to a slight elongation of the horn-blende individuals parallel to the schistosity. The orientation of the hornblende is probably largely due to the more vigorous attack by solutions upon those hornblendes of the monzonite at right angles or highly inclined to the plane of developing schistosity than those whose elongation was originally parallel to it. Apatite, zircon and titanite in certain instances show marked parallelism to the gneissic structure, indicating the extreme recrystallization to which the rock has been subjected.

Rudely ellipsoidal white porphyritic striated feldspar crystals lie in the medium-grained schistose aggregate of biotite, feld-spar, hornblende and quartz. These feldspars are aligned parallel to the gneissic structure and have suffered the same deformation as the smaller constituents of the rock. The quartz-monzonite-gneiss near West Geneva Creek contains also pink microcline phenocrysts, sometimes 2 inches long, often twinned according to the Carlsbad law. These have perfect crystal outlines with their longest axis at right angles to the gneissic structure even in the most metamorphosed groundmass.

Microscopic examination shows that they are uncracked while the feldspars of the groundmass are fractured. They are without much doubt of metamorphic origin and were formed after the rock became a gneiss. In certain exposures these microcline feldspars have been mashed by later deformation into ellipsoids and even into ribbon-like masses.

The original rock was a porphyritic quartz-monzonite, in some facies of which the alkali feldspar is so subordinate that the rock becomes a granodiorite. Plagioclase is more abundant than the other essential constituents, quartz, microcline, orthoclase, biotite and hornblende, and of these latter any one may predominate. Hornblende, however, is not present in some slides. The plagioclase in the "groundmass" and the ellipsoidal porphyrite crystals is either oligoclase or andesine. The porphyritic plagioclase is characterized by zonally arranged magnetite cubelets, and by rods, hexagonal plates, and dots, probably of hematite. Micropegmatitic intergrowths of quartz and each of the three feldspars occur along the borders of the grains. The alterations of biotite are interesting in that when hornblende is present epidote is the major alteration product, while, on the other hand, when hornblende is absent, chlorite or muscovite accompanied by rutile needles is the alteration product. The rock is characterized by the unusual abundance and coarseness of the accessory minerals, magnetite, titanite, apatite, zircon and pyrite. Pyrite is usually surrounded by or intergrown with magnetite.

Age.—The quartz-monzonite-gneiss intrudes and includes fragments of the Idaho Springs formation and the hornblende-gneiss. It is in turn cut by the gneissoid-granite and the igneous rocks which succeed it. While in some exposures its age relations with the Idaho Springs formation, the hornblende-gneiss and the gneissoid-granite are clear, the quartz-monzonite-gneiss usually contacts with these in a sharp line with parallel gneissic structure. South of Naylor Lake some exposures occur in which the Idaho Springs formation and the quartz-monzonite-gneiss seem to grade into one another, apparently as the result of the absorption of the schist by the monzonite when injected.

The close resemblance in mineral composition of the quartz-monzonite-gneiss to the quartz-monzonite is striking, forming a good example of the repetition of a monzonite injection.

Gneissoid-Granite.

Distribution.—Stocks and dikes of gneissoid-granite injecting the formations already described are widely distributed in the quadrangle. The gneissoid-granite covers large areas in the southwestern corner of the quadrangle and numerous

smaller areas occur east of Georgetown and west of Idaho Springs.

Petrography.—The gneissoid-granite is a fine to even-grained granite, more or less gneissoid, which is gray when fresh, and flesh pink to yellowish brown when weathered. Feldspar, quartz and biotite are visible to the naked eye, although the last is sometimes practically lacking. Muscovite plates, which reach a maximum diameter of one-half of an inch and enclose the other constituents poikilitically, are locally prominent. Magnetite, pink garnet, and sillimanite are occasionally visible.

The quartz under the microscope is of the normal granitic type except for the abundant inclusion in many of the grains of needle-like opaque microlites. Orthoclase and microcline greatly predominate over oligoclase or a related acid plagioclase. Micropegmatitic intergrowths of each of the feldspar species with quartz occur. The content of microcline, often microperthitic, increases with increase in the recrystallization to which the rock has been subjected, and, in consequence, is absent in some slides and is the predominant feldspar in others. While some microcline may be original, the larger portion is certainly of secondary origin. It occurs in wedges and hook-like masses which sometimes separate quartz or orthoclase fragments of similar orientation ; again, elongated areas are arranged end to end as if forced into planes of weakness. In other cases altered plagioclase or orthoclase grains are dotted by fresh areas of microcline similarly oriented and elongated parallel to the cleavage of the orthoclase or the albite twinning of the plagioclase. The host is often fractured and unshattered microcline bridges the crack, while a narrow rim of orthoclase or plagioclase next the microcline is fresh, in contradistinction to the altered feldspar of the main mass. While clearly later than the other feldspars, the time at which this microcline formed is unknown.

Biotite has no unusual features. The poikilitic muscovite plates, already mentioned, grade into sericitic shreds, the alteration product of the feldspar, and are themselves secondary. Sillimanite, which has also been previously mentioned, occurs in parallel aggregates in the center of muscovite plates and may be one of its alteration products. The accessory minerals constantly present are zircon, apatite and magnetite, while ilmenite and garnet sometimes occur.

The granite magma when injected must have been very fluid since it inserted itself between the folia of the earlier gneisses and replaced in a marked degree inclusions of the Idaho Springs formation. Dark bands in scroll-like patterns of more basic granite preserve the outlines of schist inclusions,

while lace-like shreds of biotite often suggest the forms of original inclusions now almost totally absorbed. Similar phenomena are referred to at greater length under the pegmatites and associated granites and granite-porphyry. (See page 386.)

The rock varies, often in the same exposure, from an almost massive to a banded rock in which quartz and feldspar layers are separated by discontinuous sheets of aligned biotite plates. Microscopic examination shows that the gneissoid structure is due largely to recrystallization and partially to granulation. The more gneissoid facies occur about the border of large areas of granite or around gneiss inclusions.

Age.—The gneissoid-granite injects and encloses portions of the formations already described and is, in turn, included in and cut by the quartz-monzonite and the succeeding igneous formations.

Quartz-Monzonite.

Distribution.—A large irregularly shaped batholith of quartz-monzonite, which disappears beneath the older rocks at rather low angles, occupies the central, north central and east central portions of the quadrangle. Minor intrusive masses are rather widely distributed.

Petrography.—The quartz-monzonite is a gray to bluish-gray, medium-grained, granular rock, often more or less porphyritic in habit. Macroscopically, feldspar, quartz, biotite and hornblende are essential constituents, while magnetite and titanite are accessories. In the porphyritic facies rather good crystals of pink microcline feldspars, which are usually twinned according to the Carlsbad law, reach a maximum length of 1 inch. A matted coating of tiny epidote crystals occurs rather characteristically along many joint fractures.

The texture upon microscopic examination proves to be hypidiomorphic granular, rather even-grained in the non-porphyritic and uneven in the porphyritic. With variation in the relative amount of the alkali and lime-soda feldspars, the rock varies from an acid to a basic quartz-monzonite with granodioritic affinities. The essential minerals in the order of their abundance are oligoclase or andesine, microcline often microperthitic, quartz and biotite, and orthoclase and hornblende if present. The accessory minerals, magnetite, apatite, pyrite and zircon, are particularly abundant. The order of the solidification is normal, although the period of the separation of biotite overlapped that of titanite, and it in turn was overlapped by that of plagioclase. Quartz is micropegmatitically intergrown with each of the feldspar species. Needle-like opaque microlites are characteristic interpositions in quartz, and magnetite enbelets and hematite in hexagonal plates occur

in plagioclase. Apatite grains in quartz are sometimes deeply embayed and resemble the familiar corroded quartz phenocrysts of rhyolite.

Near the borders of the batholith a rude gneissoid structure is developed which microscopic examination proves to be in part original and due to flow orientation of the phenocrysts and biotite in a common plane, and in part a secondary structure due to granulation and slight recrystallization.

Age.—Field observation shows that the quartz-monzonite is younger than the gneissoid granite and older than the Rosalie granite. Its relation to the quartz-bearing diorite will be discussed under that formation.

Quartz-Bearing Diorite.

Distribution.—Quartz-bearing diorite occurs in small stocks and dikes which are largely confined to the northern one-fourth of the quadrangle and are particularly abundant south of Idaho Springs and northeast of Georgetown.

Petrography.—The quartz-bearing diorite is a medium to coarse-grained, rather uneven, granular rock, composed of grayish-white striated feldspar, greenish-black hornblende, and a little quartz. Biotite plates, which reach a maximum diameter of 2 inches, poikilitically enclose the other constituents at some exposures. Epidote occurs in matted films on joint faces and in rude pseudomorphs after hornblende and biotite in the rock mass.

Under the microscope the texture is allotriomorphic or with the partial development of plagioclase individuals hypidiomorphic granular. The order of crystallization of the minerals is normal, except that biotite in some cases solidified simultaneously with orthoclase and quartz. Plagioclase varies from andesine to bytownite, a basic labradorite being the most common species. It is characterized, as are quartz and orthoclase in a less degree, by a vast number of minute tabular and circular interpositions which are black and opaque or clove-brown and translucent. Plagioclase is altered more or less completely to sericite, zoisite and quartz. Green hornblende, in elongated grains, often twinned parallel to 100, is usually riddled with blebs of the other constituents. Quartz, which with orthoclase forms wedges between hornblende and plagioclase, is micropegmatitically intergrown with each species of feldspar, biotite and hornblende. Diallage, filled with the opaque inclusions characteristic of the species, and surrounded by secondary cores of hornblende, is a rather rare constituent, although its presence is not surprising in view of the basic nature of the plagioclase. In the alteration to hornblende the dark inclusions of the diallage disappear, their substance

apparently being absorbed in the production of the hornblende. Large poikilitic plates of biotite have already been mentioned as characterizing some outcrops and small biotite blades are rather constant constituents. Biotite is also secondary to hornblende. The accessory minerals include magnetite, ilmenite, pyrite, and large and abundant crystals of apatite. Zircon and rutile are less common. Apatite crystals enclosed in feldspar have embayed borders as if magmatically corroded.

Diorite upon the borders of the intrusive masses is sometimes mashed to a gneissoid rock partly through recrystallization and partly through granulation. Hornblende and feldspar are segregated into lenses rudely elongated parallel to the parting, and blades of biotite and a colorless amphibole, probably anthophyllite, are developed parallel to the gneissic plane. The albite twins of the plagioclase are sometimes aligned parallel to the gneissic structure, while the undulose extinction of orthoclase passes into the " gitter " structure of microcline, the latter mineral being clearly secondary to the former and occurring solely in mashed facies of the diorite.

Associated with the diorite and linked to it by some gradational facies are fine-grained, granular rocks of greenish black color which are perhaps best styled hornblendites. Under the microscope some of these, with the exception of minor quantities of plagioclase, quartz and accessory minerals, are formed of green hornblende ; others are made up of large irregular green hornblende individuals enclosing poikilitically laths of biotite, grains of enstatite showing schillerization and partial columns of a colorless amphibole, probably anthophyllite. In some slides this amphibole, which alters to talc, is as abundant as hornblende. Still another of these rocks is in one portion of the slide composed entirely of hornblende and in another largely of white monoclinic pyroxene near malacolite. These fine-grained rocks have suffered considerable recrystallization and their original character is in doubt.

Age.—The quartz-bearing diorite bears the same structural relations to the other formations of the Georgetown quadrangle as does the quartz-monzonite. The contact of the two formations is nowhere well exposed in the quadrangle, although intermediate types indicate that the two may be variants of the same magma. Near St. Mary's Lake, north of the Georgetown quadrangle, the two appear at some places to grade into one another and in others the diorite clearly cuts the quartz-monzonite. The two are believed to be differentiation products of the same magma, the quartz-bearing diorite on the whole being slightly younger.

Rosalie Granite (Biotite-Granite).

Distribution and Name.—Exposures of the Rosalie granite are confined to the southern portion of the Georgetown quadrangle. The type locality is that in the southeast corner of the quadrangle on Deer and Elk creeks, where the granite weathers into dome-shaped hills and gentle valleys, covered by mushroom-like forms of granite. A second area forms the ridge between Mount Evans and Mount Rosalie and the granite is named from the latter peak.

Petrography.—The Rosalie granite is a coarse-grained, massive, granular rock whose predominant constituent is a salmon-pink microline often showing Carlsbad twinning. These feldspars, which vary in length from one-half to two and one-half inches, are rudely tabular in form and are separated from one another by ramifying bands of quartz, feldspar, biotite and magnetite, all of medium size.

Under the microscope the texture is uneven and hypidiomorphic granular. The essential constituents of the rock began to separate in the order usual in granites, but the periods of separation of all overlapped, and in consequence each constituent encloses blebs and partial crystals of the others. Magnetite in some cases separated simultaneously with quartz and feldspar. The minerals in the order of their abundance are microcline, quartz, orthoclase, oligoclase and biotite. Microcline, often microperthitic, contains hexagonal plates, dots and rods of hematite. These interpositions also occur frequently in plagioclase and less frequently in quartz, and in association with them in the latter mineral are opaque hair-like inclusions. Quartz at its contact with the various feldspar species and biotite forms micropegmatitic intergrowths. Zircon, apatite and magnetite are constant accessory minerals, while muscovite, titanite and pyrite are less frequent. With the exception of minor granulation, the Rosalie granite is but little deformed.

Age.—The Rosalie granite cuts the quartz-monzonite and in turn is intruded by dikes of apparently the Silver Plume granite described below.

Silver Plume Granite (Biotite-Granite).

Distribution and Name.—Stocks, dikes and irregular intrusive masses of the Silver Plume granite are especially well developed in the vicinity of Georgetown, north of Meridian Hill and on Alps Mountain, but occur widely distributed throughout the quadrangle except in the extreme northeast and southeast corners. It forms the south wall of the Clear Creek canyon at the mining town of Silver Plume and it derives its name from this village.

Petrography.—The Silver Plume granite is a medium-grained hypidiomorphic granular rock which by the increase in size of the pinkish-white porphyritic feldspars (Carlsbad twinned microcline) and the decrease in size of the encircling quartz feldspar and biotite individuals passes near the contact with older rocks into granite-porphyry. Some of the smaller dikes are wholly of the granite-porphyry facies. The granite at some localities is notably rich in biotite and is then dark gray in color mottled by the pink feldspars; at other localities the biotite content is normal and the rock is pinkish-gray.

Under the microscope the essential constituents of the granite in descending order of abundance are alkali feldspars, quartz, biotite and oligoclase and oligoclase-albite. Original muscovite is lacking in some slides, in others it is associated with biotite, and in certain rare instances is the only mica present. Muscovite also forms large plates which poikilitically enclose quartz globules; these plates grade into sericitic shreds secondary to orthoclase and are themselves evidently secondary to feldspar. The order of the consolidation of the minerals from the magma is normal, although the periods of separation somewhat overlapped each other. Quartz is of chief interest from the constant presence in it of thread-like opaque inclusions; these are less abundantly present in feldspar. Of the alkali feldspars, microcline, often with microperthitic bands, predominates in some slides and is lacking in others. While sometimes occurring in secondary veins in orthoclase and oligoclase, it is in the main an original constituent. Among the accessories zircon and apatite are abundant, magnetite rather common, and ilmenite, pyrite, titanite and rutile rare.

The phenocrystic feldspars near the contacts of the granite mass are arranged in well defined planes which follow the sinuosities of the contact. The rock has not been recrystallized and the parallel orientation and the poorly defined cleavage consequent thereto are original structures due to movements in the magma prior to final solidification. Secondary gneissic structure has only been formed over small areas subjected to unusual dynamic movement.

Age.—The Silver Plume granite cuts all of the formations previously described and with the exception of the pegmatite and associated granite and granite-porphyry is the youngest member of the pre-Cambrian formations.

Pegmatite and Associated Granites and Granite-Porphyry.

Distribution.—These rocks, the youngest of the pre-Cambrian formations, nowhere form large areas, but are, on the other hand, present in small bodies in almost every outcrop in the quadrangle.

Pegmatite. — While each of the granular igneous rocks already described grades into a pegmatite, the pegmatite of most interest is that which intrudes or grades into the youngest pre-Cambrian granites and granite-porphyry. In a single exposure the pegmatite and granite may grade into one another at one point and at another the rocks may be sharply differentiated, the pegmatite as a rule being younger.

Salmon-pink feldspar, either orthoclase or microperthitic microcline, is usually the predominant mineral of the pegmatite. A greasy-gray, acid plagioclase is restricted in its distribution to pegmatite dikes in the quartz-monzonite. Slightly smoky quartz, which microscopic examination shows to contain abundant opaque thread-like interpositions and myriad fluid inclusions, is always present and, in the tiny banded quartz apophyses which are given off from the large dikes, it is the only constituent of the pegmatite. Biotite is more common than muscovite and the two micas characteristically occur in separate bodies of pegmatite, although they are sometimes associated in the same masses and in rare instances a core of biotite is surrounded by a muscovite border. An interesting form of pegmatite is composed of diamond-shaped muscovite plates up to 1 inch in diameter embedded in quartz, each mineral being present in nearly equal amounts. The rock is closely allied to beresite from the Ural mountains and to a rock described by Mr. J. E. Spurr from Belmont, Nevada.[*]

Magnetite is a widely distributed constituent and in some cases forms over one-third of the pegmatite mass, which in consequence becomes a lean iron ore. Magnetite occurs in octahedral crystals of a maximum diameter of 4 inches or in irregular aggregates up to 6 inches across. It is in some instances the only femic mineral of the pegmatite, but is usually associated with biotite and less often with muscovite.

Black tourmaline is a widely distributed but never abundant mineral in the pegmatites. It occurs either in crystals embedded in quartz or orthoclase, in micropegmatitic intergrowths with quartz and feldspar, in feldspar metasomatically replacing it or in felts along cracks in the pegmatite. Hence while tourmaline usually solidified prior to quartz and feldspar, it sometimes solidified contemporaneously with them and rarely after them. The femic mineral usually associated with tourmaline is muscovite, both of which minerals from other localities usually contain some fluorine. Red garnets are locally very abundant in the more siliceous pegmatites. Rare constituents include allanite, apatite, hornblende, beryl and a quartz-feldspar pseudomorph, probably of spodumene.

[*] This Journal, vol. x (1900), p. 351.

The pegmatite dikes are sometimes rudely banded, quartz being usually segregated in the center. Such banded dikes along their strike pass into coarsely granular pegmatite. The various textures of the pegmatites and the granular texture of the granite sometimes grade into one another in a single outcrop 100 feet in diameter, and in consequence the physical conditions which in some cases determined the production of one texture could have varied little from those which produced others.

While typically massive the pegmatites are locally mashed into gneisses, partly by granulation and partly by recrystallization. Quartz-magnetite pegmatite was particularly subject to recrystallization, producing a quartz-magnetite-gneiss in which eyes and thin bands of magnetite lie in quartz. The pseudomorphous gneissic structure sometimes present in pegmatite surrounding schist inclusions will be described later.

The magma appears to have varied from a comparatively dry magma from which the granites solidified, through molten masses rich in water from which some of the pegmatites solidified, to a body so saturated with water that the banded quartz veins deposited by it resemble water-deposited veins.

The extreme fluidity of the magma which deposited the pegmatites is indicated by a number of characteristics of that rock. The pegmatitic magma or fluid sought out the smallest cracks and crevices and deposited its material therein, and the presence of pegmatite in small masses in nearly every outcrop in the quadrangle indicates that the older rock masses were thoroughly saturated with the pegmatitic material. That the process was one of saturation rather than ordinary igneous injection is shown by the presence in the biotite-sillimanite-schist of the Idaho Spring formation of isolated lenticular " eyes " of pegmatite similar to that of the larger pegmatite masses. The constituents of these " eyes " are absolutely uncrushed and cannot be considered segments of a sheared pegmatite dike. The pegmatites further absorbed considerable masses of this schist and from the center of the larger inclusions gradations occur in certain instances from pure schist to schist containing thin bands of pegmatite along its folia, thence to pegmatite in which only a few scroll-like figures of darker pegmatite faintly suggest the crenulations of the almost totally absorbed schist, and lastly to pure pegmatite. In the latter, however, a fair parting is sometimes preserved, indicating that the structure of the schist is partially preserved by metasomatic replacement, and the parting may be considered a pseudomorph of that of the schist.

A further proof of the extreme fluidity of the pegmatite magma is the influence upon the mineral composition of the

pegmatite exerted by the rock in which the pegmatite was injected. Biotite is the characteristic femic mineral of pegmatites which inject the granites already described, the quartz-monzonite-gneiss, the quartz-bearing diorite, and the hornblende gneiss, although hornblende is often the typical dark mineral of pegmatites in the last two formations. Muscovite is the typical femic mineral of pegmatite dikes in the Idaho Springs formation, and 98 per cent of the occurrences are in this formation. The pegmatite dikes in quartz-monzonite areas are characteristically without femic minerals and often contain, instead of an alkali feldspar, a soda-lime feldspar. Magnetite alone of the abundant femic constituents of the pegmatites is not influenced by the rock intruded and was evidently an original constituent of the pegmatite magma. In areas of unusually complex injection where the Idaho Springs formation and the granular igneous rocks are in approximately equal development, both biotite and muscovite are often associated with one another. Where the pegmatite passes from a fairly large area of granite to an area of the Idaho Springs formation, the substitution of muscovite in place of biotite is usually coextensive with the boundaries of the two formations. Where, on the other hand, the pegmatite has traversed a single formation for a long distance and then passes to a second formation, there is a distinct "lag" in the introduction of the mineral characteristic of the pegmatite in the second formation. This is well seen on the north side of the quartz-monzonite batholith where the quartz-feldspar pegmatite extends several hundred yards into the biotite-sillimanite-schist of the Idaho Springs formation, before muscovite, the characteristic mineral of pegmatites in that formation, is present.

A chemical discussion of these observations is impossible, since the composition of the pegmatite is unknown. It is indeed probable that the pegmatitic substances left the cooling mass of granite at widely varying times and at their birth probably varied in chemical composition. Field evidence, however, indicates that the pegmatitic substances prior to solidification abstracted sufficient material from the enclosing rocks to materially modify their chemical composition. The lag already mentioned indicates that the change in composition did not occur immediately upon entering a formation, but only after the pegmatitic magma had traversed it for some distance.

The Granites and Granite-Porphyry.—The granites associated with the pegmatites are massive granular rocks characterized by a fine or medium-grained allotriomorphic texture. While the granites intergrade, not only with pegmatite but with one another, certain types are rather well defined.

In the northern part of the quadrangle a white medium-grained muscovite-granite, which often has pink garnet as an abundant accessory, grades into muscovite-pegmatite. North of Georgetown the granitic rock is a gray muscovite-bearing alaskite in which quartz predominates over feldspar. In the central or southern parts of the quadrangle a pink or pinkish gray fine-grained biotite-granite predominates. The same granite in the southeast corner of the quadrangle is medium-grained.

Under the microscope the order of crystallization is normal except that the rare accessory mineral titanite in certain instances lies in irregular grains between quartz and feldspar and therefore separated simultaneously with them. Microcline, usually with microperthitic bands, is the predominant constituent of most of the granites. Orthoclase and an acid plagioclase, oligoclase-albite, are also usually present. Quartz forms micropegmatitic intergrowths with the three species of feldspars and is further characterized by abundant thread-like inclusions. Biotite and muscovite are in no way peculiar although original muscovite is more widely distributed than in any other granite of the quadrangle. Zircon, magnetite and apatite are common and abundant accessory minerals, while titanite, garnet and fluorite sometimes occur.

In the southeastern portion of the quadrangle pegmatite and the associated granite grade into pink granite-porphyry. The groundmass is a fine-grained microgranitic aggregate of microcline and quartz, and in some facies orthoclase and magnetite and in others biotite. The phenocrysts include pink tabular microcline and orthoclase, rounded slightly smoky quartz, biotite and sieve-like hornblende crystals. Titanite and magnetite are accessory. Fluorite is a rather constant accessory of the granite-porphyry and the associated granite. It forms transparent colorless wedges, dotted by deep purple spots, between quartz and feldspars, which in contact with it have slightly rounded faces. Fluid inclusions are fairly abundant. Fluorite occurs in an area ten miles distant from known mineralized veins, and from this and the uniform distribution of the mineral in the slides examined it is believed to have been deposited in minute cavities in the rocks by pneumatolytic action.

Similarity of the Pre-Cambrian Granites.

Although no chemical analyses of the rocks of the Georgetown quadrangle have been made, microscopic examination shows a marked mineralogic similarity in the granites, the intrusions of which were separated in every case by considerable time intervals and in one case by the intrusion of more

basic rocks.   The granites are characteristically biotite-granites in which microcline, which undoubtedly is in some cases a product of recrystallization and in others of deformation, is usually the predominant feldspar.   Orthoclase in turn predominates over oligoclase or oligoclase-albite.   Microcline throughout the series is characterized by microperthite bands which are less common in orthoclase.   The presence in quartz of abundant thread-like inclusions of undetermined nature is also characteristic.   Biotite appears to contain titanium, since rutile or some other titanium mineral is a by-product of its alteration.   Original muscovite, except in certain of the pegmatitic granites, is present in negligible amounts.   Of the accessory minerals, apatite, zircon and magnetite are constantly and rather abundantly present.   The granites of the Georgetown quadrangle present a rather interesting example of the repeated injection of a granitic magma or magmas of rather constant composition.   Mr. E. B. Mathews[*] emphasized the close chemical and mineralogical similarity of the granites of the Pike's Peak (Colorado) quadrangle, which lies at the south end of the Colorado Range.   The granites of this region and those of the Georgetown quadrangle possess many characteristics in common.

[*] Journal of Geology, vol. viii, pp. 214–240.

Art. XXXV.—*Lower Paleozoic Formations in New Mexico;** by C. H. Gordon and L. C. Graton.

Students of New Mexico geology have hitherto generally agreed in asserting the absence of the older Paleozoic forma-tions in that region. Endlich,[†] followed by Clark,[‡] considered certain limestones and quartzites occurring at the base of the sedimentary section of Lake Valley, Sierra County, to be Silurian, and some quartzites east of the Sandia Mountains, in Sandoval and Bernalillo counties, have been regarded, probably erroneously, as Cambrian.[§] With these and possibly a few other exceptions, it has commonly been stated that rocks rep-resenting the Lower Paleozoic periods are wanting in the Territory, and that the Carboniferous formations rest directly on granites, gneisses and schists, which are generally considered to be pre-Cambrian, although in some cases the granites are thought to be of later age. This prevailing view has recently been summarized as follows :

"At present there is no reliable evidence that any of the Lower Paleozoic beds are represented within the limits of New Mexico. The great Cambrian, Silurian, Ordovician and Devonian systems which are so extensively developed in other parts of the American continent have thus far failed to be observed in the southern Rocky Mountain region."[‖]

Herrick states that in southwestern New Mexico occur strata supposed to be older than the Burlington " some of which have been referred to the Devonian (Hamilton)," but adds that "as far north as Socorro County the stratified rocks overlying the granite have revealed no remains indicating an earlier age than the Carboniferous, and the writer knows of no positive datum representing anything older than the Coal Measures.[¶]

During the past season a reconnaissance study of the mining districts of New Mexico was carried on by the U. S. Geologi-cal Survey under the direction of Mr. Waldemar Lindgren. In the prosecution of this study many facts of stratigraphic significance were obtained, and it soon became evident that in certain places pre-Carboniferous strata are present. Although

the studies of these rocks are yet incomplete and their geographical distribution or extent has not been fully defined, sufficient data are at hand to show that resting upon the preCambrian rocks is a series of beds of a maximum thickness of over 2,000 feet which are representatives of the Cambrian, Ordovician, Silurian and Devonian systems, and that these rocks are present along a belt which crosses Grant, Sierra, and Luna counties, and extends from the east side of the Rio Grande westward beyond the Arizona line and probably connects with the similar formations of the Clifton copper district of Arizona.* The localities where these rocks are best exposed are in the Caballos Mountains near Shandon, in the Hillsboro and Kingston mining districts along the east side of the Black Range, in the vicinity of Cook's Peak and the Florida Mountains, and just west of Silver City. Rocks which unquestionably belong in the same systems occur in the Georgetown and Lone Mountain mining districts, and probably in the Telegraph district.

Cambrian.—This system is known to be present in the Bisbee district in southeastern Arizona, and in Texas, and recently Mr. G. B. Richardson of the U. S. Geological Survey has found Cambrian fossils in the Franklin Mountains just south of the New Mexico line.† Rocks which have been referred to this system are known in the Clifton district in Arizona, but heretofore there has been no final proof of the existence of Cambrian formations in northeastern Arizona nor in New Mexico.

The Cambrian rocks in southwestern New Mexico consist of massive and flaggy quartzites, indurated sandstones, sandy shales, all more or less ferruginous, with occasional beds of siliceous limestone. These strata, which vary from 50 to 1,100 feet in thickness, are separated from the underlying preCambrian gneisses and schists by a great erosional unconformity. In the eastern part of the area where these quartzites have been found there appear to be certain well-marked divisions of the rocks. The lowest consists of a coarse, dark brown or red ferruginous quartzite, the lowermost beds of which are conglomeratic. As observed in the Florida Mountains, this division has a thickness of about 60 feet. Overlying these dark quartzites in some places, and replacing them in others, is a white quartzite, sometimes shaded pink, which varies from a few to 75 feet in thickness. In the Shandon district at the base of the Caballos Mountains this white quartzite is only 4 or 5 feet thick, and in places rests directly on the granite. The maximum development of the white quartzite was observed

* Lindgren. W., Clifton Folio, U. S. Geological Survey, No. 129.
† Science, vol. 23, No. 581, p. 267.

in the Florida Mountains, where the uppermost beds alternate with thin beds of limestone, forming a transition to the limestones above. The highest division is a series of beds having a maximum thickness of 40 feet, composed of dark brown and green, sandy shales and thin-bedded quartzites. These latter rocks are well developed in the Caballos Mountains near Shandon, where in certain layers they contain linguloid shells which have been identified by Dr. Charles D. Walcott as *Obolus* (*Westonia*) *stoneanus* Whitfield, a form of the Upper Cambrian, found at Newton, N. J., and in the St. Croix sandstone of Wisconsin. In no one place were all three divisions observed, and it may be the white quartzite is but a local phase of one of the other divisions.

Near Silver City these rocks have a thickness of nearly 1,100 feet. They consist mostly of quartzites of dark red, brown or black color due to iron stain, which contain three beds of cherty limestones 30 to 75 feet thick, and near the top and near the bottom a thin band of shale; a few feet at the very base is a conglomerate.

Ordovician.—A series of limestones, for the most part massively bedded and having a maximum thickness of 1,200 feet, rests conformably upon the Cambrian rocks. The thinly bedded cherty members of the lower portion of this series suggest resemblance to Abrigo limestone of the Bisbee district,[*] which is Middle Cambrian, but some poorly preserved organic remains found about 100 feet above the quartzite in the Silver City section are regarded by Mr. E. O. Ulrich of the U. S. Geological Survey as belonging certainly in the Lower Ordovician. At this place, where the upper limit is not definite, the limestones considered to be Ordovician are about 770 feet thick, consisting at the bottom of 265 feet of cherty limestone overlain by 185 feet of alternating narrow bands of limestone and chert, and succeeded by about 330 feet of gray or pinkish, fine-grained, siliceous limestone.

In other localities the limestones of the lower portion of the series are notably crystalline, and near the axis of the Black Range at Kingston and in the Carpenter district they are essentially marbles, often mottled blue and white. In these crystalline beds no fossils have been found. The upper members are in part composed of thin cherty beds. A stratum of quartzite from 3 to 5 feet thick is present in places near the top of the series, but is not persistent.

Fossils are fairly abundant in the upper part of these limestones. Corals are most common, and at Silver City brachio-

[*] Ransome, F. L., Prof. Paper, U. S. Geol. Surv., No. 21, p. 33.

pods are plentiful just above the most cherty beds. Both the corals and the brachiopods belong in the Richmond division of the Upper Ordovician.

The character of transition of the rocks of this system into those above is not yet wholly established. Locally the upper portion of the limestone series is coarsely brecciated, the beds being composed of blocks of various sizes up to 10 feet in breadth and the spaces between filled with calcareous material derived from the disintegration of the same beds. The disturbance appears in some instances to have involved a bed of quartzite or gritstone, fragments of which occur along with those of the limestone.

In Sierra County the surface of the limestone is undulating or billowy, and over considerable areas the topmost layer is altered to a highly siliceous rock, in places quartzose and drusy, in others constituting a flint breccia. In some cases the silicification and brecciation was observed to extend along cracks downward into the lower limestone beds, which fact, taken in connection with other facts touching the nature and occurrence of the phenomena, warrants the conclusion that the silicification has been effected by hot waters coming up from below and spreading out along the contact with the overlying impervious shales. The silver deposits at Kingston and in adjoining districts occur in the upper part of this limestone.

Whether the coarse brecciation and billowy surface represent a kind of unconformity caused by a retiring of the waters following a period of limestone formation, as suggested by Chamberlin,[*] or whether it is due to underground solution, crustal movement, or to some other cause, we are as yet unable to decide.

At Silver City a perplexing feature of different character arises. In the 870 feet of limestones which overlie the Cambrian quartzites, there is no visible stratigraphic break; and in the upper 420 feet, no lithologic difference has been noted, yet in the lower part of this 420 feet are found Ordovician fossils, while near the top a Silurian fauna is present. It should be said that the rocks at this critical point are not so well exposed as they are at most places in the section, and that the original character of the limestones is somewhat obscured by impregnation of ore-bearing minerals and by their decomposition products. It may be added that in the Clifton district Devonian strata rest with apparent conformity on the Ordovician limestones, while in the Bisbee region both Ordovician and Silurian are absent although there is no structural break in the stratification.

[*] Geology of Wisconsin, vol. 1, pp. 138–140.

Silurian.—The general position of the rocks belonging in this system, which have been identified only in the Silver City region, and at Lake Valley, has already been stated. They occur at the upper part of a series of limestones which throughout the greater portion contain Ordovician fossils. In this upper portion, near Silver City, close to the top, are found pentameroids and other brachiopods which Mr. Ulrich places in the Silurian and regards as the equivalent of the Silurian horizon found in the Franklin Mountains near El Paso. These rocks, as has been said, differ little if any in appearance from Ordovician rocks underlying, and hence the bottom limit of these Silurian rocks is not definite. Since corals considered to be Ordovician have been found within a hundred and fifty feet of the top of this limestone series, an arbitrary thickness of 100 feet is assigned to the Silurian. It is possible that small thicknesses of Silurian strata occur at other places in the territory and have been overlooked; but it is more reasonable to suppose that they are absent, and the Silver City region thus stands as the only locality of Silurian rocks in western New Mexico or eastern Arizona. The silver deposits of Chloride Flat, near Silver City, are situated in the topmost portion of this limestone.

Devonian.—Where Silurian rocks are absent, Devonian strata rest directly upon the Ordovician limestones. In some places there is a well-marked unconformity at this horizon but in others no unconformity is apparent. Where the Devonian rocks overlie the Silurian at Silver City, the succession of sedimentation seems to have been perfect. The formation, which has a maximum thickness of 465 feet, consists almost wholly of shales and presents two well-marked divisions, the lower composed of black carbonaceous fissile shales, and the upper of blue shales which weather to a buff or brownish red color, and are more or less calcareous. In Sierra County the black shales are from 100 to 200 feet thick, but at times vary greatly in thickness within short distances due to the uneven character of the limestone surface upon which they rest. No fossils have been discovered in these lower or black shales. At Lake Valley they have heretofore been included in the Lower Carboniferous.* In the same region the upper or blue shale division has a thickness of 50 to 100 feet and in places is highly fossiliferous, notably at Kingston and 2 miles east of Hillsboro, where the beds contain brachiopods in profusion. Fossils were also known to occur between the Santa Rita and Georgetown districts. Dr. George H. Girty of the Geological Survey, to whom the fossils were referred, states that the fauna is characteristically Upper Devonian and adds that it is one of peculiar interest

* Cf. Clark, E., loc. cit.

inasmuch as it is the same which was discovered years ago in the Ouray limstone in southwestern Colorado by Mr. Endlich. It is characterized by the large and striking species *Camarotœchia endlichi* Meek, and heretofore has not been recognized outside of the San Juan Mountains.

At Silver City the Devonian system is represented by fissile shales,—about 200 feet of black shales at the bottom followed by 260 feet of red shales, in neither of which have fossils been found.

It may be added that the Devonian system is not represented in the Franklin Mountains of Texas, but is present in eastern Arizona.

Carboniferous.—In the northern half of New Mexico, where the pre-Cambrian compiex is overlain by sediments, the lowest and oldest stratified rocks are Carboniferous. The work of the past summer indicates that in these instances, with possibly one or two exceptions, the Pennsylvanian division of the Carboniferous lies at the base of the section. It is interesting to note, however, that wherever the lower Paleozoic rocks are present, the Mississippian or Lower Carboniferous strata separate the Devonian from the Pennsylvanian rocks. This is the well known Mississippian fauna which was first recognized in New Mexico in the Lake Valley mining district.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *Carbon Suboxide.*—From certain results that they had obtained by the action of phosphorus pentoxide upon nitrogenous organic compounds, DIELS and WOLF were led to investigate the action of this oxide on ethyl malonic ester, an organic substance containing no nitrogen. As a result a remarkable compound free from hydrogen was obtained, which is actually a new oxide of carbon C_3O_2, or, structurally, $OC : C : CO$. The reaction taking place is represented by the equation

$$CH_2(CO_2C_2H_5)_2 = 2H_2O + 2C_2H_4 + OC : C : CO.$$
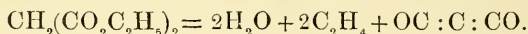
This action is brought about by distilling the malonic ester at a diminished pressure of 12^{mm} and passing the vapor through a large bulb containing phosphorus pentoxide distributed upon glass wool and heated to about 300°. Any unchanged ester is condensed in a well cooled receiver, while the more volatile ethylene and carbon suboxide are condensed in a second receiver by means of liquid air. The ethylene is finally allowed to evaporate and the carbon suboxide is purified by distillation at a low temperature. The formula was established by elementary analysis, vapor density determination, and by the explosion of a measured volume of the vapor with an excess of oxygen in a eudiometer. Practically no contraction took place after this explosion, and three volumes of carbon dioxide were formed, as shown by the equation

$$C_3O_2 + 2O_2 = 3CO_2.$$
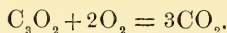
The new compound is a colorless, highly refracting liquid having a powerful, unendurable odor. It boils at $+7°$ and solidifies at a low temperature. The vapor violently attacks the eyes and respiratory organs, and is evidently very poisonous. It burns with a very smoky flame which shows a blue border. In its reactions it behaves as an anhydride of malonic acid, readily forming this acid when brought into contact with water. Upon being kept in a sealed tube it undergoes spontaneous decomposition, with the formation of red products which are evidently complex in their nature. The decomposition takes place almost instantly at 100°.—*Berichte*, xxxix, 686.   H. L. W.

2. *New Method for the Quantitative Determination of Halogens in Organic Compounds.*—VAUBEL and SCHEUER have devised a method for this purpose, which is applicable to many substances, and which appears to be simpler and more convenient than the methods now in vogue. About 0.2 to 0.5^g of the substance is weighed out into a dry fractioning bulb, the side tube of which is attached rather low down on the neck and slants upward at first to serve to some extent as a reflux con-

denser for sulphuric acid. The side tube then turns down perpendicularly and is connected with a Volhard's flask (a conical flask with a triple-bulb connected to it near the bottom). The Volhard's flask is charged with an aqueous solution of silver nitrate into which the delivery tube does not dip. To the fractionating flask containing the substance is attached a dropping funnel, the stem of which reaches nearly to the bottom of the flask, by means of an ordinary cork, or better with a ground glass connection, and by means of this 30 to 50^{cc} of concentrated sulphuric acid are delivered upon the substance. The acid is gradually heated with aspiration of air through the apparatus during the heating or at the end of the operation as occasion may require. In cases where bromine or iodine are set free a little filter paper or metallic copper is used with the substance in order that enough sulphur dioxide may be produced to reduce these substances. After the halogen acid or free halogen has been distilled over, the liquid in the receiver containing the silver halide as well as much silver sulphite is transferred to a beaker, treated with considerable water and 50^{cc} of concentrated nitric acid and heated gradually at first, and finally strongly. The silver halide is collected and weighed as usual.— *Chemiker Zeitung*, xxx, 167. H. L. W.

3. *The Distillation of Metals of the Iron Group.*—MOISSAN has continued his investigations upon the boiling and distillation of metals, and finds that the metals of the iron family have very different boiling points. Manganese is the most volatile of all, and it distils easily at a lower temperature than lime. Next comes nickel, which boils quietly ; then chromium, which distils in a regular manner with a current of 500 amperes and 110 volts. It is more difficult to boil iron, and before boiling takes place there is a tumultuous disengagement of gas which the metal has taken up, but with a current of 1000 amperes and 110 volts 400^{g} of iron were distilled in 20 minutes. Uranium has a higher boiling point than iron, while uranium and tungsten are still more difficult to bring to boiling. The latter metal could only be brought to regular ebullition by the use of a current of 800 amperes and 110 volts after an exposure of 20 minutes.— *Comptes Rendus*, cxlii, 425. H. L. W.

4. *Atomic Weight of Radium.*—The question as to whether this atomic weight is 225 as determined by Mme. Curie by a chemical method, or 258 as found by Runge and Precht from a study of the spectrum, has been discussed by H. C. JONES. He shows clearly that no valid objection can be raised to the higher value on the ground of position in the periodic system, for the higher number readily allows it to be placed in the group with barium, but in a series below the one in which it would be placed as 225. He prefers the higher atomic weight on the ground that he believes that the greater the mass of the atom, the less is its stability and consequently the greater is its radio-activity. This view is contrary to Rutherford's conception of the transforma-

tions of the radio-active elements, but Dr. Jones brings forward the argument that radium is not formed *directly* from radium, and favors the view that the production of radium is a product of synthesis, not of mere decomposition. The question can be finally settled only after a considerable amount of pure radium material is available, and some time must elapse before this is realized.—*Amer. Chem. Jour.*, xxxiv, 467.   H. L. W.

5. *Mechanical Separation of Organic Substances.*—BORDAS and TOUPLAIN have applied a novel method for the detection of adulterations and impurities in chocolate, which will probably be applicable in other cases. The insoluble matter freed from fat was treated with liquids of increasing densities, from 1·340 to 1·600, made by mixing carbon tetrachloride and benzine, in such a manner that successive portions were caused to float when whirled in centrifugal tubes. The different ingredients were thus readily distinguished by their colors, they could be collected upon filters and weighed, and then be subjected to microscopic examination. Oil-cake, germs, shells, potato-starch, and mineral-matters were thus easily separated in the case of chocolate.—*Comptes Rendus*, cxlii, 639.   H. L. W.

6. *Constitution of the Electron.*—W. KAUFMANN, whose experimental proof that the mass of the electron increases with its velocity, and that this mass is probably largely electrical, has been prompted by late theoretical discussions to repeat his work with a view of determining which theory best explains the experimental results. The theories he takes are those of Abraham, Lorentz and Bucherer. The theory of Abraham may be called the theory of the rigid electron, in which the field of the electron extends outwardly to infinity and within to the surface of a sphere of constant radius a; and the Maxwellian equations relating to a solid sphere with surface or volume charge in space are employed. H. A. Lorentz assumes (Versl. Kon. Akad. Wett. Amsterdam, 27 May 1904) that the dimensions of all bodies, including the molecules and the electrons, change their dimensions with velocity; and that mechanical mass changes in the same or analogous way as that of the electron. Bucherer supposes that the electron undergoes a deformation, keeping a constant volume. He makes use of the so-called "Heavyside ellipsoid," and can translate his theoretical results into those of Lorentz by this theory of deformation.

Kaufmann employs in his experiments a crystal of radium bromide, submitting its β-radiations to both electrical and magnetic fields; and carries out the research with remarkable skill. His entire apparaus can be clasped in a man's hand, and the almost microscopic details are carried to great perfection. He arrives at the result that Abraham and Bucherer's theories agree better with the experimental results than that of Lorentz. The ratio of charge to mass deduced from the various theories are as follows :

$$\frac{e}{\mu_0} = 1,878.10^7 \quad \text{Abraham}$$
$$" = 1,876.10^7 \quad \text{Bucherer}$$
$$" = 1,881.10^7 \quad \text{Lorentz}$$

—*Ann. der Physik*, No. 3, 1906, pp. 487–553.   J. T.

7. *Retardation of the Velocity of the a Particles in passing through Matter.*—Professor RUTHERFORD gives a preliminary note on this subject. He has repeated his former results, and concludes that further experiments confirm them. An active wire was coated with radium C. The velocity of the a particles was found to decrease in passing through aluminum. The lowest value of the velocity observed was $.64V_0$, where V_0 is the initial velocity of projection of the a particles from the bare wire. The value of $\frac{e}{m}$ for the a particle from radium C after passing through a screen equal in absorbing power to 5.5^{cms} of air, was found to be the same as for the a particle of the bare wire. This experiment shows that the a particle retains its charge and mass unaltered over a great part of its range in air.—*Phil. Mag.*, April, 1906, pp. 553–554.   J. T.

8. *Electrical Conductivity of Flames containing Salt Vapors for alternating currents.*—For rapidly alternating currents a flame containing an alkali-salt vapor behaves like an insulating medium having a high specific inductive capacity. The view is confirmed that the negative ions from all salts have the same velocity. Not more than one molecule in 30 salt molecules is ionized at any instant in the flame, but each molecule is probably ionized and recombines several million times per second. The steady currents observed through salt vapors in flames are very far from the maximum possible currents corresponding to the number of ions produced per second. The paper is a full one and is by Prof. N. A. WILSON, and E. GOLD.—*Phil. Mag.*, April, 1906, pp. 484–505.   J. T.

9. *Electrically prepared Colloidal Solutions.*—The size of the diameters of the particles of gold, silver and platinum in electrically prepared colloidal solutions lies between the limits $(2–6) \times 10^{-5 \text{ cms}}$. The electro-negative, non-oxidizable metals, gold, silver and platinum, give solutions in water and ethyl malonate, in which the particles are negatively charged. The electropositive, oxidizable metals give solutions in water, methyl alcohol and ethyl alcohol, in which the particles are always positively charged. The velocity of the particles under a known electric force have been determined and the potential differences between the liquid and the particle have been deduced by using the formula $V = \frac{4\pi}{K} \cdot \frac{\mu v}{X}$.—E. F. BURTON, Cavendish Laboratory, *Phil. Mag.*, April, 1906.   J. T.

10. *Recombination of Ions in Air and other Gases.*—Among the large number of important papers on ions in the April num-

ber of the Philosophical Magazine is a very suggestive one by Prof. W. H. Bragg and Mr. R. D. Kleeman on this subject. They conclude in the main that (1) the range varies inversely as the pressure; (2) that the total number of ions set free in a gas is independent of the pressure, but is different in different gases. —*Phil. Mag.*, April, 1906.   J. T.

11. *Nucleation of the Atmosphere.*—The subject of the nucleation of the atmosphere, discussed by C. Barus in a series of papers published in this Journal (volumes xiii to xx) is treated at length by the same author in the following exhaustive memoirs :

A Continuous Record of Atmospheric Nucleation ; pp. xvi, 226, from volume xxxiv of the Smithsonian Contributions to Knowledge. The investigation was carried on with the aid of a grant from the Hodgkins Fund.

The Nucleation of the Uncontaminated Atmosphere; pp. xii, 152. Publication No. 40 of the Carnegie Institution of Washingon

II. Geology and Mineralogy.

1. *Geology ;* by Thomas C. Chamberlin and Rollin D. Salisbury. In three volumes, *Vol. II, Earth History, Genesis–Paleozoic,* pp. xxvi, 677 and index, with geological map of the United States compiled by Bailey Willis, numerous paleogeographic maps and other illustrations. *Vol. III, Earth History, Mesozoic–Cenozoic,* pp. xi, 578 and index to vols. i, ii, iii. Maps and illustrations, as in the preceding volume. New York, 1906 (American Science Series, Advanced Course. Henry Holt & Co.). —Since the publication of Vol. I of this work in 1904, with its able and original discussions of earth processes, every geologist has awaited with much interest the completion of the series. This interest has been justified, for the volumes now issued are conspicuous, even more than the first, for the many original points of view and the radical departure from the older manuals both in methods and subject matter. This series will doubtless give a marked stimulus to investigation for the forthcoming decade. This is partly due to the fact that the volumes look forward rather than backward, an unusually large place being given to working hypotheses, while unsolved problems are frankly recognized and the student is carried along with the investigator to the still debatable ground.

The chief innovations are found in the chapters devoted to "Hypotheses of Earth Origin" (81 pp.), and "Hypothetical Stages leading up to the known eras" (50 pp.). The Proterozoic, a name long since proposed by Irving, is used as the approximate equivalent of the Algonkian and 55 pages are given to this era. Ordovician is fully adopted in place of the long-contested name of Lower Silurian ; the Subcarboniferous for the first time in a text-book is given the dignity of a separate period of equal rank with the Devonian, and called the Mississippian ; the true Carboniferous becoming the Pennsylvanian. The lower Cretaceous

is similarly separated into the Comanchean, of equal rank with the Jurassic and Cretaceous. The discussions are based upon the doctrines of the permanency of continents and that of the world-wide character and periodicity of the great deformative movements, the latter being used as the basis for the separation of the Mississippian and Comanchean. The problems of the Permian and Pleistocene receive considerable attention, the former occupying 59 pages, much in small print, and the latter 190 pages.

As stated in the preface "the familiar calling of the biological roll under each period is abandoned, and will perhaps be missed." The paleontological side of the earth history is subordinated in space to the paleogeographical and the problems dealt with are chiefly the origins and mutations of the faunas and floras.

From the preceding necessarily brief statements it is seen that these volumes are strikingly radical and stimulating both in their method of treatment and in the subject matter. For these reasons, however, they do not supplant the standard manuals at present before the public, but rather supplement them. Taken in connection with Dana's Manual and the fourth edition of Geikie's Text Book, the advanced student is, at present, admirably provided with condensations of geological knowledge. The authors state that the "three volumes are designed to furnish the basis for a year's work in the last part of the college course, or in the early part of a graduate course." Many teachers, however, may question whether such students are sufficiently mature to use these volumes as texts, but they certainly furnish much lecture material for the teacher and form excellent reference books for mature students. To the young student, with an insufficient basis of facts and limited experience in their interpretation, the prominence given to hypothesis, though otherwise an excellent feature, may be dangerous, possibly leading him to neglect the detail of the science for this more attractive field. Geology is a science which has suffered much in the past from ungrounded speculation, since speculation is easier than investigation, and interpretations must be largely based upon the unseen. These volumes, however, should be carefully read by every advanced student in geology and no teacher can consider himself abreast of the times until he has become familiar with them. They will also be found intelligible and interesting by men in other branches of science.   J. B.

2. *Traité de Géologie;* par A. DE LAPPARENT. 5th edition in three volumes, 2015 pages. Paris, 1906 (Masson & Co.).— This elaborate work of the eminent French geologist and geographer, considerably enlarged from the previous edition, suggests a comparison with the three-volume Geology of Chamberlin and Salisbury, lately completed. De Lapparent devotes one volume to "phénomènes actuels," morphology, physiography, erosion, volcanoes, earthquakes and so on, and two volumes to "géologie proprement dite," under which an elaborate review of historical geology is presented, covering all parts of the earth,

although Europe is naturally more fully treated than the other lands. While one cannot expect to find in a general work of this kind detailed accounts of all topics, nevertheless the space given to many problems suffices to place them definitely before the student; for example, the changes of level along the coast of Holland and Flanders in historic times are well summarized near the end of the first volume. Among the features of the work that will excite much attention are the maps of the world, on which the successive formations are charted, and on which lines are drawn, even across the oceans, to indicate in a general way the probable division of land and water in different epochs. Thus it is brought forth in a striking manner, that eastern South America, nearly all Africa, southern Asia, and much of Australia agree in lacking marine deposits during long consecutive periods ; they are therefore looped together and regarded as parts of a great unit. Although there must be much of speculation in such maps, as no one can know better than the author, they perform a great service in giving the student a rapid summary of facts of distribution, to be amplified by the text. The evolution of terrestrial relief is treated near the end of the third volume, where among other reasons for not accepting Suess' theory of horsts, a strong point is made of the long persistence of littoral conditions in certain districts (as in N. W. France), for such persistence would not be a natural consequence of Suess' views.   W. M. D.

3. *Coon Butte, Arizona, and the Canyon Diablo Meteorites.*— Recent papers on this subject by D. M. Barringer and B. C. Tilghman give a detailed description of the crater-like form of Coon Butte, and reaffirm with confidence the hypothesis early suggested that it was formed by the impact of an enormous meteorite falling with something like its original planetary velocity.* As is well known, this region has afforded many thousand masses of meteoric iron varying in weight from a thousand pounds and more down to a few ounces, the total amount aggregating, it is stated, more than ten tons. Further, since the gentlemen above mentioned have taken possession of the property, their search has revealed several thousand additional masses, aggregating more than a ton. The various remarkable features of the iron are too well known to need to be rehearsed here, but it is interesting to note that Professor J. W. Mallet has found both platinum and iridium in samples of residues from solution in hydrochloric acid. Besides the iron, large quantities—a ton or more in weight—of magnetic oxide of iron have been found distributed over the surface of the rim and the surrounding plain. This "iron shale" contains nickel, iridium, and platinum, and

* The theory, advanced in 1896 by G. K. Gilbert, that "the crater, although exhibiting no volcanic rock, is essentially volcanic, having been produced by an explosion of steam generated by some subterranean volcanic intrusion," has hitherto been generally accepted. See G. K. Gilbert, in U. S. G. S., 14th Ann. Rep., I, 187, also Science, iii, 1, 1896.

apparently in the same proportion as in the meteorite itself, from which it is believed it was derived. Similar material, consisting of magnetite in various forms, was also found within the crater at depths varying from 300 to 500 feet. Part of this was in form of small spherules or "shale balls"; these showed a nucleus of metallic iron with an envelope of magnetite. The character and distribution of this magnetic oxide, the latter similar to that of the masses of iron, furnish the authors with confirmation of the meteorite hypothesis as to the origin of the crater. Further confirmation is found in the distribution of the masses of meteoric iron found, in the large amount of minutely pulverized silica, as well as fragments of limestone, within the crater, and in the absence of volcanic rocks or volcanic phenomena from the immediate region. The meteoric masses have been found distributed over a crescent-shaped area surrounding the hole and concentric with it, extending from northwest to east. Only two or three masses of the iron have been found within the crater itself. A number of borings with the diamond drill were made in the effort to locate the supposed mass or masses within the crater, one of these to a depth of over 1000 feet. Several of them met with an obstruction of undetermined nature, which was believed to be the expected meteorite. The authors state that they have already begun to sink a shaft in the center of the crater and that they propose to carry it, if possible, to a depth sufficient to settle the question beyond all possibility of doubt. It is much to be hoped that this plan will prove practicable and that it may be carried to a successful conclusion. It would be a matter of extraordinary and unique interest to establish positively the truth of the hypothesis named.

It is interesting to note, also, though not immediately connected with the subject in hand, that a meteoric stone was found by Mr. Barringer in June, 1905, not far from Coon Butte ; this is described by Professor Mallet on an earlier page of this present number.—*Proc. Acad. Nat. Sci. Philad.*, pp. 861–904, 1905.

4. *Geology of the New Hebrides ;* by D. Mawson. Proc. Linn. Soc. N. S. Wales, 1905, pt. 3, pp. 400–485, pls. 15.—For the benefit of the general reader it may be said at the outset that the New Hebrides are an island group in the Pacific between lat. 14° and 21° S. and long. 168° and 170° E. They are mountainous, partly volcanic, heavily wooded, unhealthy, inhabited by about 50,000 natives, of Papuan stock, governed by a mixed commission of English and French naval officers. Area about 5100 square miles, divided among 12 principal islands. The larger islands are high and show extensive exposures of volcanic rocks underlying areas of raised coral formations, the latter showing in places elevations of nearly 2000 feet. The smaller islands are sometimes volcanic, sometimes of coral formation. There are several active volcanoes in the group. The author describes these geological features, listing the Miocene fossils in the bedded rocks and giving in detail the petrography of the lavas. We quote the following analyses made by him :

	SiO$_2$	Al$_2$O$_3$	Fe$_2$O$_3$	FeO	MgO	CaO	Na$_2$O	K$_2$O	H$_2$O+
I	63·60	15·84	1·45	2·72	1·14	3·03	4·33	3·26	3·88
II	46·78	21·22	4·63	6·17	4·30	12·07	1·40	0·64	0·94
III	43·98	17·69	5·97	6·68	7·83	11·71	1·34	0·64	1·77
IV	60·96	16·62	3·87	2·61	0·95	6·35	3·01	3·40	1·03

	H$_2$O−	CO$_2$	TiO$_2$	P$_2$O$_5$	Cr$_2$O$_3$	MnO	Cl	Total	Sp. gr.
I	0·30	none	0·70	0·10	tr.	tr.	tr. =	100·35	2·51
II	0·50	tr.	1·20	0·31	0·05	tr.	tr. =	100·21	2·90
III	0·95	tr.	1·20	0·32	0·05	tr.	tr. =	100·13	2·95
IV	0·18	0·10	0·50	0·25	0·04	tr.	tr. =	99·87	2·54

I   Hypersthene andesite perlite (adamellose) Leleppa Island.
II Basalt porphyrite (hessose) Mau Island.
III Basalt porphyrite, dike (auvergnose) Fatmalapa, Efate Island.
IV Hornblende andesite (harzose) Wai Malikoliko, S. W. Santo.

In concluding the author notes that the coral formations in recording crustal movements have developed three main types of islands corresponding to as many possible land-movements.

First, in regions of *continuous upheaval,* islands veneered with coral limestone terraces like the New Hebrides.

Second, on *subsiding areas,* islands which are typical atolls like those of the Ellice group.

Third, in regions of *both upheaval and subsidence,* islands in which coral limestones are interbedded with volcanic submarine tuffs or other products; seen in the larger islands such as Viti Levu of the Fiji group.

The work is accompanied by a number of maps and interesting photographs of the island scenery, rock sections, etc., and is an excellent contribution to Pacific geology.   L. V. P.

5. *Salient Geological Features of British New Guinea ;* by A. G. MAITLAND, West Aust. Nat. Hist. Soc., April 11, 1905, 26 pp.—This gives a brief résumé of the observations made by the author in a trip along the coast in a Government vessel with excursions inland. It was found that the coastal districts and many of the adjacent islands were composed of extinct volcanoes and their ejections and on the northeast coast and the Louisade Archipelago of horizontal limestones, upraised coral formations. A large portion of the backbone of the mainland is formed of ancient crystalline rocks with bedding at high angles. The country is beginning to yield an increasing amount of gold, amounting in the year 1902–03 to over $200,000.   L. V. P.

6. *Geological Survey of Canada:* ROBERT BELL, Director. —The following publications have recently appeared :

ANNUAL REPORT, Part B. Report on the Klondike Gold Fields ; by R. G. McCONNELL. Pp. 71, with colored map. This gives the results of field work carried on during the season of 1903.

Part J. Report on the Geology of a Portion of Eastern Ontario ; by R. W. ELLS. Pp. 89, with colored map.

Recent Mineral Discoveries on Windy Arm of Tagish Lake, Yukon ; by R. G. McCONNELL. Pp. 12. The quartz veins described carry various silver and copper ores.

Although many interesting results are obtained, no explanation is arrived at for the luminescence of the mineral; it is concluded that there is no proof that the organic substance present in the mineral, to which the color is probably due, has anything to do with the fluorescence and the thermo-luminescence. The regeneration of the latter power of chlorophane seems to indicate that a part of the emitted light at least has an inorganic source. —*Proc. Amer. Acad.*, xli, No. 27, March, 1906.

10. *International Geological Congress.* — The tenth annual meeting of the *Congrès Géologique International* will be held in the City of Mexico from September sixth to thirteenth. A most interesting series of excursions is announced in the preliminary circular.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *National Academy of Sciences.*—The Spring meeting of the National Academy of Sciences was held at Washington on April 16–18; thirty-four members were in attendance. The following gentlemen were elected members of the Academy: Benjamin O. Peirce, of Cambridge, Mass.; W. B. Scott, of Princeton, N. J.; and Josiah Royce, of Cambridge, Mass. Prof. Wilhelm Ostwald, of Leipzig, and Prof. H. A. Lorentz, of Leiden, were elected foreign associates. The Draper medal was presented to W. W. Campbell of the Lick Observatory at a dinner given by Professor Alexander Agassiz at the new Willard Hotel on April 17th.

The following is a list of the papers presented at the meeting:

J. McK. CATTELL: The distribution of American men of science.

C. S. PEIRCE: Recent developments of existential graphs and their consequences for logic.

THEO. HOLM: Commelinaceæ. Morphological and anatomical studies of the vegetative organs of some North and Central American species.

A. AGASSIZ and H. L. CLARK: On the classification of the Cidaridæ.

THEO. GILL: Interference of oviposition of a Sargasso fish with a flying fish.

H. F. OSBORN: Faunal and geological succession in Eocene and Oligocene Basins of Rocky Mountain region.

W. J. SINCLAIR: Volcanic ash in the Bridger Beds of Wyoming.

C. E. DUTTON: Radio-activity and volcanoes.

C. D. WALCOTT: Cambrian faunas of China.

GEORGE E. HALE: Recent solar investigations.

W. W. CAMPBELL and C. D. PERRINE: Some recent solar eclipse results.

M. I. PUPIN: Feeble, rapidly alternating, magnetization of iron.

J. M. CRAFTS: Primary standards for temperature measurements between 100° and 350°.

ASAPH HALL: Biographical memoir of Admiral John Rodgers.

W. M. DAVIS: Biographical memoir of George P. Marsh.

THEO. GILL: The life history of Pterophryne.

2. *The Franklin Bi-Centenary.*—A General Meeting of the American Philosophical Society was held at Philadelphia on April 17–20 in celebration of the two hundredth anniversary of the birth of Benjamin Franklin. The introductory exercises were held on Tuesday (17th); Wednesday was devoted to the

reading of original papers on scientific subjects, and the special commemoration exercises and addresses were given on Thursday and Friday. The occasion was throughout one of the very highest interest.

3. *Chemistry of the Proteids;* by GUSTAV MANN. Based on Professor Otto Cohnheim's 'Chemie der Eiweisskörper.' 1906. Pp. 606. London and New York, 1906 (The Macmillan Co.). —The publication of an important volume exclusively devoted to the proteid substances, within two years after the appearance of the second, enlarged edition of Cohnheim's Eiweisskörper, brings evidence of the growing interest which the newer knowledge of the albuminous substances has begun to awaken. Dr. Mann's book, although primarily based upon the well-known German compilation, can justly lay claim to considerable original merit in addition to that of a successful translation ; for aside from bringing the literature practically up to date, the author has both revised the German version and somewhat extended its scope. Among the more important innovations may be mentioned: the physiological considerations (somewhat concise) introduced in connection with several aspects of the chemical study of the proteids ; the more detailed discussion and interpretation of physico-chemical problems here concerned and in which Dr. Mann departs at times from Cohnheim's views; a valuable résumé of the chemistry of the autodigestion of nucleoproteids and its attached significance ; a well-arranged digest of the very recent work on the synthesis of compounds of the polypeptid type ; additional references to the historical aspects of the included topics.

It is impossible to subject the vast array of detailed information to a critical review here. Sufficient must be the praise to which the painstaking and distinctly critical (though unbiased) efforts are richly entitled to. Dr. Mann's book will be an almost indispensable reference work in the physiological laboratory ; and it is likely to do commendable service to biological science by affording to those less conversant with its chemical problems a more ready opportunity to become acquainted with its progress and present status—to study the cell as " a chemical and physico-chemical mechanism." L. B. M.

4. *Wilhelm Fliess und Seine Nachentdecker,* O. *Weininger und H. Swoboda;* von RICHARD PFENNIG. Pp. 66. Berlin, 1906 (Emil Goldschmidt).—This monograph is a defence of the priority claims of Fliess in respect to the formulation and publication of his somewhat startling theories of the " permanent bisexuality " characterizing living things and the periodicity of biological processes. It therefore possesses little more than polemical value.

5. *The Lagoon of Venice.*—The Venetian Institute of Science, Letters and Arts has undertaken a systematic study of geophysical phenomena which concern directly and indirectly the Lagoon of Venice. With this object a special commission has been

appointed, and the preliminary investigations, bearing principally on the tidal-waves in the upper Adriatic together with the rivers flowing into it and the lagoon of Venice, intrusted to Dr. Giovanni Piero Magrini, who is to be assisted by Professors Luigi de Marchi and Tullio Gnesotto of the University of Padua. Any publications which might prove useful in this undertaking are solicited by the President, A. Favaro.

6. *The Philippine Journal of Science.*—The second number of volume one of this new periodical (see xxi, p. 336) has been recently issued, accompanied by Bulletin No. 36, having the title : A Hand-list of the Birds of the Philippine Islands ; by Richard C. McGregor and Dean C. Worcester. Pp. 123.

7. *Field Columbian Museum.*—The following publications have been recently issued :

Botanical Series, Vol. II, No. 3, Prænunciæ bahamenses—I. Contributions to the Flora of the Bahamian Archipelago ; by C. F. MILLSPAUGH. Pp. 137–184.

Report Series, Vol. II, No. 5. Annual Report of the Director, FREDERICK F. J. SKIFF, to the Board of Trustees for the year 1904–1905. Pp. 333–435, plates lxi–lxxi.

La Matiére, sa Naissance, sa Vie, sa Fin ; par P. DE HEEN. Pp. 119, with 61 figures. Bruxelles, 1905, Hayes (Imprimeur des Académies Royales de Belgique).

Nouvelles Orientations Scientifiques : Ouvrage traduit du catalan avec l'autorisation de l'auteur ; par J. PIN Y. SOLER. Pp. 164, with 36 figures. Paris ; 1905 (Garnier Frerès, Editeurs).

The Universal Kinship ; J. HOWARD MOORE. Pp. 329. Chicago, 1906 Charles H. Kerr & Co.).

OBITUARY.

JAMES MILLS PEIRCE died suddenly in Cambridge on the 21st of March, 1906, in the 72d year of his age.

A member of the faculty of Harvard College for nearly 50 years, he served the University as Tutor in Mathematics, as Assistant Professor, and as Professor and Dean of The Graduate School and Dean of The Faculty of Arts and Sciences.

He was remarkable for the breadth and depth of his scholarship and for the thoroughness and finish of his work whether as lecturer, legislator, or administrator, rather than for his scientific productiveness. His students knew him as a helpful friend and as an inspiring teacher, his associates as one of the most genial and lovable of men.   W. E. B.

NATHANIEL S. SHALER, Professor of Geology in Harvard University and Dean of the Lawrence Scientific School, died on April 10th, at the age of sixty-five years ; a notice is deferred until another number.

M. P. CURIE, the French chemist and physicist, to whom, with Mme. Curie, our knowledge of radium and its properties is largely due, was accidentally killed in Paris on April 19th.

Professor LIONEL SMITH BEALE, well known through his works on the microscope, died on March 28 at the age of seventy-eight years.

CONTENTS.

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics—Carbon Suboxide, Diels and Wolf : New Method for the Quantitative Determination of Halogens in Organic Compounds, Vaubel and Scheuer, 396 —Distillation of Metals of the Iron Group, Moissan : Atomic Weight of Radium, H. C. Jones, 397.—Mechanical Separation of Organic Substances, Bordas and Touplain : Constitution of the Electron, W. Kaufmann, 398.—Retardation of the Velocity of the *a* Particles in passing through Matter, Rutherford : Electrical Conductivity of Flames containing Salt Vapors for alternating currents, Wilson and Gold : Electrically prepared Colloidal Solutions, Burton : Recombination of Ions in Air and other Gases, Bragg and Kleeman, 399.—Nucleation of the Atmosphere, 400.

Geology and Mineralogy—Geology, Chamberlin and Salisbury, 400.—Traité de Géologie, A. de Lapparent, 401.—Coon Butte, Arizona, and the Canyon Diablo Meteorites, Barringer and Tilghman, 402.—Geology of the New Hebrides, Mawson, 403.—Salient Geological Features of British New Guinea, Maitland : Geological Survey of Canada, 404.—Mica : its Occurrence, Exploitation and Uses, F. Cirkel : Beiträge zur Mineralogie von Japan : Studies in Fluorite, H. W. Morse, 405.—International Geological Congress, 406.

Miscellaneous Scientific Intelligence—National Academy of Sciences : Franklin Bi-Centenary, 406.—Chemistry of the Proteids, G. Mann : Wilhelm Fliess und Seine Nachentdecker, O. Weininger und H. Swoboda, R. Pfennig : Lagoon of Venice, 407.—The Philippine Journal of Science : Field Columbian Museum, 408.

Obituary—James Mills Peirce, Nathaniel S. Shaler, M. P. Curie, Lionel Smith Beale.

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Art. XXXVI. — *The Radio-Activity of the Salts of Radium ;*[*] *by* Bertram B. Boltwood.

The relation between the *a*-ray activity of a salt of radium from which all the emanation and the corresponding active disintegration products have been removed and the *a*-ray activity of the same salt when the total, equilibrium quantity of emanation and active products are present, does not appear to have been previously determined with any great degree of accuracy. According to Mme. Curie,[†] the maximum activity attained by solid salts of radium after several months is five to six times that which they possess when first separated from a solution. It is stated elsewhere in the same work (p. 116) that when a sample of radium-barium chloride was heated to a red heat, the final, maximum activity was about 1·5 times greater than that attained by the same salt in the normal, crystalline condition, while, in the case of a similar preparation which had been heated to fusion for several hours, the final activity attained a value over twice as great as that ultimately reached by the salt in the form separated from solution. For radium-barium chloride which had been heated to a cherry-red heat for several hours, the activity of the salt immediately after heating was found to be only 16·2 per cent of the activity of the same salt when tested fifty-seven days later (p. 117).

Rutherford and Soddy[‡] have also determined the rise in activity of a solid radium salt in the form of a thin film

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[*] The general results and conclusions reached in this paper were presented at a meeting of the American Physical Society held in New York City on February 24, 1906.

[†] Untersuchung über die Radioaktiven Substanzen. Uebersetzt von W. Kaufmann. Braunschweig, 1904, p. 32.

[‡] Phil. Mag. (6), v, 445, 1903.

obtained by the evaporation of a solution from which all eman-
ation had been removed. The activity of the freshly prepared
residue from this solution was found to be 25 per cent of the
activity of the same residue twenty-one days later.

In none of the papers mentioned are the conditions of exper-
iment shown to be such as to preclude the escape of a portion
of the emanation from the material tested, nor do they afford
any data on the proportion of the total emanation which was
retained by the solid radium compound. Experiments con-
ducted by the writer on uranium minerals[*] have demonstrated
that it is possible for this class of radium compounds to lose at
ordinary temperatures very considerable proportions of the
radium emanation produced within them.

Since the numerical value of the ratio of the activity of
radium itself to the activity of its disintegration products is of
considerable importance, and since, moreover, a knowledge of
the value of this ratio was essential for the interpretation of
other more complicated relations, the following experiments
were undertaken in order to determine the relative a-ray
activity of radium salts from which all emanation had been
removed and the activity of the same salts when the total,
equilibrium quantity of radium emanation was retained within
them.

Activity of the Salts.

The radium salt used was a weak preparation of radium-
barium chloride, having an activity not over 100 times that of
uranium. The salt had been prepared about six months pre-
viously by chemical operations and repeated recrystallization
of the chloride with the object not so much of obtaining a
strongly active material as of separating any actinium or polon-
ium which might have been present in the raw material. A
few milligrams of this salt were dissolved in 250^{cc} of distilled
water to which a few drops of dilute hydrochloric acid had
been added. Of this solution exactly 10^{cc} were introduced
into a glass bulb by means of a standard pipette, the solution
was diluted to about 100^{cc} with water, and the bulb was sealed
by fusion. After about sixty days the emanation and other
gases in the solution were removed by boiling and were intro-
duced into an air-tight electroscope. The leak after three
hours, as indicated by the fall of the gold leaf, was equal
to 4·60 scale-divisions per minute. This corresponded to a
quantity of radium in solution in the bulb equal to $8·5 \times 10^{-6}$
milligram, or to a content of $8·5 \times 10^{-7}$ milligram of radium in
1^{cc} of the original solution.

A number of very thin films of the radium salt were now
prepared by slowly evaporating to dryness 10^{cc} of the standard

[*] Ibid. (6), ix, 599, 1905.

solution in each of several flat, glass dishes 50^{mm} in diameter and 9^{mm} in depth. The time taken for the evaporation was about three hours, and the salt was deposited in a fairly uniform and extremely thin layer on the bottom of the dish. The freshly prepared films were introduced into an electroscope and their activity measured.

The electroscope in which the solids were measured consisted of an ionization vessel of sheet metal 14^{cm} in height, circular in cross-section, 15^{cm} in diameter at the top and bottom and 19^{cm} in diameter at a point midway between the top and bottom. A circular aluminium plate, 7·5^{cm} in diameter, was supported 9·5^{cm} from the bottom by a vertical, insulated, brass rod, which extended through the top of the ionization vessel and carried a small gold leaf at its upper extremity. This gold leaf was surrounded by a metal case provided with small mica windows. The insulated plate could be charged at will to a potential of about 400 volts from a small storage battery, and the leak of the charge from the plate determined by the fall of the gold leaf which was observed through a microscope with a transparent scale in the eye-piece. The lower half of the ionization chamber could be swung to one side about a pivot without disturbing any other part of the instrument, permitting the placing on the bottom of the ionization chamber of the dishes containing the substances to be tested. When in its normal closed position, the bottom of the ionization chamber was held firmly by three small spring clamps. The entire metal case of the electroscope was electrically connected to earth, as was also the positive pole of the battery. The insulated plate was in all experiments charged negatively.

The initial activity of the films having been determined, they were placed in an air-tight bell-jar over fresh, concentrated sulphuric acid and allowed to remain in this desiccating atmosphere during the intervals between the different measurements. The experiments were conducted during the winter months in a building heated by steam, and measurements were made only on clear, cold days when the atmosphere in the laboratory contained a minimum amount of moisture. When a measurement was to be made, the dish carrying the film was removed from the bell-jar, placed immediately in the electroscope and the measurements carried out as rapidly as possible. The dish was then replaced in the bell-jar and another one removed and measured.

The initial activities of the several films and the activities after the lapse of the stated times is given in the following table in terms of the fall of the gold leaf in divisions per minute. The readings in each case are corrected for the

natural air-leak of the instrument, which averaged 0·038 division per minute.

TABLE I.

Film No.	Initial activity	Activity 3d 22hrs	Activity
1	1·14	3·02	
		12 days	31 days
2	1·20	4·84	5·21
		17 days	
3	1·12	4·60	

When the last measurement given in the table was made, the dish containing the film was quickly placed in the bottom of a small copper can having a capacity of about 300^{cc}. The can was closed with a tight-fitting cover provided with two openings to which were fitted glass tubes. One of these tubes was attached by a short piece of rubber tubing closed with a pinchcock to the Reichardt apparatus,* and from the other tube, which extended nearly to the bottom of the can, about one-half of the air in the can was exhausted by suction. About 150^{cc} of warm water containing a little hydrochloric acid was introduced through the tube, and the tube was then connected with a flask containing boiling water. A current of steam was passed through the can, and the displaced gases were collected in the Reichardt apparatus. After passing steam for about 15 minutes the accumulated gases were introduced into the air-tight electroscope. The activity of the emanation obtained from the films is given in the following table (Table II) in terms of the fall of the gold leaf in divisions per minute. The percentage of the total emanation present in each film was calculated by dividing the observed leak by the leak caused by the total, equilibrium quantity of emanation corresponding to the amount of radium in the film (4·60 divisions per minute).

TABLE II.

Film No.	Observed leak	Per cent of emanation present
1	1·65	35 9
2	3·29	71·5
3	3·07	66·5

Knowing the length of time which had passed from the time when the emanation had been wholly removed from the salt† to the time when the emanation retained by the film was removed and measured, it is possible to calculate what proportion

* This Journal, xviii, 379, 1904.

† A freshly prepared film was subjected to the same treatment as were the older films, and the complete absence of emanation from the fresh films conclusively proven by experiment.

of the emanation formed from the radium was actually re-
tained by the solid salt. In the following table (Table III)
the per cent of the total emanation contained in each film is
given in the first column, the per cent of the total emanation
which would have been found after the stated time had elapsed,
if none had escaped, is given in the second column, and the
ratio of these, or the per cent of the emanation actually formed
which was retained by the film, is given in the third column.

TABLE III.

Film No.	1.	2.	3.
1	35·9%	50%	71·8%
2	71·5%	100%	71·5%
3	66·5%	95%	70·0%

It is apparent from these numbers that in the films used the
radium salt retained only from 70 to 71·8 per cent of the total
radium emanation formed within them.

Since the increase in the activity due to the accumulation
of definite proportions of emanation and products is given in
Table I, it is possible to calculate the activity which the films
would have ultimately attained if no emanation had escaped
from them. Thus in the case of film No. 1, the difference
between the initial activity and the activity at the end of 3
days 22 hours was 1·88. This represents the activity due to
35·9 per cent of the emanation and active products of rapid
change. One hundred per cent of the emanation and active
products would therefore have an activity of 5·23 div. per
minute, and the maximum value of the activity would be 1·14
plus 5·23, which is 6·37. Dividing 6·37, the maximum activ-
ity, by 1·14, the initial activity, gives the value 5·59 for the
ratio of these two numbers. The corresponding data for all
three of the films is given in the following table (Table IV).

TABLE IV.

Number of film	Initial activity	End activity	Per cent of emanation retained	Activity of 100% emanation	Activity if all emanation is retained	Ratio
1	1·14	3·02	35·9	5·23	6·37	5·59
2	1·20	5·21	71·5	5·61	6·81	5·68
3	1·12	4·60	66·5	5·23	6·35	5·67

The average value of the ratio of the activity of the salt free
from emanation to the activity of the salt containing all of its
radium emanation is, from the above, 5·64.

The increase in the activity of a film of pure radium bromide
was also determined by evaporating a solution of pure radium
bromide containing a little hydrochloric acid to dryness in one
of the glass dishes. The activity of the freshly prepared film

was determined and the dish was then allowed to remain in a desiccator over sulphuric acid for about six weeks. At the end of this period the activity was again determined, and was found to have risen to 3·1 times the initial activity. It is evident that this film retained only about 45 per cent of the emanation formed within it. For the solution from which it was prepared I am indebted to Mr. A. S. Eve of McGill University.

Conclusions.

The ranges in air at atmospheric pressure of the a particles from radium and its disintegration products of rapid change have been determined by Bragg and Kleeman.[*] The ranges which they found were the following:

1	Radium	3·5^{cm}
2	Emanation or Radium A	4·23
3	Radium A or Emanation	4·83
4	Radium C	7·06

The sum of these numbers is equal to 19·62 and this number is 5·60 times the range of the a particle from radium itself. The value found for the relative ionization or activities of the different products, namely 5·64,[†] agrees so closely with the ratio of the relative ranges of the same products that it appears highly probable that the a-ray activities of the different products are proportional to the ranges of their a particles. Moreover, since according to the disintegration theory when the parent substance and the products are in radio-active equilibrium the same number of atoms of each are undergoing disintegration per second and the same number of a particles are projected from each exploding atom, it would appear probable that the ionization produced by each a particle is proportional to its range. That the ionization measured was produced almost wholly by the a particles was demonstrated by covering one of the films which had attained its maximum activity with a sheet of aluminium 0·1^{mm} in thickness. The ionization then produced was only about 0·3 per cent of the ionization produced by the bare film.

New Haven, Conn., April, 1906.

[*] Phil. Mag. (6), viii, 719, 1905.

[†] The value for the ratio was also determined in an electroscope having an ionization chamber 16^{cm} long, 8·5^{cm} wide and 7^{cm} high. The charged plate, 13^{cm} long and 5^{cm} wide, was suspended 3·5^{cm} from the bottom. The ratio of the activity of the emanation-free salt to the activity of the same substance containing all of its emanation as determined in this smaller electroscope was 5·35, and this lower value is to be attributed to the fact that a portion of the a particles of longer range were stopped by the walls and plate before they had completed their full paths, which resulted in a corresponding reduction in the total ionization.

ART. XXXVII.—*The Radio-Activity of Thorium Minerals and Salts ;*[*] by BERTRAM B. BOLTWOOD.

THE radio-activity of the element thorium has been the cause of much discussion and the subject of many apparently contradictory statements in the literature. Following the original announcements by Schmidt[†] and by Mme. Curie,[‡] that the thorium minerals and salts possessed radio-active properties, Hofmann and Strauss published a paper[§] in which it was stated that they had separated an inactive thorium compound from a specimen of the mineral euxenite. In a paper by Hofmann and Zerban[‖] the claim was later made that an inactive thorium preparation had been obtained from a Brazilian monazite sand, and that thoria separated from bröggerite, cleveite and samarskite, although active when first prepared, had lost its activity some months after its removal from the minerals. Following this in another paper,[¶] the same authors claimed to have separated entirely inactive thorium oxide from a specimen of Norwegian gadolinite. It has also been stated by Baskerville and Zerban[**] that a new source of inactive thorium had been found in a "rock" from South America.

In apparent contradiction to the above we have the statements of Rutherford and Soddy[††] that ordinary commercial thorium nitrate and the purest thorium nitrate obtainable gave equal proportions of thorium-X ; the statements of Strutt[‡‡] that he was able to obtain measurable amounts of thorium emanation from solutions of all of the thorium-bearing minerals, including euxenite and a large number of others, which he tested ; and the statements of Mme. Curie and a number of other investigators who had in all cases detected radio-active properties in the thorium minerals which they had examined.

The announcement by Hahn[§§] that he had obtained a highly radio-active preparation, from certain residues separated from the mineral thorianite, which was many thousand times more active than ordinary thorium and which gave out

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[*] The general results and conclusions reached in this paper were presented at a meeting of the American Physical Society held in New York City on February 24, 1906.
[†] Annal. d. Phys., lxv, 141, 1898.
[‡] Compt. rend., cxxvi, 1101, 1898.
[§] Berichte d. chem. Ges., xxxiii, 3126, 1900.
[‖] Berichte, xxxv, 531, 1902.
[¶] Berichte, xxxvi, 3093, 1903.
[**] Jour. Am. Chem. Soc., xxvi, 1642, 1904.
[††] Proc. Chem. Soc., xviii, 120, 1902.
[‡‡] Proc. Roy. Soc. Lond., A lxxvi, 88 and 312, 1905.
[§§] Proc. Roy. Soc. Lond., A lxxvi, 115, 1905.

a proportionately larger amount of the characteristic thorium emanation, appeared at first to add a further complication to the question as to the radio-activity of ordinary thorium salts. Hahn has suggested,[*] however, that this novel radio-active body, which has been named "radio-thorium," is itself a disintegration product of ordinary thorium. If this hypothesis is correct, it is to be expected that, in the natural minerals containing thorium, the parent substance and its product will have reached a state of radio-active equilibrium and the total activity of the thorium and its products will be proportional to the absolute amount of the element thorium which is present.

The experiments which are described in the present paper were undertaken with the object of determining what proportion of the total a-ray activity of radio-active minerals was produced by the thorium present and whether the activity due to thorium was in all cases proportional to the actual amount of this element contained in the mineral.

Composition of the Minerals.

The minerals used in these experiments were thorianite, thorite, orangite and monazite. The determination of the percentage of thorium oxide in each mineral was carried out in the following manner. The thorianite was dissolved in concentrated nitric acid and the thorite and orangite in dilute hydrochloric acid. The solutions were evaporated to dryness and the residues heated to render the silica insoluble. The residues were then moistened with concentrated hydrochloric acid, boiling water was added and after a short period of digestion the insoluble portions were removed from the solutions by filtration. The filtrates were again evaporated to dryness, the residues treated with a few drops of hydrochloric acid followed by a small quantity of water and the solutions thus obtained were filtered to remove traces of separated silica. The solutions were cooled and diluted, and then treated with an excess of hydrogen sulphide. The precipitated sulphides were filtered off, the filtrates were boiled to remove the excess of hydrogen sulphide, and were poured into boiling solutions containing a considerable excess of oxalic acid. The mixed solutions were then allowed to stand at ordinary temperature and at the end of 24 hours the precipitates of oxalates of the rare earths were collected on filters. The oxalates were converted into nitrates and the excess of nitric acid in the solutions was removed by evaporation. A solution of ammonium oxalate saturated in the cold was prepared and portions of this containing a considerable excess of the salt over the amount necessary to pre-

[*] Jahrb. d. Radioaktivität, ii, 425, 1905.

cipitate all of the rare earths as oxalates were measured out. These portions of the ammonium oxalate solution were heated to boiling and the dilute, boiling solutions of the neutral nitrates of the rare earths were poured into them with constant stirring. The mixed solutions were diluted with water to twice their initial volume and were allowed to stand in the cold for 48 hours, when the precipitates formed were removed, converted into neutral nitrates and again subjected to the treatment with an excess of ammonium oxalate. The second precipitate of rare earths free from thorium was filtered off, and the two ammonium oxalate solutions were combined, heated to boiling and an excess of hydrochloric acid was added. The solutions were then allowed to stand at ordinary temperatures for 48 hours, the precipitated thorium oxalate was collected on a filter and was ignited to convert the oxalate into oxide.

The finely pulverized monazite was treated with sulphuric acid in a platinum dish. The resulting product was treated with ice water, and the insoluble portion was again treated with sulphuric acid. After removing the part soluble in ice-cold water, the insoluble material remaining was a third time treated with hot sulphuric acid, and a residue amounting to 3·0 per cent of the original mineral remained, which was not further attacked by sulphuric acid. The combined aqueous solutions were made strongly alkaline with ammonia, and the precipitate of phosphates was removed, washed free from sulphates and dissolved in nitric acid. The dilute, nitric acid solution was heated to boiling and poured into a boiling solution containing an excess of oxalic acid. After 24 hours the precipitate of oxalates was removed, the oxalates were converted into chlorides, and the precipitation of the rare earths as oxalates was repeated. The second precipitate of oxalates was converted into chlorides, and to the dilute, boiling solution of the chlorides was added an excess of sodium thiosulphate. The solution was boiled for about 20 minutes until the odor of sulphurous acid could no longer be detected in the steam. The precipitate was then separated from the solution, was treated with hot, dilute hydrochloric acid, the residue of sulphur was removed, and, after the excess of hydrochloric acid present had been largely neutralized with ammonia, the treatment with sodium thiosulphate was repeated. The second precipitate was treated with hot, dilute hydrochloric acid, the chlorides obtained were converted into the neutral nitrates, and the solution of the nitrates was twice treated with an excess of ammonium oxalate in the manner described for thorite and thorianite. The thorium was finally weighed in the form of the oxide. The rare earths were all recovered

from the various solutions which had been obtained in the above series of operations and were reworked for the separation of any thorium which might have escaped the first treatment. Only an insignificantly small amount of thorium was recovered by this second treatment. The residues of sulphur from the precipitates formed by the sodium thiosulphate were also examined for traces of thoria, but with negative results. Exactly 10 grams of monazite was taken for the analysis.

The thorium oxide finally obtained in all cases was perfectly white after intense ignition over the blast lamp.

The percentage of uranium in the minerals was determined in the case of thorianite by direct analysis, carried out by the method which has been previously described.* In the case of the other minerals, and also in the case of thorianite, the uranium present was determined indirectly by comparisons of the amounts of radium emanation produced in the minerals with the amount of emanation produced in a standard, analyzed sample of uraninite.† With the thorianite the results obtained by these two independent methods were in excellent agreement.

Radio-activity of the Minerals.

The radio-activity of the different minerals was determined by a method very similar to that which has already been described by McCoy.‡ The minerals were ground to an impalpable powder with redistilled chloroform in an agate mortar. In the form of a thin paste with chloroform, the powder was then painted with a camel's-hair brush on a thin plate of aluminium. The sheets of aluminium were 7·5^{cm} wide, 9^{cm} in length and approximately 0·1^{mm} in thickness, and weighed about 2 grams each. After the chloroform had evaporated it was possible to determine the increase in weight due to the film with considerable accuracy. In order to avoid the necessity of making corrections for the absorption of the rays by the material itself,§ the films were made very thin with a weight of only about 5 milligrams of material on a surface of 60 sq. cm. The errors then due to the absorption of the rays were very small and were within the limit of error of the other measurements. It was found that the activities of films of approximately equal weight prepared from the same material by the above method were in good agreement, and that for films weighing up to 10 milligrams the activities were quite closely proportional to the weight of material taken.

The ionization produced by the films was measured in two different electroscopes, a smaller one having an ionization

* Boltwood, Phil. Mag. (6), ix, 603, 1905.
† Boltwood, loc. cit.
‡ Jour. Am. Chem. Soc., xxvii, 391, 1905 ; Phil. Mag. (6), xi, 176, 1906.
§ McCoy, loc. cit.

chamber 16^{cm} long, 9·5^{cm} wide and 7^{cm} high, with a charged plate 13^{cm} long and 5^{cm} wide suspended 3·5^{cm} from the bottom, and a larger electroscope with an ionization chamber 15 to 19^{cm} in diameter and 14^{cm} in height, having a circular plate 7·5^{cm} in diameter at a distance of 9·5^{cm} from the bottom. The electroscopes are described in greater detail in an accompanying paper (p. 411).

Calculation of the Thorium Activity.

From the weight of mineral in a given film and the corresponding activity as measured in the electroscope, it is a simple matter to calculate the activity of one gram of the mineral in terms of the fall of the gold-leaf in scale divisions per minute. It has been stated by McCoy[*] that for uranium minerals containing no thorium, the total activity is directly proportional to the amount of uranium present, and experiments made by the writer on a series of uranium minerals have led to a similar conclusion, provided that corrections are introduced for the amount of radium emanation which escapes from the minerals when in a finely powdered condition. There are therefore two methods available for calculating the activity due to thorium in a series of minerals containing both thorium and uranium. One of these is to determine, from the measurement of a mineral containing uranium only, the activity corresponding to one gram of uranium with its active disintegration products. Knowing this value, it is a simple matter to deduct from the activity of a uranium-thorium mineral of known composition that part of the activity due to uranium and products. If no other radio-active bodies than thorium are present, the remaining activity will be due to thorium and its products only, and on dividing this by the weight in grams of thorium present the activity of thorium per gram will be given. The other method of calculating the activity of the thorium is to solve by algebraic methods the equation obtained through the measurement of two or more unlike thorium-uranium minerals, the equations having the form

$$a\mathrm{U} + b\mathrm{Th} = \mathrm{C},$$

where a is the weight of uranium in one gram of the mineral, b the weight of thorium in the same quantity, and C is the total activity of one gram of the mineral. This second method is only applicable if the activity of the thorium is a constant.

The results as given in this paper were calculated by the first method. The activity corresponding to one gram of uranium and products in a mineral retaining all of its radium emanation

[*] Phil. Mag. (6), xi, 176, 1906.

was determined for each of the electroscopes,[*] and after deduct-
ing that part of the activity of the thorium minerals due to
uranium, the remainder was divided by the weight of thorium
oxide per gram of the mineral. The number thus obtained
represented the activity of one gram of thorium in the min-
erals. The general results obtained are given in the table
which follows (Table I). The activities are given in terms of
the fall of the gold-leaf in the scale divisions per minute. The
numbers printed in ordinary type refer to the measurements
made in the smaller electroscope, those in italics to the meas-
urements made in the larger electroscope.

TABLE I.

Mineral.	Per cent uranium.	Per cent ThO$_2$.	Activity per gram of mineral.			Activity per gram of ThO$_2$.
			Total.	Due to uranium.	Due to thorium.	
Thorianite,						
Ceylon _____	11·2	78·8	85	35	50	63
			153	*59*	*93*	*118*
Thorite,						
Norway ____	0·4	52·0	34	1	33	63
			62	*2*	*60*	*115*
Orangite,						
Norway ____	9·4	51·1	63	30	33	64
			108	*50*	*58*	*114*
Monazite,						
N. Carolina	0·35	4·66	4·1	1·1	3·0	64
			7·1	*1·8*	*5·3*	*113*

It will be seen from the numbers given in the last column
that the activity of one gram of thorium oxide in the four dif-
ferent minerals varied less than one per cent when determined
in the smaller electroscope and not over two per cent from the
average when determined in the larger electroscope. This
variation is within the limits of error of the several measure-
ments.

It is therefore evident that for the four minerals examined
the activity of thorium per gram, or as it will be called, the
specific activity of thorium, was a constant. The difference in
value between the specific activity as determined in the smaller
electroscope is due in part to a greater sensitiveness for the
larger instrument and in part to the fact that more complete
ionization was obtained in the larger ionization vessel than in
the smaller. In the smaller electroscope a portion of the *a*-par-
ticles of longer range are stopped by the walls and charged

[*] The experimental determination of this factor will be described in a
later paper.

plate before they have reached the ends of their free paths in air, as a result of which the maximum ionization is not obtained. This is shown by the value of the ratio of the activities of the films in the smaller electroscope to the activities of the same films in the larger electroscope, which for the thorium minerals was equal to approximately 1·8, while the same ratio for a film of pure uranium oxide was only 1·6. This indicates that the average range of the a-particles from thorium is greater than the average range of the a-particles from uranium.

Radio-activity of Thorium Salts.

In order to determine whether the activity of thorium salts which had been separated from various minerals by different chemical methods was the same per gram of thorium as the specific activity of the thorium contained in the minerals, the following salts were examined :

1. Portion of about 18 grams of pure thorium oxide which had been obtained by working up a quantity of old worn-out incandescent gas mantels obtained from various sources. The mantel dust had been treated with sulphuric acid to convert the earths into sulphates, and the sulphates in dilute solution had been precipitated as oxalates with oxalic acid. The thorium in the oxalates was then extracted by boiling with a strong solution of ammonium oxalate, the solution was greatly diluted and was then allowed to stand in the cold for 48 hours, when the insoluble oxalates were filtered off. The thorium was precipitated as oxalate from the filtrate by the addition of hydrochloric acid to the boiling solution, and the oxalate was converted into oxide by intense ignition over the blast lamp. The oxide thus obtained was pure white.

2. Portion of a quantity (1 kilo) of thorium nitrate obtained from the Welsbach Light Co. A few grams of this nitrate were dissolved in water and the thorium was precipitated as hydroxide, which was then converted into the oxide by intense ignition over the blast lamp. The nitrate had been prepared by the Welsbach Co., by their customary process, from North Carolina monazite sand.

3. Thorium oxide prepared from the same material as No. 2. A portion of the nitrate was converted into the hydrated, crystalline sulphate $[Th(SO_4)_2 . 9H_2O]$. A few small, perfectly clear crystals were selected and converted into the oxide by intense ignition over the blast lamp.

4. A portion of the nitrate mentioned under No. 2 was converted into the anhydrous sulphate. The solution of the sulphate in cold water was heated and a quantity of the so-called

" basic " sulphate of thorium separated. This was ignited to a high heat to form the oxide.

5. Thorium oxide prepared from thorianite by the analytical method described earlier in this paper. The mineral was first dissolved in concentrated nitric acid.

6. Thorium oxide which had been prepared from thorianite. The mineral had been decomposed by fusion with sodium bisulphate and the thorium salts purified by conversion into the double ammonium oxalate as in the case of No. 5 above.

7. Thorium oxide obtained from North Carolina monazite sand by the operations described under the analysis of this mineral.

8. Thorium oxide supplied by Mr. H. S. Miner, chemist of the Welsbach Light Co., and stated by him to have been obtained from monazite sands by the ordinary analytical operations in which the thorium was separated from the other rare earths by repeated precipitation with sodium thiosulphate.

All of the samples of oxides here mentioned had been prepared at least one month previous to the time at which the measurements given in the table were carried out, and all had been subjected to the highest temperature of the blast lamp at the time of their preparation.

TABLE II.

Number.	Source of oxide.	Activity per gram of oxide.	
		Small electroscope.	Large electroscope.
1	Mantel dust	28	50
2	Welsbach nitrate	23	41
3	" "	26	46
4	" "	28	49
5	Thorianite	75	124
6	"	66	116
7	N. C. monazite	63	113
8	Miner's oxide	62	110

The activities of the oxides were determined for thin films in exactly the same way that the activities of the minerals were determined.

It is important to mention the fact that careful attention was given to the question of the emanating power of both the natural minerals and the separated thorium oxides described in this paper. The minerals were chosen particularly because of their low emanating power for both radium and thorium emanations, which was not over one per cent for the highest. Rutherford has shown[*] that the emanating power of ordinary

[*] Phys. Zeit., ii, 429, 1901.

thoria is greatly reduced by heating the material to a white heat. The oxides used in the present research were all heated in a platinum crucible to the highest heat of the blast lamp. Quantities several hundred times the weights of the films employed were tested for emanation by placing them in a closed vessel for 24 hours with a plate charged negatively to about 400 volts at a distance of about one centimeter above them. The plate was then tested in the electroscope, but no evidence of an active deposit was obtained. The oxides were therefore essentially non-emanating.

Discussion of Results.

The results obtained from the measurements of the activity of the separated thorium oxides indicate a number of interesting facts with regard to the activity of thorium. The oxides obtained from the commercial thorium salts (Nos. 1 to 4) are uniformly about half as active as the oxides separated from, or contained in, the natural thorium minerals. Since the source of the commercial thorium salts is monazite sand, and since it is shown that the thorium in this mineral and in the salts prepared from it by certain described analytical methods are of normal activity, it is obvious that the chemical treatment to which the commercial salts are subjected results in the separation of about one-half of their radio-active constituents. If it is assumed that the activity of thorium salts is due to the presence of radio-thorium and its disintegration products, then it must be assumed that in the salts of lower activity about one-half of the total radio-thorium present in the mineral has been separated from these salts. From the data given by Hahn[*] it would appear that in the method of separation by which his radio-thorium was obtained not more than at most two per cent of the total radio-thorium was separated from the mineral. The commercial method of preparing pure thorium salts is therefore much more efficient in effecting the separation of the radio-thorium.[†]

The fact that the specific activity of the thorium in the minerals was found to be constant is strongly in support of the theory that radio-thorium is a disintegration product of ordinary thorium. It would appear quite impossible to explain the agreement by any other assumption.

[*] Loc. cit.

[†] Several pounds of residues obtained from the treatment of monazite with concentrated sulphuric acid were kindly supplied by the Welsbach Company. These residues were examined for the presence of radium and radio-thorium, but with practically negative results for both substances. The amounts of these elements retained in the residues could not have been, at most, more than a fraction of a per cent of the amounts contained in the original mineral.

The data given in this paper has also a direct bearing on the claim made by Hofmann and Zerban[*] that the activity of thorium in a mineral is dependent on the amount of uranium contained in the mineral. There is a great variation in the uranium content of the two minerals thorianite and thorite, in fact the former contains nearly 18 times as much uranium per gram of thoria as the latter, but as shown in the table the specific activity of the thorium in both minerals is the same. This is also true for the thorium in the orangite and thorite. It is interesting to note that Dr. Zerban was so kind as to send the writer a specimen of 100 grams of gadolinite from Sotersdalen, Norway, supposed to be similar to that examined by Hofmann and Zerban. The mineral was slightly but quite measurably radio-active, was found to give off small quantities of radium emanation (corresponding to about 0·01 per cent U) on solution in acids, and on being worked up furnished a small quantity of thorium oxide of approximately normal activity. The same results were obtained with gadolinite from Llano County, Texas, and the same species of mineral from Ytterby, Sweden. In the published writings of Hofmann and Zerban there is nothing to indicate that any account was taken of the actinium in the minerals with which they worked. This radio-active element invariably accompanies the separated thorium, and in the thorium oxide separated from minerals containing much uranium and little thorium the activity due to the actinium may be much greater than the activity due to the thorium present. Thus, for example, the thoria separated from a sample of North Carolina uraninite, containing 1·5 per cent of ThO_2 and 68 per cent of uranium, was found 40 days after separation to have an activity measured in the smaller electroscope equal to over 550 divisions per minute, or nearly ten times the normal activity. A solution of ten grams of this mineral was, however, examined by Mr. Dadourian, using the excited activity method (see p. 427 of this number), for determining the activity of the thorium in solution, and the activity of the thorium as determined in this manner was found to be normal. All the data available at present point to the conclusion that the amount of actinium in a radio-active mineral is proportional to the amount of uranium in the mineral, and it is the opinion of the writer that the results obtained by Hofmann and Zerban are merely in support of this conclusion and have no direct bearing on the question of the activity of thorium and thorium compounds. In the table on page 422 of this paper (Table II), the high result obtained for the activity of the thorium oxide separated from thorianite (No. 5) is without doubt to be attri-

[*] Loc. cit.

buted to the presence of actinium in the compound. In the oxide, No. 6, the greater portion of the actinium had been separated from the thorium in some stage of the chemical treatment.

It is important to mention a certain fact with regard to the chemical properties of radio-thorium. Particular emphasis has been laid by Ramsay* on the statement that the oxalate of radio-thorium is insoluble in an excess of ammonium oxalate. It has already been pointed out by Mme. Curie† that the chemical properties of a radio-active element can not be determined with certainty from experiments conducted on a mixture of a small quantity of the active element with very large proportions of a neutral substance. The writer has found this to be particularly the case with actinium, which, when separated from a mineral containing thorium and other rare earths, persistently remains with the thorium through subsequent chemical operations, including the extraction of the thorium oxalate from a mixture of rare earth oxalates by an ammonium oxalate solution, but which, when separated (as "emanium") from a mineral containing no thorium, remains just as persistently with the lanthanum, if this element is present in the original mineral or is added to its solution, and remains undissolved if the lanthanum oxalate is treated with boiling ammonium oxalate solution. Similar conditions appear to hold for radio-thorium, and when accompanied by thorium its oxalate is readily soluble in a solution of ammonium oxalate. The insolubility of the radio-thorium in the thorium-free preparation described by Ramsay can in no sense be considered as indicative of its chemical behavior in an entirely pure condition. In these cases we have probably to do with a peculiar and novel sort of chemical entrainment which is quite distinct from the ordinary processes of solution and precipitation.

It is a very fortunate circumstance that, while the work described in this paper was in progress and before any definite conclusions had been reached, the investigation of the radio-active properties of thorium was quite independently undertaken by Mr. Dadourian, who now presents his results in a paper published in this same number of the Journal. Mr. Dadourian made use of a method which was distinctly different from that of the writer, and which depended on the measurement of the activity of the deposit formed on a negatively charged plate exposed to the emanations escaping from solutions of thorium salts and minerals. The agreement

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* Journ. de Chem. Phys., iii, 617, 1905.
† Compt. rend., cxxxii, 273, 1906.

shown in the results obtained by these two independent methods is certainly striking, and would seem to warrant the conclusions which have been reached in the matter. The thorium nitrate from thorianite used by Mr. Dadourian was prepared from the thorium oxide No. 6, mentioned on page 422 of this paper, and the thorium nitrate from North Carolina monazite was prepared from the thorium oxide denoted in the list as No. 7. The fact that Mr. Dadourian's values for the thorium activities of these two preparations are quite independent of any actinium or radium which might have been present, adds a special significance to the numbers obtained by him, as well as to the numbers which he obtained for the other thorium preparations. The agreement of the results obtained by both of us would appear to support the suggestion made by Hahn,[*] that the disintegration of thorium itself is rayless.

It affords me much pleasure to acknowledge my indebtedness to the Welsbach Light Company, and especially to their chemist, Mr. H. S. Miner, for their great kindness and generosity in supplying me with the greater part of the materials used in these investigations. Their uniform courtesy and liberality has been sincerely appreciated.

Conclusions.

1. The specific activity of thorium with its equilibrium quantities of disintegration products is constant.

2. Radio-thorium is a disintegration product of ordinary thorium.

3. Certain of the ordinary, commercial salts of thorium contain only about one-half of the equilibrium quantity of radio-thorium corresponding to the thorium present.

4. The change undergone by thorium in disintegrating to form radio-thorium is probably rayless.

New Haven, Conn., April, 1906.

[*] Loc. cit.

Art. XXXVIII. — *The Radio-activity of Thorium ;** by
H. M. Dadourian.

It has been shown by O. Hahn † that it is possible to sepa-
rate from thorianite minute quantities of a radio-active sub-
stance which is far more active than what is known as thorium.
The fact that this substance gives off the same emanation as
thorium has led him to suggest that the activity of thorium
may be due to the presence in thorium of this substance, which
he has named radio-thorium. He has further made the natural
supposition that radio-thorium is a disintegration product of
thorium. But so far as the writer knows, radio-thorium has
not yet been separated from any source except thorianite and
no quantitative determi-
nations of the relation
between the amount of
thorium and its r a d i o -
activity has been made,
so that the interesting
suggestions m e n t i o n e d
above cannot be regarded
as fully confirmed.

The following experi-
ments were undertaken in
order to determine the
quantitative relation be-
tween the thorium activ-
ity of various · minerals
and separated salts, and
their content of thorium.

The m e t h o d used is
· based upon the measure-
ment of the excited activ-
ity obtained by exposing
a negatively charged body to the emanations evolved by the
substance to be tested. The adjoining figure is a sketch of
the charging vessels used in these experiments. Each mineral
or salt to be tested was dissolved and the solution poured into
a flat-bottomed glass dish, A, of 9·5^{cms} diameter and 4^{cms}
depth. This was placed in a tin vessel, C, of 15^{cms} diameter
and 18^{cms} height, which had a movable cover and could be made
air-tight. The body upon which the active deposit was to be
obtained was a circular copper plate, BB, of 11^{cms} diameter,
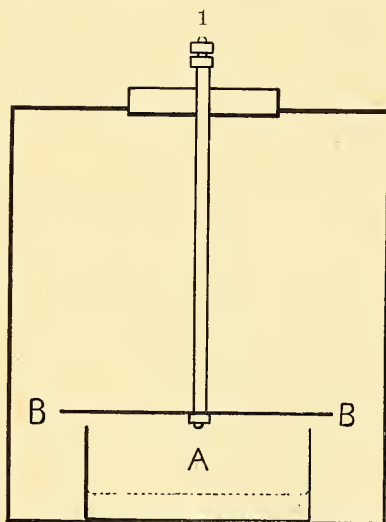
* Read before the American Physical Society, Feb. 24, 1906.
† Chemical News, April 28 and Dec. 21, 1905, Jahrbuch für Radioactivität
und Electronik, 1905.

insulated from the tin vessel and connected to the negative terminal of a battery of 400 volts, the other terminal being connected to the tin vessel.

After exposures of 19 hours the copper plates were taken out of the charging vessels and introduced into a testing vessel connected with a Dolezalek electrometer, and the activity observed as usual. Another testing vessel, containing a uranium oxide standard, was connected with the electrometer, in parallel with the first testing vessel, in order to test the sensitiveness of the electrometer during the experiments and allow for changes in the sensitiveness if there were any. The electrometer had a sensitiveness of about 200^{cms} per volt with 100 volts on the needle and the scale at a distance one meter from the mirror.

The emanation generated at a given horizontal layer of the solution has to diffuse through the liquid above that layer in order to reach the surface. Therefore on account of the rapid decay of the thorium emanation (half-value period being 54 seconds) the percentage of the emanation, generated at that layer, which reaches the surface of the solution, will depend upon the depth of the layer. Thus the concentration being the same, the emanation which crosses a square centimeter of the surface per second depends upon the depth of the solution, provided it is not so deep that the emanation produced at the bottom has time enough to decay to a negligible value before reaching the surface, in which case it will be independent of the depth of the solution. The solutions used in these experiments were not deep enough to fulfill the above condition, therefore it was necessary to make all the solutions of the same depth. The equality of depth was realized by putting equal volumes (50^{cc}) of each solution in the flat-bottomed dishes, which were of the same diameter (9·5^{cms}). For similar reasons the negatively charged plates were kept at equal distances from the surface of the solution to which they were exposed.

The solutions tested were of different concentration, therefore in order to be able to compare their activities it was necessary to determine the quantitative relation between the concentration of the solution and the amount of emanation obtained. Two solutions of thorium nitrate were prepared, one of which had a concentration twice as great as the other. Equal volumes of these solutions were placed in flat-bottomed glass dishes of equal diameter, thus securing equal depths. Two copper plates were exposed to these solutions under similar experimental conditions and introduced into the testing vessel. The ionizations produced by the active deposits obtained from the more concentrated and the less concentrated

solutions were found to be 10·9 and 5·4 respectively. These results show that, everything else being the same, the amount of emanation obtained is strictly proportional to the concentration of the solution, as would be expected on theoretical grounds.

The substances tested, chosen on account of their easy solubility, and the results obtained are given in the following table:

Substance.	No. of grams in solution.	Percentage of ThO₂.	No. of grams of ThO₂.	Observed activity.	Specific activity.
I.	II.	III.	IV.	V.	VI.
Thorite	2·00	51·7	1·034	25·7 / 26·3	24·8 / 25·4
Thorianite	1·29	76·5	0·987	21·2 / 25·2	21·5 / 25·5
Thor. nitrate (1)	2·20	45·6	1·003	10·7	10·7
" " (2)	2·15	46·6	1·002	12·5	12·5
" " (3)*	1·00	38·0	0·38	4·3	11·3
" " (4)	0·77	48·9	0·376	8·3	22·1
" " (5)	2·07	48·3	1·00	22·0	22·0

Column I. The thorite was dissolved in dilute hydrochloric acid. The solution was evaporated to dryness, to render the silica insoluble, the silica filtered off and the filtrate diluted in 50ᶜᶜ of distilled water. The thorianite was dissolved in concentrated nitric acid, the solution diluted and a slight residue of insoluble material filtered off. The solution was then evaporated to remove the excess of nitric acid and the remainder diluted to 50ᶜᶜ with distilled water. The thorium nitrates number (1) and number (2) were prepared by the Welsbach Light Co., from North Carolina and Brazilian monazites respectively. Thorium nitrate number (3) was bought from Eimer & Amend about three years ago. Thorium nitrates number (4)† and number (5)† were prepared from North Carolina monazite and from thorianite respectively, by Dr. B. B. Boltwood, to whom the writer is indebted for the minerals and salts tested in these experiments, as well as for their chemical analyses.

Column II gives the number of grams of the substances in the solutions, column III the percentage of thorium oxide in each substance.

In column IV the number of grams of thorium oxide present in the solutions is given. It is obtained by multiplying the numbers of column II by those of column III.

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* The percentage of ThO₂ of this salt was not known, therefore it was calculated from the formula Th(NO₃)₄+12H₂O. This gives the minimum percentage, hence the calculated specific activity is maximum.

† The process of preparation of these salts is given in a paper by Dr. B. B. Boltwood, in this number of the Journal.

Column V gives, in centimeters per minute,* the average of the ionization produced by the active-deposit measured between 4 and 5 hours after the removal of the potential difference from the negatively charged plate. Some of the substances tested contained more or less radium and actinium. Therefore a comparison of the activities observed during the first few hours, after the removal of the potential difference, could not have been a comparison of the activities due to thorium. But thanks to the rapid rates of decay of the excited activities due to radium and actinium compared with that due to thorium, the activities observed after 4 hours from the removal of the potential difference were entirely due to thorium, the part contributed by radium and actinium having become negligible. Two sets of observations were taken for thorite and thorianite, of which the second set was taken under more favorable experimental conditions. The average observed activities obtained from the first set were 25·7 for thorite and 21·2 for thorianite, while those obtained from the second set were 26·3 and 25·2 respectively.

In column VI the activity per gram of thorium oxide of each substance is given. It is obtained by dividing the numbers of column V by those of column IV. For brevity this will be called the specific thorium activity of the substance.

The agreement between the specific thorium activities of thorite and thorianite is striking, when the difference in nature and origin of these minerals and the experimental difficulties are taken into consideration. On the other hand, there is just as close an agreement among the specific thorium activities of the first three thorium nitrates in the table. Yet there is a marked difference between the specific activities of these two groups, the thorium in the salts being only about half as active as the thorium in the minerals. This difference could not be explained by possible experimental or accidental errors. It was to be accounted for in some other manner. At first it was assumed that thorium might be composed of two or more simple elements of which only one was undergoing radio-active disintegration and giving off the characteristic thorium emanation. According to this, the specific thorium activity will be different for different substances which do not have a quantity of the emanating component proportionate to their content of the remaining components. Thus the difference among the specific activities is accounted for, but the agreement, which is of greater significance, remains to be explained. On account of its improbability and insufficiency this assumption, with some others which will not be considered here, was abandoned in favor of another.

* The spontaneous ionization in the testing vessel was 0·45^{cms}.

According to this hypothesis radio-thorium is a disintegration product of thorium and the producer of thorium X. Thorium emanation being a radio-active product of thorium X, the amount given off by a substance is proportional to the quantity of thorium X present. For a substance in which thorium X and radio-thorium are in radio-active equilibrium, the quantity of thorium emanation given off will be proportional to the amount of both thorium X and radio-thorium but not necessarily to that of thorium present in the substance. If, however, all three, thorium, radio-thorium and thorium X, are in radio-active equilibrium, the proportionality will hold for each of them. All of the substances tested were in radio-active equilibrium as regards thorium X. Therefore the quantity of thorium emanation evolved by any of them should be proportional to the amount of radio-thorium only or to the amount of both radio-thorium and thorium present, according as the latter were or were not in radio-active equilibrium in the substance.

The experimental results given in the above tables follow as natural consequences of this hypothesis. Thus the amount of thorium emanation evolved by the solutions of the minerals should be proportional to their content of thorium as well as radio-thorium, as these are, in all probability, in radio-active equilibrium in the minerals. In other words, the specific thorium activity of the minerals should be the same. This was shown to be the case for the minerals tested, and thorium nitrate number (5), which was prepared from thorianite.

On the other hand, this hypothesis leads to the conclusion that the low specific thorium activity of the commercially prepared salts is due to the loss of part of the radio-thorium in the process of chemical preparation. Therefore, if thorium nitrate salts are prepared from minerals without losing any radio-thorium, their specific thorium activity should be the same as those of the minerals. In order to test this, thorium nitrate number (4) was prepared from 10 grams of North Carolina monazite. The specific thorium activity of this salt was found to be 22·1. This is about the same as the specific thorium activities of thorium nitrate number (5) and the minerals thorite and thorianite. But thorium nitrate number (1), which was prepared from the same mineral (North Carolina monazite), had a specific thorium activity of only 10·7.* The only rational explanation of this great difference in the activity of thorium obtained from the same mineral but by two different analytical methods, is the one just given.

Thus thorium and radio-thorium were in radio-active equilibrium in the specimens of North Carolina monazite from

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* Dr. B. B. Boltwood tested these substances by a method described in a paper in this number of the Journal and arrived at similar results.

which thorium nitrates number (1) and number (4) were prepared. No appreciable amount of radio-thorium was lost in the preparation of thorium nitrate number (4). Therefore thorium and radio-thorium were in equilibrium in this salt. This accounts for the fact that its specific thorium activity was about the same as those of the minerals.

About half of the equilibrium quantity of the radio-thorium, on the other hand, must have been separated from thorium nitrate number (1) during the process of its chemical preparation. The few years' time which had elapsed between its preparation from the mineral and these experiments was too short for the thorium and radio-thorium, in the salt, to come into radio-active equilibrium, hence the low specific thorium activity.

The more important conclusions arrived at by the above experiments may be summed up as follows :

First. The amount of radio-thorium in minerals is proportional to the quantity of thorium present. Therefore radio-thorium is a transformation product of thorium.

Second. If thorium and its successive products radio-thorium and thorium X are in radio-active equilibrium in a substance, the amount of thorium emanation evolved by the substance is proportional to the quantity present of any and all of them.

Third. The difference in the specific thorium activities of substances which are in radio-active equilibrium with regard to thorium X, is due to the separation of some of the equilibrium amount of the radio-thorium from the substance.

Fourth. The fact that thorium nitrate number (3), which was prepared over three years ago, was notably deficient in radio-thorium, indicates that the rate of recovery and consequently the rate of decay of radio-thorium is very slow, and that the half-value period cannot be below two years.

In conclusion, I wish to express my hearty thanks to Professor H. A. Bumstead for suggesting these experiments and for the kind interest he has shown during the progress of the work.

Sheffield Scientific School of Yale University,
        New Haven, Conn.

Art. XXXIX.—*The Relation between the Radio-activity and the Composition of Thorium Compounds;* by H. N. McCoy and W. H. Ross.

The work here described was undertaken with two objects in view. The first was to determine the relation between the radio-activity of thorium minerals and their thorium content, and the second to determine the intensity of radio-activity of thorium, free from its transformation products. The first of these problems was readily solved in a very decisive manner; but the complete separation from thorium of all of its products has proved to be so difficult that we shall not longer delay reporting on the results already obtained.

One of us has shown[*] that the total activity of any pure uranium compound or of any uranium mineral, free from thorium, is, for each class, proportional to the uranium content of the substance; but that minerals are 4·15 times as active as the pure compounds of equal uranium content. The excess of activity of the ores is due to radium, etc.; and the above results seem to show that all of the radio-active bodies found in thorium-free uranium minerals are transformation products of uranium.

The present study, in a similar manner, of compounds and minerals containing thorium, with or without uranium, forms the natural sequel to the work on uranium. The reports of the interesting work of Ramsay,[†] Sackur[‡] and Hahn[§] on the isolation, in a crude state, of a very highly active body, called radio-thorium, from a thorium ore, though they appeared while the present work was in progress, only served to increase the importance of this investigation.

All of the thorium minerals which we have studied contained uranium in measurable, though often very minute, quantities. When the activity due to uranium and its products had been allowed for, the remaining activity, due to the thorium and its products in the mineral, was, in every case, proportional to the thorium content of the sample. The activity due to 1^g of thorium, together with its products, in a mineral, is about 950, the unit of activity being that due to $1^{sq\ cm}$ of a thick film of uranium oxide, U_3O_8.[||] The activity of pure

[*] McCoy, Ber. d. chem. Ges., xxxvii, 2641, 1904; Phil. Mag. [6], ix, 176, 1906.

[†] J. de Chimie Phys., iii, 617, 1905.

[‡] Ber. d. chem. Ges., xxxviii, 1756, 1905.

[§] Hahn, ibid., xxxviii, 3371, 1905, Radioaktivität, ii, 233, 1905.

[||] The activity of 1^g of uranium in a pure compound is 791, while that of the same quantity of uranium, plus its products, in a mineral, is 3280. $3280 = 4·15 \times 791$.

thorium dioxide, ThO_2, resulting from the analysis of thorium minerals, increases with time and reaches a maximum about thirty days after extraction ; at the end of this time the activity due to the thorium and products is practically equal to that of an equal mass of thorium contained in a mineral.

Since it has been shown[*] that radio-thorium, Rt, extracted from a thorium mineral, gives ThX, etc., it would seem almost certain that the following series represents the successive products of thorium, if, as the present work clearly shows, Rt is the product of Th.

$$Th \rightarrow Rt \rightarrow ThX \rightarrow Em \rightarrow ThA \rightarrow ThB.$$

Rutherford and Soddy[†] have shown how ThX and subsequent products may readily be removed, and Schlundt and Moore[‡] have confirmed and extended these observations. It is an easy task to reduce, by the methods of these investigators as well as by a number of other new methods which we have found equally effective, the activity of thorium to a small fraction of the original value ; but within a month practically the whole of the activity is regained. These processes do not appreciably remove radio-thorium, the separation of which from thorium is a difficult matter, and one which we have not yet completely accomplished.

The determination of the radio-activity of thorium compounds is not as simple as in the case of uranium compounds, because the former produce a gaseous emanation, the activity of which is considerable compared with that of the solid film. One of us has shown[§] that the total radio-activity of a uranium compound may be determined in two ways. Each of these two ways involves the quantitative measurement of the activity of thin films of the substance, of known weight, varying from about 1 to 20^{mg} per sq. cm. The thickest of such films of all uranium compounds show maximum activity. The total activity of unit weight of a uranium compound is twice the activity due to one surface of an infinitely thin film of unit weight. The activity of such an ideal film is found by graphical extrapolation, for zero weight, of the observed values of the ratio of the weight, w, to the activity, a, of very thin films. The limiting value of this ratio is designated as $\left(\dfrac{w}{a}\right)_0$. The total activity of unit weight of the compound, $k_1 = 2/\left(\dfrac{w}{a}\right)_0$. This method may be applied to the compounds of thorium.

* Hahn, loc. cit.
† Phil. Mag. [6], iv, 370, and v, 69, 1902.
‡ J. Phys. Chem., ix, 682, 1905.
§ McCoy, J. Am. Chem. Soc., xxvii, 391, 1905.

Good films of thorium dioxide may be made, as in the case of uranium compounds, using alcohol as the suspending liquid. Critical consideration leads to the conclusion that the emanation produced by a thorium compound must be distributed into three parts; (1) *retained* in the granules of the substance; (2) *emanated* by the granules and *absorbed* by the film; (3) *emanated* by the granules and *evolved* by the film. These three portions of the emanation will be referred to as the *retained*, the *absorbed*, and the *evolved* emanation. Together the *absorbed* and the *evolved* constitute the whole of the *emanated* emanation.

The effect of the evolution of the emanation on the observed activity of the film can be determined theoretically. In the case of a film which has been freely exposed to the open air for at least several hours, the activity due to the film alone is diminished by reason of the loss of emanation. This diminution is due to a deficiency, both of the emanation and of thorium B, the active product of the emanation. The activity of ThB is approximately equal to that of the equilibrium quantity of emanation* and therefore the loss of activity is equal to twice that due to the emanation which has escaped. The activity of a film placed in a small closed space, such as an electroscope case, increases with time and reaches a maximum in about five minutes. The increase of activity is due to the accumulation of the evolved emanation. The activity of this evolved emanation is exactly twice as great as if it had remained in the very thin film, because there is now no absorption of the radiation by the metallic plate, on which the film is deposited. It follows from these considerations that the actual activity of the evolved emanation exactly compensates for the deficiency of activity of the solid film. Therefore *the observed activity of a very thin film of a thorium compound is equal to the true activity.* This relation holds very closely for films of strongly ignited thorium dioxide up to about ·005^g per sq. cm. The thorium dioxide, sample A, used in the preliminary measurements was made by heating and finally igniting strongly, in the blast, thorium nitrate made by C. A. F. Kahlbaum. This sample was said to contain ammonia only as an impurity. Its purity otherwise and freedom from non-volatile impurities was established by the analysis of a solution made by dissolving about 4^g in 250^{cc} of water. 25^{cc} evaporated to dryness and ignited gave 0·1750^g of residue; portions of 25^{cc} diluted and precipitated with ammonia gave upon ignition ·1746 and ·1748^g. Finally portions of 25^{cc} gave by Neish's method† ·1751 and ·1754^g of pure ThO$_2$. The

* Rutherford, Radioactivity, p. 307, 1904.
† J. Amer. Chem. Soc., xxvi, 780, 1904.

close agreement of the results of the three methods shows clearly the purity of the sample. The activity of sample A was determined more than a month after preparation; when it had attained a constant (maximum) value.

Table I gives the results obtained with very thin films of sample A of thorium dioxide; w is the weight of the film; a is the observed activity of the film, the unit of activity being that due to $1^{sq\ cm}$ of a thick film of pure U_3O_8. The area of each film was $39.8^{sq\ cm}$.

<div align="center">

TABLE I.   THORIUM DIOXIDE—A.

w	a	$\dfrac{w}{a}$
·2798	41·36	·00676
·2020	30·80	·00599
·1026	20·70	·00495
·0546	12·27	·00444

$$\left(\frac{w}{a}\right)_0 = ·00387$$

1

</div>

Weight, w.
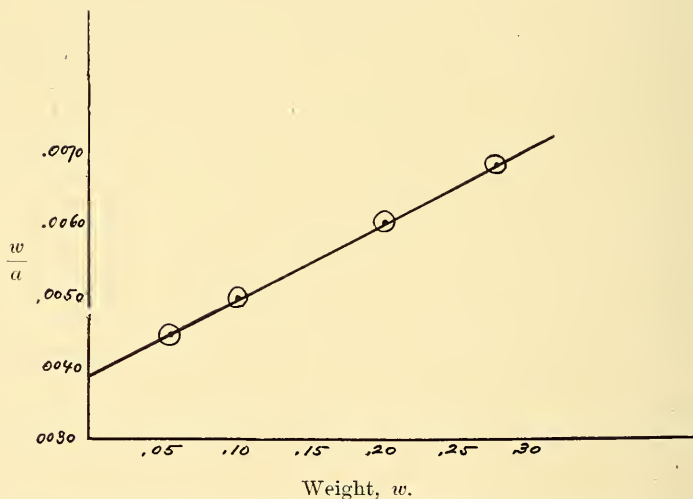
Curve I, which is nearly a straight line, represents Table I. $\left(\dfrac{w}{a}\right)_0 = ·00387$. Accordingly k_1, the specific activity of this sample of thorium dioxide, is equal to $\dfrac{2}{·00387} = 517$.

The observed activity of thicker films of thorium compounds must be corrected for the effect of the emanation. To do this the activity of the evolved emanation must be known. This was found as follows: the film was allowed to remain

in the electroscope case for 5 or 6 minutes in order to allow the maximum amount of emanation to accumulate. The electroscope was then charged and as soon as the leaf had reached the beginning of the scale, in the subsequent discharge, the film was rapidly withdrawn from the case, by means of a thread. The small door of the case opened and closed automatically. At the instant of removing the film the position of the leaf on the scale was noted and the stop-watch was started. The leaf continued to move with gradually decreasing velocity for about 5 minutes; at the end of which period the emanation had almost completely decayed and the motion of the leaf had become very slow and uniform, corresponding to the natural leak of the instrument. Calling D the number of divisions of the scale traversed by the leaf in 5 min., corrected for the natural leak, and E the initial activity of the emanation, then $E = \cdot 173 \, D$; as shown by the following calculation. Unit activity discharged the electroscope $\cdot 075$ division per sec. Therefore $\dfrac{dD}{dt} = \cdot 075 E_t$

$$E_t = E e^{-\lambda t}$$

$$\frac{dD}{dt} = \cdot 075 E e^{-\lambda t}$$

$$D_t = \frac{\cdot 075 E}{\lambda} (1 - e^{-\lambda t}).$$

For the thorium emanation $\lambda = \cdot 013$. If $t = 300$ sec. $e^{-\lambda t} = 0$ practically, and therefore

$$E = \cdot 173 \, D$$

E is very small except for the thicker films. Table II gives the results for some thick films of sample A of thorium dioxide.

TABLE II.

w	E	$\dfrac{w}{E}$	F
1·8893	2·17	·87	·68
·9182	1·20	·77	·80
·2798	·43	·65	·90

$$\left(\frac{w}{E}\right)_0 = \cdot 58$$

$\left(\dfrac{w}{E}\right)_0$ represents the value of the ratio $\dfrac{w}{E}$ for an infinitely thin film, curve II. For such an ideal film of unit weight, the activity of the *evolved* emanation would be $\dfrac{1}{\cdot 58} = 1 \cdot 71$. This is also the activity of the *emanated* emanation of unit weight

of this sample of thorium dioxide, since there would be no absorption of the emanation by such a film. The fraction emanated, of the whole amount of emanation produced by the sample, can now be calculated. About one-fourth of the activity of ThO_2 is due the emanation.* Therefore the total activity of the whole of the emanation of 1^g of the sample $= \dfrac{517}{4} = 129$. $\dfrac{1·71}{129} = ·013$. Therefore $1·3$ per cent of the whole emanation is emanated. The last column of Table II gives the fraction, F, of the *emanated* emanation which is *evolved* by the film.

The above results may now be used to correct the observed activity of a thick film. The observed activity, a_1, of a film of

Weight, w.
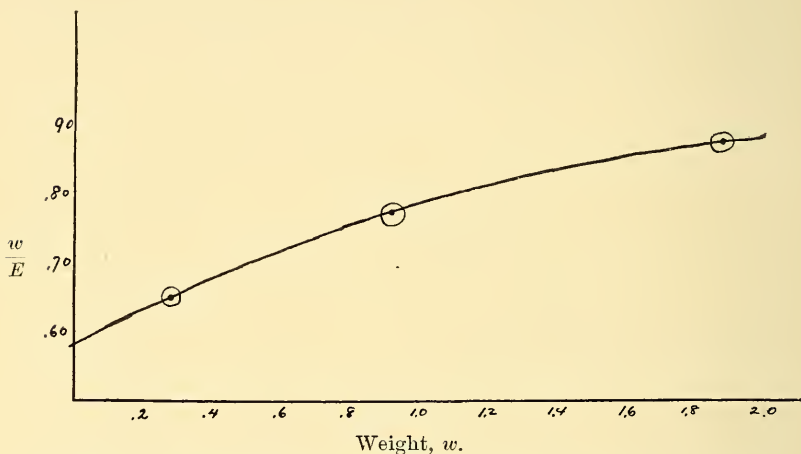
a thorium compound is too great by the amount E, the activity of the *evolved* emanation. But the value $a_1 - E$, which represents the activity of the solid film alone, is too low, because the film has lost a fraction of its emanation and ThB. The lost activity is equal to $2E$ since the activity of the ThB is equal to that of the equilibrium amount of the emanation. The total activity of the film is $k_1 w$. Therefore the true activity of the film is

$$a = \frac{a_1 - E}{1 - \dfrac{2E}{k_1 w}}$$

Table III gives in column 2 the observed values of the activity, a_1, and in column 3 the corrected values, a. The

* Rutherford, loc. cit.

fourth column contains the values of the ratio, x, of the activity of any film to that of a thick film of maximum activity. $x = \dfrac{a}{56 \cdot 9}$.

$$k_2 = \frac{2 \cdot 303\, s}{w} \log \frac{1}{1-x}$$

k_2 is the absorption coefficient* and s is the area of each film, $39 \cdot 8^{\text{sq cm}}$.

TABLE III. THORIUM DIOXIDE—A.

w	a_1	a	x	k_2
·0546	12·27	12·26	·216	177
·1026	20·70	20·66	·363	175
·2020	33·80	33·66	·592	177
·2798	41·36	41·0	·721	182
·9182	55·6	54·7	- - -	- - -
1·8893	58·8	56·9	- - -	- - -
			Mean	178

The specific activity, k_1, of the sample can now be calculated from the absorption coefficient.

$$k_1 = \frac{2 k_2 a}{s} = \frac{2 \times 178 \times 56 \cdot 9}{39 \cdot 8} = 509$$

The mean value of k_1, for the two methods, is 513.

Thorium dioxide contains 87·9 per cent of thorium. Therefore the activity of unit weight of thorium, together with its active products in sample A, is $\dfrac{513}{879} = 584$. The activities of several thorium minerals have been determined by the extrapolation method as worked out for sample A of pure thorium dioxide. The locality of origin and the composition are shown in Table IV.

TABLE IV.

No.	Name.		Per cent Th.	Per cent U.
1	Orangite	Langesundsfjord, Norway	43·1	7·76
2	Thorite	" "	46·6	6·26
3	Monazite	McDowell Co., N. Carolina	5·27	·33
4	"	Roade, Norway	15·18	·46
5	"	Commercial sample	2·72	·12

The analyses for thorium were made by the method of Neish† and for uranium by reduction with zinc in sulphuric acid

* McCoy, J. Chem. Soc., xxvii, 395, 1905.
† Loc. cit.

solution and titration with permanganate* after separation as phosphate by the method of Brearley.†

The activity of films of thorium minerals can be corrected for the effect of the emanation according to the formula applied to films of pure ThO_2. In calculating a from a_1, the approximate value of k_1, as found from the uncorrected activity of the thinner films, was used. This procedure involved no appreciable error.

The results are given in Tables V to IX. The significance of the symbols has already been given. The curves for all the minerals were smooth. It is not necessary to reproduce them here.

TABLE V.   ORANGITE, No. 1.

w	a_1	a	$\dfrac{w}{a}$	E
1·2400	52·29	47·2	·02628	5·8
·3415	45·01	44·1	·00775	1·5
·2259	39·24	38·8	·00583	1·0
·1212	28·46	28·3	·00428	‡(·55)
·0526	14·85	14·8	·00355	(·24)

$$\left(\frac{w}{a}\right)_0 = ·00310 \qquad\qquad \left(\frac{w}{E}\right)_0 = ·22$$

TABLE VI.   THORITE, No. 2.

w	a_1	a	$\dfrac{w}{a}$	E
1·1825	50·51	47·1	·02511	3·90
·3243	43·03	42·4	·00765	1·16
·2339	39·37	39·0	·00600	·88
·1349	29·74	29·6	·00456	(·53)
·0904	22·61	22·6	·00400	(·34)

$$\left(\frac{w}{a}\right)_0 = ·00301 \qquad\qquad \left(\frac{w}{E}\right)_0 = ·26$$

TABLE VII.   MONAZITE, No. 3.

w	a_1	a	$\dfrac{w}{a}$	E
1·0587	4·70	4·55	·233	·17
·2825	3·96	3·94	·0717	·04
·2059	3·43	3·42	·0602	(·03)
·1094	2·36	2·35	·0466	(·02)
·0476	1·23	1·23	·0387	(·01)

$$\left(\frac{w}{a}\right)_0 = ·0332 \qquad \left(\frac{w}{E}\right)_0 = 6·2$$

* Kern. J. Amer. Chem. Soc., xxiii, 685, 1901 ; Pulman, this Journal, xvi, 229, 1903.

† Analytical Chemistry of Uranium, 1903.

‡ The values of E in parenthesis are calculated from $E = w \Big/ \left(\dfrac{w}{E}\right)_0$.

TABLE VIII.   MONAZITE, No. 4.

w	a_1	a	$\dfrac{w}{a}$	E
1·1081	12·83	12·27	·0903	·64
·2973	10·75	10·64	·0279	·17
·2123	9·53	9·48	·0224	·12
·1078	6·26	6·24	·0173	(·06)
·0526	3·68	3·67	·0143	(·03)

$$\left(\frac{w}{a}\right)_0 = ·0122 \qquad\qquad \left(\frac{w}{E'}\right)_0 = 1·7$$

TABLE IX.   MONAZITE, No. 5.

w	a_1	a	$\dfrac{w}{a_1}$	E
1·0590	2·15		·493	
·3174	1·89		·168	
·2156	1·70	a is practically equal to a_1	·127	Too small to be accurately measured
·1375	1·37		·100	
·1170	1·25		·094	
·0785	·89		·088	
·0348	·46		·076	

$$\left(\frac{w}{a}\right)_0 = ·067$$

In Table X, k_{1m} represents the total activity of 1^g of the mineral as calculated from

$$k_{1m} = 2 \Big/ \left(\frac{w}{a}\right)_0$$

k_{1U} represents the activity due to the uranium and products contained in 1^g of the mineral. This is equal to 3280 times the weight of uranium in 1^g of the mineral, since it has been shown[*] that the total activity of that quantity of any thorium-free mineral containing 1^g of uranium is 3280 units. k_{1Th} is the difference between k_{1m} and k_{1U}; it represents the total activity, due to the thorium and its products, in 1^g of the mineral. In the last column P_{Th} is the weight of thorium in 1^g of the mineral. $\dfrac{k_{1Th}}{P_{Th}}$ is as nearly constant as one could reasonably expect, considering that all of the errors of experiment are accumulated on this ratio. The radio-activity of any mineral which is sufficiently old, geologically, is therefore equal to $3280\,P_U + 953\,P_{Th}$.

TABLE X.   THORIUM MINERALS.

No.	Name	%Th	%U	k_{1m}	k_{1U}	k_{1Th}	$\dfrac{k_{1Th}}{P_{Th}}$
1	Orangite __	43·1	7·76	649	255	394	914
2	Thorite ___	46·6	6·26	664	205	459	985
3	Monazite __	5·27	·33	60·2	10·9	49·3	935
4	" __	15·18	·46	164	15	149	982
5	" __	2·72	·12	29·8	4·0	25·8	950

Mean = 953

[*] McCoy, Phil. Mag. (6), xi, 176, 1906.

All of the thorium activity measurements, as well as those of uranium compounds and minerals, were made with a distance of $3\cdot5^{cm}$ between the active films and the charged electrode. While this thickness of air is sufficient to absorb practically all of the alpha rays of uranium, it is scarcely great enough to absorb completely the more penetrating alpha rays of some of the radium and thorium products.* With a greater distance than $3\cdot5^{cm}$ between the films and electrode a somewhat greater activity will be found for uranium and thorium minerals. The general relationship between the radio-activity and the composition of such minerals having now been fully established, we are starting a new series of measurements on minerals with the object of determining their activities under conditions such that the maximum ionizations due to the alpha rays can take place in the space between the film and the electrode.

In the analyses of the minerals the thorium was weighed as dioxide. This was very pure, chemically. It had been separated by Neish's method, having been precipitated once by oxalic acid, once by potassium hydroxide and two or three times by m-nitrobenzoic acid. The activity measurements of three such samples, B, C, and D, were made from time to time until after about one month the activities had reached constant maximum values. The ThO_2 then contained the maximum amounts of ThX, Em, ThA and ThB. The results of the maximum values are given in Tables XI to XIII with a summary in Table XIV.

TABLE XI.   THORIUM DIOXIDE B.

w	a_1	a	$\dfrac{w}{a}$	E
$\cdot2267$	$61\cdot4$	$60\cdot9$	$\cdot00372$	$1\cdot04$
$\cdot1170$	$40\cdot2$	$40\cdot1$	$\cdot00292$	$(\cdot5)$
$\cdot0673$	$25\cdot1$	$25\cdot1$	$\cdot00268$	$(\cdot3)$

$$\left(\frac{w}{a}\right)_0 = \cdot00243$$

TABLE XII.   THORIUM DIOXIDE C.

w	a_1	a	$\dfrac{w}{a}$	E
$\cdot2634$	$68\cdot2$	$67\cdot8$	$\cdot00389$	$1\cdot04$
$\cdot1292$	$41\cdot8$	$41\cdot7$	$\cdot00310$	$(\cdot5)$
$\cdot0657$	$24\cdot1$	$24\cdot1$	$\cdot00273$	$(\cdot2)$

$$\left(\frac{w}{a}\right)_0 = \cdot00230$$

*Rutherford Radioactivity, p. 135, 1904; Bragg, Phil. Mag., viii, 721, 1904; Bragg and Kleeman, Ibid., x, 318 and 600, 1905.

TABLE XIII. THORIUM DIOXIDE D.

w	a_1	a	$\dfrac{w}{a}$	E
·2088	57·6	57·2	·00365	1·1
·1083	35·9	35·7	·00303	(·6)
·0585	21·6	21·5	·00272	(·3)

$$\left(\frac{w}{a}\right)_0 = ·00240$$

TABLE XIV. THORIUM DIOXIDE.

Sample	Source	$\left(\dfrac{w}{a}\right)_0$	k_1	$\dfrac{k_1}{P}$
A	Th Nitrate _____	·00387	517	588
B	Orangite No. 1 _____	·00243	823	936
C	Thorite No. 2 _____	·00230	870	989
D	Monazite No. 4 _____	·00240	833	948
	Mean of B, C and D __			958

The mean value of $\dfrac{k_1}{P}$ for the last three samples is 958, while the value of the corresponding ratio for thorium in minerals is 953. From this it follows that none of the radiothorium has been separated from the thorium by the processes of analysis. However, we have been able by certain other processes, many times repeated, to reduce the permanent activity of thorium considerably below that of sample A, presumably by the removal of part of the radio-thorium, but we have not yet obtained thorium which is, or remains, entirely inactive. We shall discuss this problem fully in a later paper. It is possibly still a question whether thorium, entirely freed from radio-thorium, ThX, etc., will produce rays capable of ionizing gases;[*] but that it is undergoing transformation, rayless or otherwise, which gives rise to active products, seems certain from the fact that the portion of the radio-activity due to thorium, of any mineral, is directly proportional to the thorium content of that mineral. We believe our experiments also show clearly that the activity of thorium compounds is not due to bodies accidentally retained by thorium (as radium frequently is by barium sulphate), but that the radio-thorium, ThX, etc., are disintegration products of thorium.

Kent Chemical Laboratory,
University of Chicago, April, 1906.

[*] Inactive or slightly active thorium has been reported several times (Hofman and Zerban, Ber. d. chem. Ges., xxxvi, 3093, 1903; Zerban, ibid., xxxviii, 557, 1905; Baskerville and Zerban, J. Amer. Chem. Soc., xxvi, 1642, 1904; but in such cases no statement has been made of the minimum intensity of activity that could have been detected.

Art. XL.—*Prorosmarus alleni, a new genus and species of Walrus from the Upper Miocene of Yorktown, Virginia;* by Edward W. Berry and William K. Gregory.

During a recent excursion of one of the classes in geology of the Johns Hopkins University, one of the students, William E. Curley, Jr., found on the beach at Yorktown, Va.,* a left mandibular ramus of a new extinct mammal evidently allied to, but much more generalized than the existing species of walrus, *Odobænus rosmarus* and *Odobænus obesus.* The specimen was presented to the Department of Geology of the University, where it is now deposited under the care of Professor William Bullock Clark, who has generously entrusted it to the present writers for identification and description.

The new genus agrees with *Odobænus:* (1) in the general characters of the mandible; (2) in the general location of the mental foramen, which is in each case followed by a much smaller foramen; (3) in the cylindrical shape of the cheek teeth. In other characters *Prorosmarus* is much more primitive and approaches the Otariidæ or Eared Seals in the following features: (1) The mature jaw retains two well developed incisors in each ramus as in the young walrus, the adult walrus lacking the incisors. (2) The canine retains its primitive position and caniniform shape, whereas in the walrus the canine has been taken over into the molariform series, as shown by its biting against the molariform outer upper incisor and by its separation from the molariform series in the young jaw. The interpretation of this tooth as a canine in *Odobænus* was adopted by Flower, Huxley, and J. A. Allen† in the solution of the long vexed question of the homologies of the unique dentition of the walrus. (3) The inner side of the lower canine of our specimen is considerably worn, and hence to judge from the conditions in other Pinnipeds the upper jaw must have retained three functional incisors in the adult. (4) Viewed from the side the whole ramus is less curved downward and the chin and symphysial surface is much more slender and slopes more forward than in *Odobænus,* but is much heavier and more roundly developed than in the Otaries. The posterior half of the ramus is thus relatively deeper and the anterior half is relatively shallower than in *Odobænus.* (5) The opposite symphysial surfaces did not be-

* These late Tertiary littoral deposits have been recently recognized by Clark and Miller as distinct from the underlying beds and formally named the Yorktown formation.

† See summary in Allen's "History of North American Pinnipeds." Washington, 1880, pp. 47–57.

come anchylosed as is the case in even the young walrus, but remained separate, although the deeply corrugated surfaces were closely appressed and doubtless firmly bound together by ligament. (6) The coronoid process is relatively higher, more

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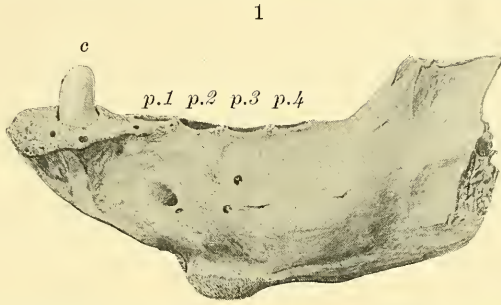
Fig. 1. The type of *Prorosmarus alleni*, lower jaw (left ramus), external view. One-third natural size.

slender and more inclined backward than in *Odobænus*. (7) Viewed dorsally, the opposite mandibular rami rapidly converge to a point opposite the first "molar" when they sud-

2
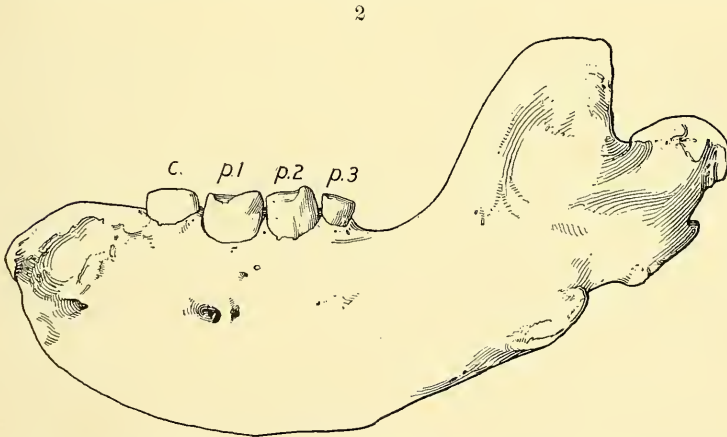
Fig. 2. Lower jaw (left ramus), external view, of an old male Atlantic Walrus (*Odobænus rosmarus*). One-third natural size.

denly expand into a broad spatulate everted lower lip. In cross section this region is broad at the top, narrowing rapidly below (figs. 1, 4A). In *Odobænus*, on the contrary, the rostrum is much compressed above and broadly convex below (figs. 2, 4C). (8) In *Prorosmarus* on the lower border of the jaw below

the second and third "molars" is a prominent rounded protuberance about 4^{cm} long and gradually fading away posteriorly. This protuberance may have furnished attachment for ligaments binding the rami together as well as for the digastric muscle which depressed the jaw. In the modern walrus this process is indicated in the young jaw, but becomes strongly inflected, lengthened, and less conspicuous in the adult. Additional and less important differences from *Odobænus* are as
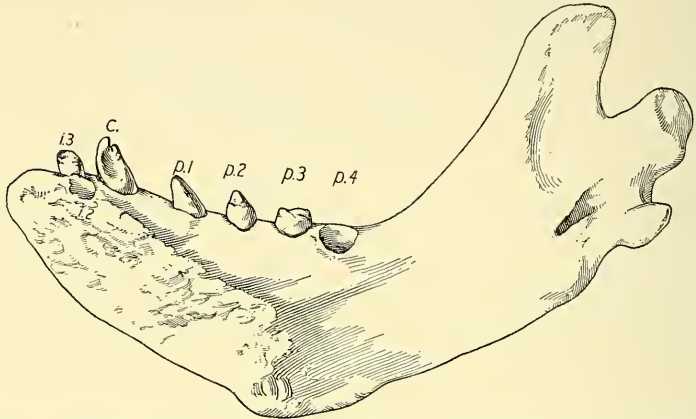
FIG. 3.   Type lower jaw (right ramus) of *Alachtherium cretsii* DuBus. Internal view, one-fourth natural size.   (After Van Beneden.)

follows: (9) The subequal size of the molariform teeth which in *Odobænus* successively decrease in size, the most anterior (*c*) being the largest.   (10) The molars must have been circular in section whereas in the adult walrus they are laterally compressed.   The molariform teeth probably also had a somewhat more pointed tip than in *Odobænus*.   (11) *Prorosmarus* retained one more fully functional molariform tooth (p_4), which is vestigial or absent in the walrus.

In brief the jaw of *Prorosmarus* seems to be much less specialized than is the modern walrus jaw. In the latter, doubtless in response to the need for an effective crushing apparatus, the distal portion of the jaw has become very massive; the enormous growth of the upper canines has caused the disappearance of the incisors and the transference of the lateral upper incisor and the lower canine to the molariform or cheek series; the effective center of the lower molar series has gradually been shifted forward and the upper molar series have acquired oblique wearing surfaces, so that the shock of impact is partially transmitted to the massive upper canines.

The detailed description of the specimen is as follows:

Prorosmarus alleni gen. et sp. nov.

Mandibular ramus complete except posteriorly, the coronoid process and the region of the mandibular angle being broken off at a point which leaves the inferior dental canal (8^{mm} in diameter) centrally located and on a horizontal line with the alveolar border. The jaw is extremely massive throughout and is vesicular anteriorly and along the alveolar region. The *canine* alone is in place and from its worn appearance indicates an old animal, as does also the character of the whole specimen.

Dental formula.—The *dental formula* of the lower jaw is $I_{\frac{3}{2(i_2,\ i_3)}}$, $C_{\frac{1}{1}}$, $P_{\frac{4(p_1-p_4)}{}}$, $M_{\overline{0}}$, but judging by analogy with the walrus one or more of the true molars may have been present in the young jaw, and even as vestiges, without alveoli, in the adult. It would be interesting to know whether the milk teeth were better developed than in *Odobænus*, as Flower believed that in *Odobænus* the vestigial milk teeth "never cut the gum, but are absorbed rather than shed," this process commencing before birth. In the upper jaw there must have been three incisors (the existence of the outer pair being plainly indicated by the worn antero-internal face of the lower canine), a canine not nearly so much enlarged as in *Odobænus*, four premolars and possibly one or more much reduced molars. The outer lateral incisor, like its opposing tooth the lower canine, had not yet been taken over into the molariform series. Thus the complete dental formula of the adult was probably $I\frac{3}{2}$, $C\frac{1}{1}$, $P\frac{4}{4}$ $M\frac{?}{?}$.

The *internal incisor* (i_2 of the typical Eutherian formula) was evidently considerably reduced in size as compared with the other teeth, but still functional, and was apparently retained in the specimen until after the death of the animal. It is placed almost behind the outer incisor, decumbent, directed forward at an angle of about 45°. Alveolus round, 8^{mm} in diameter and 2^{cm} in depth. The *outer incisor* (i_3) is large, approximately paralleling the canine in direction. Alveolus 13×15^{mm} in diameter, the longest diameter being transverse; depth 5^{cm}.

Canine—Bluntly conical, directed slightly forward and outward and curving slightly backward, nearly circular at the base in cross section but slightly flattened anteriorly. Much worn on the antero internal quadrant, presumably by the attrition of the upper outer incisor. Height $2\cdot2^{cm}$, diameter $1\cdot7^{cm}$, diastema $1\cdot4^{cm}$. The premolars were all rounded, simple and deep-set. The first alveolus indicates a vertical, slightly forward direction and is $1\cdot7^{cm}$ in diameter and $4\cdot4^{cm}$ in depth. The second alveolus indicates a slight outward and forward direction and is $1\cdot8^{cm}$ in diameter and 4^{cm} in depth. The third alveolus is very slightly

inclined backward and is 1·9^{cm} in diameter and 3·8^{cm} in depth. The fourth alveolus indicates a considerable backward inclination of the contained tooth, and is 1·8^{cm} in diameter and 3·2^{cm} in depth. Thus we see a progressive shortening of the alveoli from before backward, but apparently no diminution worth taking into account in the diameter of the teeth for the whole molariform series. There is no indication of an additional molar, which is remarkable, when we consider the large size of the fourth premolar, and indicates that the fifth tooth in the molar series was vestigial or absent.

Anterior mental foramen large. Mandibular symphysis 11^{cm} long and 4^{cm} in greatest height, very massively corrugated throughout. The *muscular attachments* are all strongly marked.

Measurements.

Total length, condyle to incisive border (estimated) ..... 21·5^{cm}
Anterior border of first "molar" (p$_1$) to posterior border of
    coronoid (estimated) 17
Breadth of coronoid at base .... 2·1
Horizontal diameter of coronoid at base .... 4·5
Length of molar series................................. 8
Antero-posterior diameter of alveolus, first incisor .... 8^{mm}
              "   second " 13
              "   canine 17
              "   pm$_1$ 17
              "   p$_2$ 18
              "   p$_3$ 19
              "   p$_4$ 18
Estimated depth from top of coronoid to angle of jaw... 10^{cm}
Depth of jaw behind p$_4$ .... 6·1
  "   " below p$_3$ 6
  "   "   "   p$_2$ .... 6·9
  "   "   "   p$_1$ .... 7·5
  "   "   " canine 5
Height of canine crown.................................. 21^{mm}
Extreme length of symphysis .... 11^{cm}
Thickness of ramus.................................... 3·5
Breadth of jaw opposite canine (estimated).............. 7

The species is named in honor of Dr. J. A. Allen of the American Museum of Natural History, author of well known contributions on the Pinnipedia and other marine Mammalia.

Relationships of Prorosmarus.

Prorosmarus seems to have been only one of a number of genera of Odobænidae which must have flourished during the late Miocene and Pliocene epochs. Of these, the European forms

Alachtherium cretsii DuBus (figs. 3, 4B) and " *Trichechodon* " *koninckii* Van Beneden from the lower Pliocene (Scaldisien, probably homotaxial with the Plaisancien of the Mediterranean region) near Anvers in Belgium, and *Trichechodon huxleyi* Lankester from the " red crag " of Suffolk, England, have been fully described and figured by Van Beneden in his
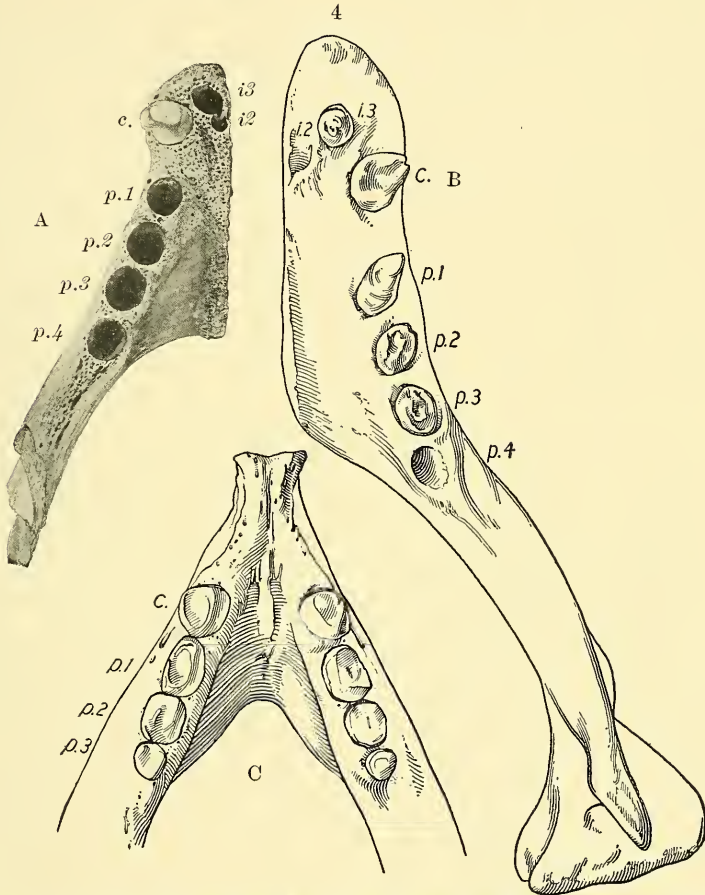
Fig. 4.   A. Type of *Prorosmarus alleni,* lower jaw (left ramus) superior view.   B. Type of *Alachtherium cretsii,* lower jaw (right ramus) superior view.   (After Van Beneden.)   C. Old male (cf. fig. 2) of *Odobœnus rosmarus* lower jaw, superior view.   All one-third natural size.

Description des Ossements Fossiles des Environs d'Anvers (Ann. Mus. roy. d'His. nat. de Belgique, tome 1, 1877).

The mandible of *Alachtherium* (figs. 3, 4B), has been identified as positively Odobænid, while at the same time retaining certain characters of the Otaries. It resembles that of *Prorosmarus* in the dental formula, in the general form and arrangement of the teeth, in the persistent separation of the opposite rami of the jaw at the symphysis, in the long sloping chin and the slender coronoid. It differs from the mandible of *Prorosmarus* in being relatively longer, more slender, and shallower, and much more upwardly curved anteriorly, the long axis of the symphysial face being almost at right angles to a line drawn through the front border of the coronoid. This implies a shorter, more upturned facial region. The distance from the last molar to the condyle is relatively greater and the bony "lip" of the jaw is much more produced anteriorly and lacks the eversion of the anterior margin. There is no narrowing of the upper border of the jaw immediately behind the canine, the inferior mental protuberance is much less marked, the posterior dental foramen is farther forward, and the jaw as a whole is much larger than that of *Prorosmarus*, the total length being about 37^{cm} from the incisive border to the condyle as against an estimated length of $21\cdot5^{cm}$ in *Proromarus*. The molar series in *Alachtherium* measures about $9\cdot5^{cm}$ as against 8^{cm} in *Prorosmarus*, that of the latter being thus relatively longer. The molars are also considerably more widely spaced and thus relatively smaller in *Alachtherium*, especially p_4. In *Alachtherium* the lower canine seems to be in a fair way towards being taken over into the molariform series and the projection and narrowing of the bony "lip" beyond the canine may foreshadow the compressed rostrum of *Odobænus*.

Trichechodon huxleyi Lankester is known only from imperfect upper canine tusks which were very large but not equal to, and more recurved than, those of the existing *Odobænus*. These tusks are correlated by Van Beneden with the remains described by him as "*Trichechodon*" *koninckii*. The latter animal agrees with *Prorosmarus* in possessing four lower "molars," but, as represented in Van Beneden's plates, was extremely short-jawed, with very short mandibular symphysis, stout ramus and very large transversely expanded molars. In front of the molars was a still larger excavation or sinus which apparently opened externally and served to lodge the presumably immense upper canine.

All these forms strengthen the inference that the Walruses have been derived from some primitive member of the Otariidæ, probably during the middle Tertiary.

Art. XLI. — *A new form of " Container " for use in Museums of Economic Botany ;* by George Lincoln Goodale.

It has been found so difficult to procure prismatic glass bottles with perfectly even sides and faces, that an attempt was made in May last, in the Botanical Museum of Harvard University, to prepare a new kind of " container " with a flat front. A simple modification of the well-known *passe-partout* appeared most practicable. Many experiments were tried in order to meet the obvious objections, and at last, a form was devised which has appeared to answer every reasonable demand. At the request of many correspondents, the following details are given.

The materials are (1) lantern-slide glass of best quality and of standard size. (2) Strips of hard wood of different widths, ranging from one-sixteenth of an inch to one inch, but of perfectly uniform thickness, namely one-sixteenth of an inch for the widths below one-half and one-eighth inch for the widths above this. (3) Strong fish-glue in a liquid form. That which comes in Dennison's tubes has proved satisfactory. (4) A strong solution of potassium dichromate or a twenty per cent solution of formalin. (5) Hard paraffin. (6) Strong binding-strips well made with good glue.

From three strips of the wood neatly fastened between two thoroughly cleaned glass slides, one procures a container of the desired thickness. This is filled with the specimen of seeds or other objects and then is closed by placing the fourth strip in position. All four edges are next dipped for an instant in the solution of potassium dichromate or of formalin, in order to render the glue, after drying and exposure to the sun, wholly unaffected by moisture. If preferred, these solutions may be put on with a brush. When the filled container is completely dry, the edges are placed in a thin layer of melted hard paraffin and quickly removed. On cooling, the excess of paraffin is carefully scraped off, and the binding-strips are then applied. The prepared container is now ready for installation in any exhibition-case. Its contents are proof against invasion by moisture or any museum pests. In the very few instances where insects have been subsequently detected in the container, a small hole was made in one side of the wood, and a little carbon disulphide or chloroform thrown in by a medicine-dropper, and then the hole was closed by a bit of soft wax. In no case has it been found necessary to repeat the dose.

When the specimen is a powder which it is desired to show in a thin layer, it has been found well to proceed in a different manner. First, a flat cell is made by cementing with glue the thinnest strips of wood, on all four sides, and then drying the whole. Into this cell the powder can be put in a perfectly even layer, and then covered carefully by the other slide.

Among the advantages which this easy method possesses are the following,—economy of material, absence of distorting refractions of the container, a convenient tablet form for any exhibition-case, and a free space for labelling. To these advantages may be added the slighter but not unimportant ones; exposure of both sides of the specimen, and security against damage when used as a hand-specimen for class-work. When the container is filled and finished, the whole work and the materials used in construction have together cost less than unsatisfactory bottles.

Cambridge, May, 1906.

Art. XLII.—*Filter Tubes for Collection of Precipitates on Asbestos;* by S. L. Penfield and W. M. Bradley.

The tubes described in this article may be employed to advantage in a variety of analytical operations, and as an inexpensive substitute for a Gooch crucible, where a high temperature is not required.

The tubes (figure 1) may readily be drawn out from combustion tubing, or made from soft glass if high temperatures
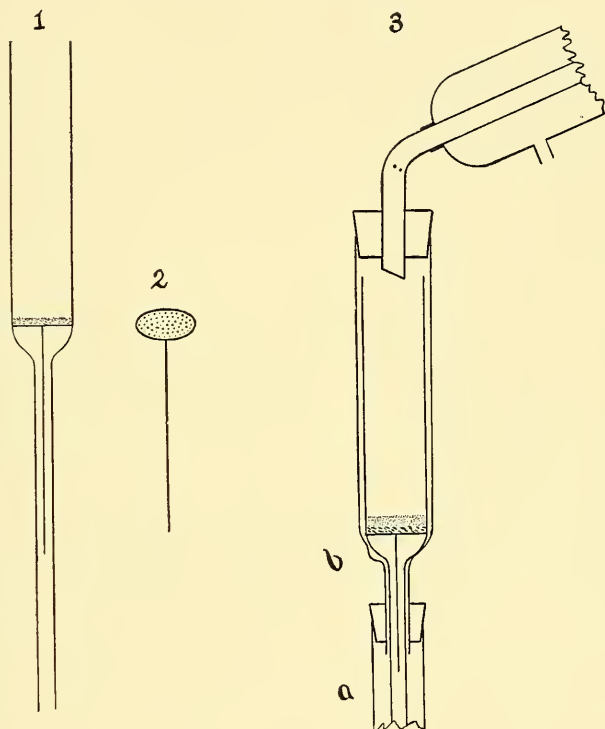
are not used. Different lengths and sizes will find a variety of uses, and diameters from 17 to 20^{mm} may be recommended for general use. The most satisfactory support for asbestos is a perforated platinum disc 0·2^{mm} in thickness, to the center of which a platinum wire three inches long is soldered (figure 2). Where conditions or expense prohibit the use of platinum, a fitter bed of quartz may be substituted with excellent results.

A large fragment is used to close the throat of the filter tube, and on this is placed a layer of powdered quartz about six or eight times as coarse as sea sand, from which fine material has been carefully removed by screening and washing. In order to deposit a uniform layer of asbestos on the quartz, it is recommended to observe the following precautions: The bottom of the filter tube is closed with the finger, and the tube is half filled with water; asbestos suspended in water is then added, when upon removing the finger, it will settle in a smooth layer upon the quartz, and may be firmly fixed by use of a filter pump. The asbestos and precipitate collected on it dry slowly in the tubes in an ordinary drying oven, but removal of water may be quickly accomplished by drawing a slow current of air through the tubes, the latter being heated in an air bath, which may be improvised from a baking powder can. Such filters may be found useful for collecting many precipitates which need not be subjected to strong ignition, silver chloride for example, and they are especially recommended for precipitates which are subsequently to be ignited in gases, as will be illustrated by numerous examples. They are admirably adapted for use with an extractor, where either a precipitate collected on the asbestos, or a powder, is to be treated with some solvent, such as either, carbon bisulphide or alcohol. The arrangement of a filter tube in an extractor is suggested by figure 3, where *a* is the neck of a flask containing some solvent, the vapors of which pass up between the filter tube and the outer jacket, and after condensation drop down upon the material collected on the asbestos. At *b* there should be some swelling of the tube to allow a free upward passage of vapors.

In case of a small amount of organic material being present, it could undoubtedly be burned in the tube in oxygen gas and the resulting carbon dioxide and water collected and weighed.

Precipitates collected on the asbestos can be ignited by applying a gentle heat to the tubes while supported in an inclined position, or the following arrangement may be found very serviceable : a small hole is pierced in the bottom of a porcelain crucible and enlarged by chipping until a hole of the desired diameter is obtained, through which is passed the smaller part of the filter tube. The crucible not only serves as a support for the tube, but also protects the glass and precipitate from too strong ignition. A ring burner is placed beneath the crucible, and so adjusted that the lower part of the filter tube passes through the center of the burner, and may by its lower end be connected to a gas generator. If it is desired to increase the temperature of the upper part of

the tube, this may be accomplished by using wire gauze, so placed as to deflect the heat to that portion.

In order to test the apparatus just described with precipitates requiring ignition in gases, a number of experiments have been carried out with the following results:

Calcium ignited in CO_2 and weighed as $CaCO_3$

	Precipitated as $CaCO_3$	Precipitated as CaC_2O_4
Calcite taken	0·7445	0·7191
$CaCO_3$ weighed	0·7450	0·7195
Error	0·0005 +	0·0004 +
Error as CaO	0·0003	0·0002

The collection of a considerable portion of calcium oxalate on an asbestos filter can scarcely be recommended because the exceedingly fine precipitate clogs the asbestos and makes the filtration tedious.

Copper in recrystallized copper sulphate was precipitated by means of hydrogen sulphide and ignited in CO_2.

$CuSO_4.5H_2O$ taken = 0·1936,

Cu_2S calculated 0·0617
Cu_2S weighed 0·0618
Error 0·0001 +

Zinc in recrystallized potassium double sulphate K_2SO_4. $ZnSO_4.6H_2O$ was precipitated by hydrogen sulphide in formic acid solution; ignited in CO_2, and, weighed as ZnS.

$K_2SO_4.ZnSO_4.6H_2O$ taken 0·5265,

ZnO calculated 0·0965
ZnO determined 0·0960
Error 0·0005 −

Lead in pure galena was precipitated by hydrogen sulphide in acetic acid solution, after decomposing the mineral with nitric acid, and dissolving lead sulphate with ammonium acetate. Lead sulphide was ignited in hydrogen sulphide and weighed.

Galena taken	0·2494
PbS weighed	0·2494
Error	0·0000

Arsenic in sublimed arsenious oxide was precipitated by hydrogen sulphide after dissolving in pure sodium carbonate, and acidifying with hydrochloric acid.

The arsenious sulphide was subjected to the action of carbon bisulphide for the removal of sulphur, using the extractor illustrated by figure 3.

As_2O_3 taken 0·1890,

As_2S_3 calculated 0·2350
As_2S_3 weighed 0·2357
Error 0·0007 +

Antimony in Japanese stibnite was precipitated by hydrogen sulphide after dissolving the mineral in hydrochloric acid.   The Sb_2S_3 was ignited in CO_2 gas.

Stibnite taken	0·1385
Sb_2S_3 weighed	0·1384
Error	0·0001 —

Bismuth in pure Bi_2O_3 was precipitated by hydrogen sulphide after dissolving the oxide in the least possible amount of dilute nitric acid, and diluting largely before precipitation. Bi_2S_3 was ignited in CO_2 and weighed.

Bi_2O_3 taken	0·3047
Bi_2O_3 determined	0·3046
Error	0·0001 —

Thanks are here expressed to Dr. W. E. Ford, who kindly furnished the results of the last two determinations.

Filter tubes such as here described have been in use for many years in our laboratory, and have frequently been employed in the estimation of potassium as platinic chloride ; on subsequent ignition in hydrogen gas the salt may be decomposed, the alkali chloride extracted with water, and tested spectroscopically for cæsium and rubidium.

Art. XLIII.—*Age and Type Localities of the Supposed Jurassic Fossils collected North of Fort Bridger, Wyoming, by Frémont in 1843;* * by A. C. Veatch.

On August 19, 1843, having turned north from Fort Bridger on the Oregon Emigrant Road and passed over Muddy Fork, or Big Muddy (which he refers to as "a salt creek about 15 feet wide") near the present site of Carter, Uinta County, Wyo., Frémont reports† that he crossed a high ridge "and descended upon one of the heads of Ham's Fork called Muddy, where we made our midday halt. In the river hills at this place I discovered strata of fossiliferous rock having an oolitic structure, which in connection with the neighboring strata authorizes us to believe that here on the west side of the Rocky Mountains we find repeated the modern formations of Great Britain and Europe which have hitherto been wanting to complete the system of North American geology. In the afternoon we continued our road, and searching among the hills a few miles up the stream and on the same bank I discovered among alternating beds of coal and clay, a stratum of white indurated clay containing very clear and beautiful impressions of vegetable remains."

These specimens were referred to James Hall, who described them‡ and gave the following additional details regarding the locality, evidently based largely on Frémont's notes.§

"Longitude 111°, latitude 41½°, Muddy River.—These specimens are of a yellowish gray oolitic limestone, containing turbo, cerithium, &c. The rock is a perfect oolite; and, both in color and texture, can scarcely be distinguished from specimens of the Bath Oolite. One of the specimens is quite crystalline, and the oolitic structure somewhat obscure. In this instance, the few fossils observed seem hardly sufficient to draw a decisive conclusion regarding the age of the formation; but, when taken in connection with the oolitic structure of the mass, its correspondence with the English oolites, and the modern aspect of the whole, there remains less doubt of the propriety of referring it to the Oolitic period. A further collection from this interesting locality would doubtless develop a series of fossils, which would forever settle the question of the relative age of the formation.

* Published with the permission of the Director of the Geological Survey.
† Frémont, Capt. J. C., Rept. of Exploring Expedition of the Rocky Mountains in the Year 1842, and of Oregon and Northern California in the years 1843–44, 28th Congress, 2d Session, House Executive Document No. 166, 1845, p. 131.
‡ Ibid., pp. 304–310. § Ibid., pp. 297–298.

"A few miles up this stream, Capt. Frémont has collected a beautiful series of specimens of fossil ferns. The rock is an indurated clay, wholly destitute of carbonate of lime, and would be termed a fire clay. These are probably, geologically as well as geographically, higher than the oolite specimens, as the rocks at this place were observed to dip in the direction of N. 65° W. at an angle of 20 degrees. This would show, conclusively, that the vegetable remains occupy a higher position than the oolite. Associated with these vegetable remains, were found several beds of coal differing in thickness. . . . . . .

"The stratum containing the fossil ferns is about 20 feet thick; and above it are two beds of coal, each about 15 inches. These are succeeded by a bed of sandstone. Below the bed containing the ferns, there are three distinct beds of coal, each separated by about 5 feet of clay. Before examining the oolitic specimens just mentioned, I compared these fossil ferns with a large collection from the coal-measures of Pennsylvania and Ohio, and it was quite evident that this formation could not be of the same age. There are several specimens which I can only refer to the *Glossopteris Phillipsii*, an Oolitic fossil; and this alone, with the general character of the other species, and the absence of the large stems so common in the coal period, had led me to refer them to the Oolitic Period. I conceive, however, that we have scarcely sufficient evidence to justify this reference; and though among the fossil shells there are none decidedly typical of the oolite, yet neither are they so of any other formation; and the lithological character of the mass is not reliable evidence."

A portion of this material found its way into the National Museum and was examined by Lesquereux, who likewise considered it Oolitic.* No similar plant remains were found by any of the several Government expeditions which visited this region after the early exploration of Frémont, and while Dr. A. C. Peale, who studied the region just north in 1877, and was therefore familiar, in a general way with its stratigraphy, attempted in 1898 to determine, in the office, from Frémont's account the locality from which the fossils were obtained, no satisfactory conclusion was reached. Dr. Peale called my attention to this unique material and the desirability of determining the true stratigraphic position of the original locality, and of making additional collections.

A special search for this locality was therefore made in connection with my study of the coal and oil fields of this general region during the summer of 1905. From this study and a careful consideration of the original notes of Frémont

* Prof. U. S. National Museum, vol. xi, 1888, pp. 37–38.

and Hall, quoted above, the locality which furnished the leaves was determined to be on the south bank of Little Muddy Creek, about one mile east of the present town of Cumberland. A considerable collection of plants of the same type was obtained from just north of the creek, and studied by Dr. Knowlton, who reports as follows :

" Plants from Sec. 29, T. 19 N., R. 116 W. One mile E. of Cumberland.

> Gleichenia. Two or three species, well preserved.
> Equisetum ? sp. Peculiar, probably new.
> Aralia, cf. *A. Saportana.*
> Dewalquea, near *D. insignis.*
> Peculiar radiate plant of unknown affinity.

" This is extremely interesting material as it is evidently from the same locality or horizon as that at which Fremont obtained a small collection in 1842, which was worked up by James Hall, who referred the beds to the Jurassic. The ferns here called Gleichenia were named Pecopteris by Hall, but they seem indistinguishable from this modern genus. The age, so far as I am able to fix it, is the lower part of the Upper Cretaceous, about in the position of the Turonian, possibly a little lower."

This horizon is stratigraphically 1,200 feet below the thick sandstone, which here forms the very prominent topographic feature known as Oyster Ridge. The geological position of the plant-bearing beds, as determined by stratigraphic data and invertebrate fossils identified by Dr. T. W. Stanton, is clearly Benton or lower Colorado. The leaf-bearing beds are underlain by black shales containing abundant fish scales, which were observed by the early explorers near Aspen, and which they correctly referred to the Benton. These fish-scale beds are underlain by the fossiliferous Bear River formation. The coal-bearing series containing the fossil plants yield at many points invertebrates with distinct Benton characteristics, and about 3,000 feet above the Oyster Ridge standstone numerous specimens of the characteristic Niobrara form, *Inoceramus exogyroides*, were found.

The invertebrates described by Hall as *Cerithium nodulosum* and *Turbo paludinæformis*[*] came from the bluffs 3 or 4 miles east of this locality, which here present a scarp face capped by this fossiliferous, somewhat oolitic limestone. These beds dip gently eastward, and it was clearly Hall's unwarranted assumption that both the plant-bearing beds and the oolitic limestone had the same dip that led to the conclusion that the fossils came from a lower horizon than the leaves.

[*] Ibid., p. 309, pl. iii, figs. 11, 12, 13.

The limestone is stratigraphically near the line of parting between the Wasatch and Green River formations. Both Meek* and White† have recognized the identity of these forms with those found in beds of undoubted Eocene age at about the same horizon, and have thus anticipated from paleontologic data the conclusion reached by visiting the type locality. Meek pointed out that the Cerithium is clearly a Goniobasis, and suggested the name of *Goniobasis nodulifera*, while White regards it as but a variety of *Goniobasis tenera (Cerithium tenerum* Hall). *Turbo paludinæformis* has likewise been referred to the fresh water genus, *Vivipara.*

Of Frémont's supposed Jurassic fossils, the plants are therefore upper Cretaceous and the invertebrates are Eocene.

U. S. Geol. Survey, Washington, D. C.

* Meek, F. B., 4th Ann. Prelim. Rept. U. S. Geol. Survey of the Territories for 1870, 1872, p. 299. Rept. Geol. Expl. 40th Parallel, vol. iii, 1877, pp. 179–180.
† White, Chas. A., 11th Ann. Rept. U. S. Geol. and Geog. Survey of the Territories for 1877, 1879, pp. 226–227.

ART. XLIV.—*Certain Suggestions by J. Willard Gibbs on Geophysical Research.*

NOTE.—Some years ago when I was interested in physical geology and after some progress had been made, I endeavored to secure the coöperation of Prof. J. W. Gibbs on the theoretical side, hoping to carry out the experimental part suggested myself. Prof. Gibbs entered into the project cordially and wrote out for me a plan of attack. Unfortunately, and to my lasting regret, circumstances beyond my control made it impossible for me to live up to my part of the project, and the scheme proved barren of results.

The suggestions of Gibbs are given below. They must be read with a time allowance for the intervening years and with the reservation that Gibbs, who was chary of print, would not probably have published them himself. On the other hand, I do not feel justified in withholding what Gibbs counseled on a subject in which he was so admirably qualified to judge, from those who may be interested in geophysical research. CARL BARUS.

A good deal of work has been spent in the endeavor to find equations which shall represent the relations p, t, v, for various substances. It would be very pleasant to have such an equation, but it is doubtful whether the relation *can* be represented by any simple formula.

Now instead of comparing the relation in any given case with an analytical formula, one may compare the relations for different substances with each other. Van der Waals has given an algebraic equation which would make the law *similar* for all substances, in this sense, that by measuring the t, p, v, for different substances in different units, the numerical expression of the relation becomes identical for all substances. Now Van der Waals' law gives only a very rough approximation. But it is worthy, I think, of much effort to find out whether, or with what degree of approximation, and within what limits, and with what exceptions, the actual laws for different substances are *similar* in the sense defined above. And if not similar, to find how many degrees of variation there are, in addition to the three connected with the measure of temperature, pressure and volume. In other words, to find how many independent constants there are in the general formula, i. e., in a formula sufficiently general to be so called. Certain cases would probably remain, which would naturally be regarded as exceptional or "abnormal."

The method to be followed would appear in the course of the investigation, but we might commence as follows. Suppose we find for various substances the limiting values of

$d \log p/d \log t$ for saturated vapor at the critical state.   The units of temperature and pressure fall out of this expression. If Van der Waals' Law were exact, the value of this expression for all substances would be 4.   Actual values seem to be much higher than this.   Suppose we had a table of these values for a considerable number of substances.   Will these values or a large part of them be identical?   In any case we can probably find several substances which have nearly the same values.   We may then ask whether, or how far, these substances, which have the same limiting values $d \log p/d \log t$, have *similar* relations between p, t, and v.   This would perhaps be most easily tested by finding whether p/p_c is the same function of t/t_c for the saturated vapor of the several substances (t_c and p_c denote t and p for the critical state) ; and this again would be sufficiently and most easily tested by a few particular cases (for each substance), as $t/t_c = 9/10$ or $8/10$, etc.

In this way we might decide whether the general (or quasi-general) equation has three independent constants (which is all that Van der Waals' theory of "corresponding states" allows) or four or more than four.   Uncritically we might push the inquiry further, if there are more than four, but with rapidly increasing difficulties of various kinds, and with diminishing value of the results obtained, since the most simple results are the most valuable.

Incidentally, such an investigation would enable us to distinguish those substances which are *typical* from those which are exceptional or "abnormal."

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *The Molecular Weight of Silver Vapor.*—Several years ago some vapor density determinations were made by Nernst at temperatures in the neighborhood of 2000° C. by the use of an iridium bulb in an electrically heated tube of iridium. The principle applied was that of Victor Meyer's method, but the process was ingeniously modified, on account of the rarity of iridium, by the use of a very small bulb, a specially devised micro-balance, and the measurement of the displaced air by means of the movement of a drop of mercury in a small, horizontal, graduated, glass tube. Nernst obtained interesting and satisfactory results with very minute quantities of several substances, but upon attempting to get the vapor density of silver his private assistant weighed a piece of platinum wire in place of supposed silver wire, so that the apparent result that silver was not volatile at 2000° was obtained. WARTENBERG, using Nernst's apparatus and method, with the iridium bulb glazed inside with rare-earth oxides, so that the silver vapor would not attack the iridium, has now made some determinations with silver. The best results showed a molecular weight not far from 107, so that it appears that silver forms a monatomic vapor in the neighborhood of its boiling-point. From experiments made by Nernst it was found that the boiling-point of the metal was about 2050°, and the experiments under consideration were probably made at temperatures but little above this point.—*Berichte*, xxxix, 381.   H. L. W.

2. *Carbon Oxybromide.*—Although phosgene, $COCl_2$, is well known and readily prepared, no method has been known, up to the present time, for preparing the corresponding bromide in a pure condition and in large quantity. A. VON BARTEL has studied this problem, and has found that while the oxybromide is formed by the direct union of carbon monoxide and bromine in the presence of aluminium bromide and also by means of the invisible electric discharge, a more satisfactory method of preparing the substance in quantity was found in the action of concentrated sulphuric acid upon carbon tetrabromide. The reactions that take place are as follows:

$$CBr_2 + H_2SO_4 = COBr_2 + 2HBr + SO_3;$$

then a part of the hydrobromic acid reacts with sulphuric acid:

$$2HBr + SO_3 = SO_2 + H_2O + Br_2.$$

To carry out the reaction, the sulphuric acid is allowed to drop slowly into the melted carbon tetrabromide at a temperature of about 150–160°. A strongly fuming, red distillate is produced, from which most of the free bromide is removed by the addition

of mercury at the temperature of ice-water. The liquid is then distilled and freed from the remaining bromine by means of powdered antimony. In the pure condition the oxybromide is a fuming, colorless, mobile liquid boiling at 64–65°. It is unstable, decomposing somewhat upon distillation, and being almost completely decomposed when its vapor is subjected to a red heat. It acts but slowly upon water at ordinary temperature. Its specific gravity is 2·45 at 15°.—*Liebig's Ann.*, cccxlv, 334.   H. L. W.

3. *The Industrial Preparation of Calcium Hydride.*—It was shown by Moissan that metallic calcium absorbs hydrogen when heated, forming the colorless hydride CH_2, and it is interesting to learn from an article by JAUBERT that this substance has already been made on a commercial scale for the purpose of preparing hydrogen for balloons. It is well adapted for this purpose since it reacts with water according to the equation

$$CaH_2 + 2H_2O = Ca(OH)_2 + 2H_2.$$
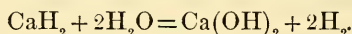
One kilogram of the substance thus liberates a cubic meter of pure hydrogen. Metallic calcium is manufactured by the electrolysis of the fused chloride. The electrical energy required for producing 100 kilograms of the metal in 24 hours is about 20 volts and 7,500 amperes, or 150 kilowatts. The hydride is prepared by heating the metal to a high temperature in horizontal retorts in which hydrogen circulates. The gas is slowly absorbed, and after several hours all the calcium is transformed into the hydride. The commercial product occurs in white or gray, irregular porous pieces, having considerable hardness. It is insoluble in the common organic solvents, but is instantly decomposed by cold water, similarly to calcium carbide. The product is about 90 per cent pure, the impurities being chiefly oxide and nitride.— *Comptes Rendus*, cxlii, 788.   H. L. W.

4. *The Synthesis of Cyanogen and of Hydrocyanic acid from the Elements.*—It is stated in most of the chemical text-books and reference-books that cyanogen gas has been produced (by Morren) by the passage of the induction spark between carbon points in an atmosphere of nitrogen. THEODORE WALLIS shows that the electric arc, instead of the induction spark, was probably used in the original experiments, and he shows further that by neither of these means is cyanogen produced. The error has arisen from the fact that hydrocyanic acid gas is formed in the presence of moisture under the conditions of the experiment, and the mistaking of this gas for cyanogen. The author has made a careful study of the methods of distinguishing and determining HCN and $(CN)_2$ in the presence of each other. The most satisfactory means of separating them appears to be based upon the fact that neutral or acid silver nitrate solution does not absorb $(CN)_2$ while it does absorb HCN.—*Liebig's Ann.*, cccxlv, 353.   H. L. W.

5. *A Gaseous Hydride of Calcium in Acetylene.*—HOFFMEISTER has noticed that acetylene when prepared from certain specimens

of calcium carbide, even after having been filtered through cotton and passed through water, deposited lime in the conducting pipes. This fact seemed to indicate the presence of a volatile compound of calcium in the gas. In order to study the matter further, a large volume of the acetylene was passed through a number of wash-bottles containing acetone, then through ammoniacal copper solution to remove the acetylene completely. A colorless gas was thus obtained, which burned in the air to calcium oxide and water, and formed an exceedingly explosive mixture with oxygen, As the gas was not obtained quite free from air, its quantitative composition has not yet been determined.—*Zeitschr. anorgan. Chem.*, xlviii, 137. H. L. W.

6. *The Electrical Nature of Matter and Radioactivity ;* by HARRY C. JONES. 8vo, pp. 212. New York, 1906 (D. Van Nostrand Company).—In this book Professor Jones gives a very clear and interesting account of the recent developments in regard to gaseous ionization, electrons, rays of various kinds and radio-active bodies. The style is semi-popular and non-mathematical, so that it is well adapted for the use of the general scientific reader. The work is to be highly recommended to those who desire to obtain an insight into the fascinating fields of work in which J. J. Thomson, Becquerel, the Curies, Rutherford and many others have been laboring. H. L. W.

7. *Energy, Duration, Damping and Resistance of Condenser Sparks.*—The art of wireless telegraphy has given a new importance to the study of electric sparks. A. HEYDWEILLER contributes an interesting paper upon the necessity of adding another term to Lord Kelvin's celebrated differential equation which expresses energy relations in regard to the discharges of a condenser. This new term expresses the spark energy : the resulting differential equation is complicated and its integration in the words of the author "must remain a pious wish"; still several solutions can be obtained by making suitable suppositions in regard to the electrical constants of the circuit. Heydweiller finds that the resistance of the condenser sparks which are usually employed in wireless telegraphy is less than an ohm.—*Ann. der Physik*, No. 4, 1906, pp. 649–691. J. T.

8. *Magnetic Relations of Powdered Iron of Various Densities.*—W. TRENKLE finds that, with equal magnetizing forces, the magnetization and susceptibility of clean iron powder is always greater than a mixture of iron powder and a non-magnetic substance : the magnetization of the iron sinks cet. par. with its density.—*Ann. der Physik*, No. 4, 1906, pp. 692–714. J. T.

9. *Spectrum of the High Tension Flaming Discharge.*—This discharge results from the high degree of ionization which is produced from the terminals of a transformer which is excited by a powerful current in the primary of the transformer. It is also the characteristic discharge of a high tension storage battery. B. WALTER finds that the spectrum of this discharge contains some very characteristic bands in the ultra-violet end of the spec-

trum which are the same bands that J. M. Eder discovered by
burning a mixture of ammonia gas and hydrogen in oxygen.
Walter believes that the discovery of these bands will be of use
in the commercial attempt to oxidize nitrogen by the electric
spark.—*Ann. der Physik*, No. 4, 1906, pp. 874–876. ᴊ. ᴛ.

10. *Photography of a Radium Crystal by its Own Light.*—
B. Walter has succeeded in photographing a particle of radium
by its own light ; and finds that there is considerable variation of
light in different portions of the particle. One portion of the
crystal which exhibited very strong light when examined under
the microscope showed a rupture of its surface. It seems pos-
sible that craters are formed which are centers of atomic con-
vulsions.—*Ann. der Physik*, No. 5, 1906, pp. 1030–1031. ᴊ. ᴛ.

11. *Ions, Électrons, Corpuscules. Mémoires réunis et publiés*
par H. Abraham et P. Langevin. 2 vols., xvi + 1138 pp. Paris,
1905 (Gauthier-Villars).—These volumes, issued by the French
Physical Society, contain a collection of papers and extracts from
papers, bearing upon the modern theory of the atomic constitu-
tion of electricity. This theory forms the basis of most of the
work which has made the last decade a memorable one in the
history of physics ; it has come to occupy a position of such
fundamental importance in many different branches of the science,
that the student who is not fairly familiar with its details is at a
decided disadvantage. The development of the theory has been
rapid, it has been applied to a great variety of problems, and
important papers are widely scattered among the scientific period-
icals of the world. It thus becomes a matter of some difficulty
to gain an adequate knowledge of the present point of view, unless
one has been particularly interested in the subject from the first.

The present volumes will give most useful help in this difficulty,
and will prove a great convenience even to those who are familiar
with the subject. The selection of papers for reprinting has
been made with great care and with admirable judgment. The
arrangement is alphabetical with respect to authors, but a well-
classified topical index makes it possible to read the papers upon
any portion of the subject in a continuous manner. In addition
to numerous subdivisions dealing with the different modes of pro-
duction of electrons and gaseous ions, and the experimental study
of their properties, there is also a series of papers upon the dynam-
ics of electrons, with applications to optics, to the phenomena
of radiation and metallic conduction. Extensive and important
theories, such as those of Lorentz and Larmor, are summarized by
the authors themselves with numerous extracts from published
papers.

It would be exceedingly difficult, if not impossible, for any one to
write a treatise which would give the reader so broad and so just
a view of the state of our knowledge of ions and electrons as do
the present volumes. A feeling of reality and intimacy comes
from reading the original papers in which important discoveries
were announced to the world, which is seldom gained from a

second-hand account. There is also the advantage of seeing with the eyes of many men and not being dependent upon the particular point of view of a single author. A careful examination of this book can scarcely fail to convince the reader that the editors have selected the best possible method of presenting the subject; they have carried out the method with a degree of judgment and discrimination which deserves hearty admiration.   H. A. B.

12. *Laboratory Course in Physical Measurements;* by W. C. SABINE, A.M.   Pp. vi + 97 (Ginn & Co).—This is a revised edition of a laboratory manual by Professor Sabine, first published in 1893. Brief directions are given for making about thirty simple physical measurements, suitable for a class of students who have had no mathematics beyond trigonometry. The experiments are well chosen, and the directions are especially to be commended in that they leave many details to be thought out by the student for himself—a process of great educational value, which is often absent from laboratory instruction.   H. A. B.

II. GEOLOGY AND NATURAL HISTORY.

1. *Contributions to the History of American Geology ;* by GEORGE P. MERRILL. Rept. U. S. Nat. Mus. for 1904, pp. 189–733, 37 plates, and 141 text-figures, 1906.—During odd moments, the Head Curator of the Department of Geology in the U. S. National Museum has collected the material for this history of the growth of geology in North America. Far more information was secured than appears in the printed work. The mode of presentation, the author states, aims to "show not merely what has been done, by whom, and how it has been done, but the gradual growth of the science and the development of powers of observation and deduction as well. To do this satisfactorily, no other arrangement than a chronological one seemed possible."

The book is divided into eleven chapters under the following headings : The Maclurean Era, 1785–1819 (Chapter I), The Eatonian Era, 1820–29 (II), The Era of State Surveys, 1830–1879, (III–VII), The Fossil Footprints of the Connecticut Valley (VIII), The Eozoon Question (IX), The Laramie Question (X), and The Taconic Question (XI).

Up to 1802, "none of the sciences were taught in the colleges and other institutions of learning in America." In 1798, Professor Dwight began to move for the "establishment in Yale College of a department for the teaching of these subjects," and in 1802 Benjamin Silliman was appointed professor of chemistry and natural science in that institution. Silliman was then twenty-two years of age, a tutor in law, "without even the most rudimentary knowledge of the science he was to teach." He then repaired to Philadelphia and for five months attended the lectures on chemistry given by Dr. James Woodhouse in the Medical School of Philadelphia. His own first lecture at Yale

was delivered April 4, 1804. In 1805 he went abroad to fit himself more fully for the duties of his professorship. Silliman "through his own efforts as a teacher, but more particularly through his personal influence as a writer and lecturer, probably" did "more to advance the science of geology than any man of his day."

From Silliman as the first teacher of geology in America, the history rapidly passes to Maclure, "the father of American geology." He produced the first geological map of the United States in 1809. Only three other geological maps had been thus far published. The next prominent figure is Parker Cleaveland, appointed in 1805 to the professorship of mathematics, natural philosophy, chemistry, and mineralogy in Bowdoin College, and the author of "Elementary Treatise on Mineralogy and Geology," 1816. It "was the first attempt made in America at a systematic treatise on Mineralogy."

In 1818 the American Journal of Science was founded by Benjamin Silliman, "and a perusal of the numbers from the date of issue down to the present time will, alone, afford a fair idea of the gradual progress of American geology." In this same year appeared S. L. Mitchill's "Observations on the Geology of North America," Amos Eaton's "Index," and Edward Hitchcock's first geological paper. These various publications make the year 1818 stand out prominently as one of the great milestones in American geology.

The first Geological Society of America was organized in 1819, in the philosophical room of Yale College, with Maclure as president. In looking over the more prominent members of this society, one is struck by the many names now among the fathers of American geology; as Gibbs, Silliman, Cleaveland, Akerly, Bruce, S. L. and J. F. Dana, Dewey, Eaton, Hitchcock, Mitchill, Rafinesque, Schoolcraft, Emmons, Harlan, Lea, Morton, Troost, and Vanuxem.

Among the admirable features of this book, in addition to the many portraits, are the maps giving the routes of travel of the various expeditions into the then unknown country; as Schoolcraft, 1820, 1821, Long, 1819–20, 1823, Stansbury, 1849–50, Foster and Whitney, 1847–49, Marcy and Shumard, 1849–52, Pacific R. R. Surveys, 1853–56, Ives and Newberry, 1857–59, Raynolds, 1859–60, etc.

This work, much of which is written in a vein of dry humor, is so full of interest and its presentation is so admirable that no geologist can afford to be without it. Its preparation has been a labor of love, and has been mainly accomplished out of official hours during the past several years. It is a worthy companion volume to Geikie's "The Wonders of Geology."   c. s.

2. *Revision of Paleozoic Insects;* by Anton Handlirsch. Proc. U. S. Nat. Mus., xxix, 1906, pp. 661–820.—This work is not only a complete study of the entire collection of American Carboniferous and Permian insects (about 750 specimens) in the

U. S. National Museum, but also includes a revision of all previously described species. The author recognizes 345 species (137 renamed or new) distributed in 169 genera (109 new). All this material is properly located in the geological formations by Mr. David White, on pages 664–668, and the horizons are correlated with standard European sections.

The horizontal distribution leads Handlirsch to the following conclusions: "Nearly all the orders occurring in America have likewise been already recognized in analogous European beds ; in like manner almost all the families rich in forms have been identified in both parts of the world. In such groups as first exist in single individuals, no sort of conclusion as to their actual horizontal distribution can obviously be drawn, and it consequently follows that there is a striking agreement in the Paleozoic fauna in both continents. Only one order (Blattoidea) represented in the Paleozoic of America extends over into the Mesozoic, with two families, while all other orders are replaced in the younger formations by those more highly specialized.

"Moreover, from a percentile comparison of the number of forms represented in the single orders in the various formations of the Paleozoic, it follows that the Palaeodictyoptera, which on morphological grounds I consider the stem group of all winged insects, appear first and decrease from the oldest beds to the younger, while the more highly specialized orders (Prodonata, Megasecoptera, Hadentomoidea, Hapalopteroidea, Mixotermitoidea, Protorthoptera, and Protoblattoidea), which I regard as connecting links between the Palaeodictyoptera and modern insect groups, and which may be designated *transitional* groups, appear later than their conjectural ancestors, attain their maximum in the middle beds, and with the close of the Paleozoic again vanish. It follows finally that the single modern order, thus far found in the American Paleozoic, the Blattoidea, first makes its appearance toward the middle of this period and continues with progressive increase to the close." c. s.

3. *A Study of the James Types of Ordovician and Silurian Bryozoa ;* by Ray S. Bassler. Proc. U. S. Nat. Mus., xxx, 1906, pp. 1–66, pls. 1–7.—Many of the Bryozoa described by the Jameses, father and son, have long remained in an obscure condition. The types now in the Walker Museum of the University of Chicago have been restudied by Bassler and adjusted to modern requirements. Of the 77 species described by James and James 44 are recognized, 32 are rejected, and 1 is a sponge.

c. s.

4. *Notes and Descriptions of Upper Carboniferous Genera and Species [of Ostracoda] ;* by E. O. Ulrich and R. S. Bassler. Proc. U. S. Nat. Mus., xxx, 1906, pp. 149–164, pl. 11.— The new genus *Paraparchites* (1 species) is described ; also new and old forms of the following genera : *Beyrichia* ? (2), *Beyrichiella* (3), *Kirkbya* (2), *Cythere* ? (1), *Bairdia* (2), *Cypridina* (1).

5. *The Osteology of Protostega ;* by G. R. Wieland. Mem. Carnegie Mus., Pittsburg, Pa., ii, 1906, pp. 279–298, text-figs., and

pls. 31–33.—This excellent paper describes and illustrates in detail the large marine turtle *Protostega gigas*, of which two good specimens have recently been secured by Mr. Sternberg for the Pittsburg Museum. Cope estimated the entire length of this turtle to be 13 feet, but a restudy of the original specimen combined with this new material has shrunk the animal to a length of less than 6 feet. However, Wieland has elsewhere described a Cretaceous turtle from Dakota, *Archelon*, having a length of 13 feet.   c. s.

6. *The Osteology of Diplodocus Marsh;* by W. J. HOLLAND. Mem. Carnegie Mus., Pittsburg, Pa., ii, 1906, pp. 225–264, pls. 23–30.—This paper treats of the additional material of the *Diplodocus carnegiei* collected since Hatcher's account published in the first volume of the same memoirs, and of the restoration of this animal recently presented by Dr. Carnegie to the British Museum of Natural History. Dr. Holland describes and figures in detail the fine skull secured by Mr. Utterback in 1902, and a fourth fine skull in the American Museum of Natural History. The author does not at all believe in the presence of a pineal eye at maturity in *Diplodocus*. Other parts described in detail are : The atlas, sternal plates, and supposed clavicle. Brief remarks are also made on the dorsal, sacral, and caudal vertebræ, and the chevrons.   c. s.

7. *A New Ruminant from the Pleistocene of New Mexico;* by J. W. GIDLEY. Proc. U. S. Nat. Mus., xxx, 1906, pp. 165–167.—Describes an incomplete skull of a new bovine genus *Liops* from Juni, New Mexico.

8. *Report on the Lead and Zinc Deposits of Wisconsin with an Atlas of detailed maps;* by ULYSSES SHERMAN GRANT. Wisconsin Geological and Natural History Survey. Bulletin No. XIV. 100 pp., 26 pls., 10 figures in text.—This is a brief report on the geology of that portion of the Upper Mississippi Valley lead and zinc district that lies in the southwestern corner of Wisconsin. This area is one that is covered entirely by early Palaeozoic sedimentary deposits, there being no igneous or metamorphic rocks exposed although such rocks have been proven by means of deep borings to exist beneath the sedimentary series. The oldest sedimentary rock is the Potsdam sandstone, of Cambrian age. Upon this lies a dolomite, called the Lower Magnesian, which in turn is overlain by the St. Peter sandstone. Then come the two limestones, the Platteville (or Trenton) and the Galena formations in which lie the bulk of the productive ore deposits. These are covered with a shale series called the Maquoketo. All of these rocks belong to the Ordovician. In isolated places remnants of an upper Silurian limestone, the Niagara, are found.

Throughout the district as a whole the rocks have a low southwest inclination. In addition to this general monoclinal structure the district is covered by a series of gentle rolls of the strata, whose axes run approximately east and west. Most of the formations show a pronounced series of joints. These are especially well

developed in the massive beds of the Galena dolomite and they play an important role in the deposition of the ores.

The ore minerals are chiefly galena, sphalerite and smithsonite, with which are associated marcasite and calcite. The ore deposits may be grouped into two divisions according to their form : first, those which occur in crevices, especially in the joints in the rocks and which are in the nature of vein deposits ; second, those which are disseminated in small particles through certain beds of the rock and which are in the nature of replacement deposits. The ores have undergone the usual alteration through the agency of descending surface waters and present three distinct mineral zones. At the top there is a zone containing large masses of galena. Below this is a zone in which smithsonite is the important ore. This last zone ends at about the level of ground water and is succeeded below by a zone in which sphalerite is the dominant mineral. The ore materials were derived from the sedimentary rocks themselves, in which they existed in a disseminated condition as original constituents, by the action of underground waters, which dissolved them out from the mass of the rock and later redeposited them in their present positions. The ore deposits, at least in the majority of cases, were found to lie in the synclinal folds of the rocks.

The atlas accompanying the report contains 18 topographic and geological maps of the area. They are drawn on a large scale and the formations are mapped on them in detail. w. e. f.

9. *The Diamond Pipes and Fissures of South Africa ;* by H. S. Harger. Trans. Geol. Soc. South Africa, vol. viii, 1905, pp. 110–134.—The author shows that in addition to the well-known volcanic necks which have been exploited for diamonds, great numbers of others exist in Central South Africa. They are found penetrating the beds of the Karroo System. Some are filled with basaltic rock and gave rise to overflows of lava, while others are filled with fragmental material, contain the kimberlite in which the diamonds occur and appear as the result of explosive action. The location and characters of a number of these are given, their minerals described and their origin discussed.

The following analyses of the altered kimberlite, called "blue ground" when soft, and "hardibank" when hard, from the Vogelfontein Mine are of interest :

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O
I	38·08	2·46	24·48	2·59	12·88	4·14	1·12	0·84
II	33·42	0·94	23·84	3·52	10·80	9·84	0·97	0·86
III	36·57	5·09	13·75	4·68	11·85	8·49	2·55	0·64

	Ign.	$H_2O^{100°}$	CO_2	P_2O_5	Cr_2O_3	MnO	TiO_2	S	Total
I	10·14	0·25	1·67	0·67	tr.	tr.	tr.	tr.=	99·32
II	7·83	0·43	5·88	0·89	tr.	0·0	0·0	tr.=	99·22
III	6·31	5·47	4·61	0·58	tr.	0·0	0·0	tr.=	100·59

I   Hard, dark hardibank.
II   Soft, light hardibank.
III   Soft, blue ground.

Regarding the origin of the diamonds in these volcanic necks, the author is not inclined to agree with those who place great stress on the presence of enormous temperatures and pressures as necessary conditions, basing their views on the artificial formation of the mineral in contracting cast iron by Moissan and others. He adverts to Friedlander's experiments by which diamonds were formed by stirring molten olivine with graphite rods, and also to the fact that diamonds have been found in the mines in olivine and in garnet, both of which are original minerals in the kimberlite. From this he concludes that if the deep-seated ferromagnesian magma contained carbon or carbon-bearing gases, its crystallization into the minerals mentioned above would naturally give rise to the formation of diamonds.   L. V. P.

10. *Petrogenesis ;* by C. DOELTER. Pp. 256, 8vo. Braunschweig, 1906 (Vieweg & Sohn).—The author, who is well known, not only through his researches during the past in different fields of petrographic study, but latterly, especially by his experiments and those of his students in the artificial production of rocks and minerals, gives in this volume a general introduction to the formation of rocks, not only igneous rocks but crystalline schists and sediments as well.

The subject is treated both from the point of view obtained by geological observation and petrographic study, and also from the results recently gained by researches along the lines of physical chemistry. The work of different authorities and the views expressed by them upon a great variety of subjects, such as the differentiation of igneous rocks, are competently treated and often subjected to a temperate criticism which the author's learning and experience render just and valuable. As an introduction into the field of theoretic petrology the work will be of great service to geologists, mineralogists and chemists. It includes separate chapters upon the earth's interior and volcanic processes; upon the mode of occurrence of the igneous rocks in which the influences of pressure, of viscosity, of the rôle of mineralizing vapors, etc., are treated ; upon the structure of igneous rocks ; upon the differentiation of igneous magmas ; upon the order of succession of magmas, etc., etc.

It is clear that a work of this character which contains so many theoretical views, often the personal ones of the author, invites much discussion and criticism and in this way will be a benefit to the science of petrology. Such discussion here would transcend the proper limits of this notice, but we think, for example, that the criticism of Professor Doelter of analytical methods used in rock analysis (p. 85) is given a somewhat sharper form than it justly deserves, and would tend, with those unfamiliar with such processes, to give a wrong impression. The methods of analysis to-day, which in the case of minerals such as tourmalines and hornblendes yield ratios of exceeding sharpness, naturally will give equal results in the case of rocks, which are only mixtures of the same oxides in somewhat different proportions, provided the

analyst has the proper skill and experience with which to use them. The weight of criticism should be laid rather on the analysts than the methods. L. V. P.

11. *Höhlenkunde ;* von W. von KNEBEL. Pp. 222, with plates and figures, 8vo. Braunschweig, 1906 (Vieweg & Sohn).—The author in this volume has brought together all of the various facts, phenomena, and theories which concern the origin and occurrence of caves and also of "karst" formation. The classification of caves, the different kinds of rocks in which they occur; the influence of ground waters, as well as the subterranean springs and rivers with the life which they contain ; the deposits found in them, the meteorological phenomena they exhibit; the influence they have exerted on the development of civilization, are illustrations of the variety of topics treated in this work.

The subject matter has been handled in a broad and yet comprehensive manner, and the text is embellished by a considerable number of excellent illustrations, which add to its value. Although written in a somewhat popular style, which thus makes the work suitable for a wide circle of readers, it will, nevertheless, be found a useful adjunct to the library of the working geologist and of the teacher. L. V. P.

12. *Coal Resources of Wyoming.*—A preliminary report on this subject by L. W. TRUMBULL is given in Bulletin No. 7 of the School of Mines, Univ. of Wyoming, Laramie. The total production of coal from the state for the year ending Sept. 30, 1905 was about five and one-half million tons.

13. *Over de Betrekking van het Bekken der Anthropoiden tot dat van den Mensch ;* door JAN VAN DER HOEVEN LEONHARD. 103 pages, 1 plate and 1 table. Amsterdam, 1905 (C. L. Petersen).—That a change in the habitual posture would affect the statical relations existing between one part of the skeleton and another, might be assumed as a matter of course. It is also well known that *luxatio coxæ,* for example, can bring about certain modifications of the bone, independent of disease. It may therefore be asked what would happen if the pelvis, for any cause whatsoever, should change its static relations to other parts of the skeleton ; and these changed relations should take place with a change of posture ?

The author has taken pelvic measurements on all anthropoid skeletons in Holland. In order to arrive at a more exact comparison with the human pelvis, he multiplied the measures of each pelvis by the quotient arising from dividing the length of the anthropoid vertebral column in question by the average length of the human pelvis. Through this reduction the natural relation of all the parts to each other is said to be retained.

Supposing that the ancestors of man resembled the anthropoids, the ancestral type of pelvis would have to undergo certain transformations in its transition to the present type, owing to the fact that the weight of the body and the counter-pressure of the

femur would operate in an entirely different direction than before. This assumption is supported in a convincing manner by the tabulated measurements. The latter tend to prove that the human pelvis, in its essential lines, can be derived from the anthropoid pelvis through the effect of static influences brought into action by a change of posture. They also throw light on the relation which exists between the pelvis of the infant and that of the adult. The difference between these two is known to rest almost exclusively on the operation of the above-mentioned forces, whose influence is manifested as soon as the erect posture is assumed. The measurements employed show in a striking manner that the infant pelvis occupies a position exactly between that of the adult and that of the anthropoid. The conclusion, therefore, is that the human pelvis must have developed from one closely related to that of the modern anthropoid.

G. G. MAC CURDY.

14. *Catalogue of the Fossil Plants of the Glossopteris Flora in the Department of Geology, British Museum (Natural History). Being a Monograph of the Permo-Carboniferous Flora of India and the Southern Hemisphere;* by E. A. NEWELL ARBER. Pp. lxxiv, 255, with 51 figures and 8 plates. London, 1905.—Twenty years since, the catalogue of the Paleozoic Plants in the British Museum by Mr. Kidston was published. It has now been decided to prepare a series of detailed catalogues, and the first of these is the volume which is before us. It deals with the Glossopteris Flora, which, aside from its very great general scientific interest, is of much practical value to prospectors for coal in India and the Southern Hemisphere. This flora has not hitherto been comprehensively treated. The author gives an account of the less abundant and less known species as well as the characteristic types represented in the Museum collection, and also gives a revision of the older records from the standpoint of present knowledge.

15. *Catalogue of the Madreporian Corals in the British Museum (Natural History).* Volume V. *The Family Poritidæ.* II. *The Genus Porites,* Part I. *Porites of the Indo-Pacific Region;* by HENRY M. BERNARD, M.A. Pp. 303, with 35 plates. London, 1905.—This fifth volume of the catalogue of Madrepore corals is devoted to the genus Porites as represented in the Indo-Pacific region. This genus is more generally distributed in the warm seas than any other of the stony corals, and on account of its closeness of texture has played an important part in reef-building. The peculiar intricacy of the structure of the skeleton has hitherto been a difficult problem to the student of coral morphology ; but the author remarks that, as the result of his labors, "the intricate skeleton of this genus can now be reduced to order and the principles of structure minutely described, although we are still far from having unravelled the exact nature of many of the variations." The difficulty of the problem will be realized from the further statement "that there

were, indeed, moments near the beginning of it when the writer was in despair and on the verge of resigning his undertaking altogether."

16. *The British Freshwater Rhizopoda and Heliozoa;* by JAMES CASH, assisted by JOHN HOPKINSON. Vol. I, Rhizopoda, part I, pp. 148, with 16 plates and 32 text-figures. London, 1905 (The Ray Society).—A systematic treatise designed to describe and illustrate as fully as possible all the species of rhizopods and heliozoans known to occur in Great Britain. The present volume takes up 14 genera of the order Amoebina and 3 genera of the order Conchulina, a new term proposed for the shelled freshwater rhizopods. Not all of the genera are tenable; for example, *Ouramoeba* was established by Leidy upon specimens of the common *Amoeba proteus,* on the body of which occurred a growth of a parasitic fungus, and the author follows Leidy's error in describing these fungi as protoplasmic filaments of the body of the rhizopod. The synonymy of the species is very complete. The illustrations are excellent, particularly those of the nine colored plates, and are mainly from drawings by the author.   W. R. C.

17. *Guide to the Invertebrates in the Collection of the Boston Society of Natural History.* — The reference to the author of this work, on p. 336 of the April number, should have read Mrs. Sheldon instead of Mr. Sheldon.

18. *Notes from the Harvard Botanical Station in Cuba.* —The production of sugar-cane seedlings, to which reference has been made several times in this Journal, is now progressing very favorably. The wide geographical range of parents has enabled us to make interesting experiments in regard to the adaptive characters of the varieties. Our stock of varieties has been obtained at different times from Australia, Java, Mexico, and the West India Islands. The larger proportion of these varieties from the West Indies may be regarded as more closely related to our original Cuban strains. In the earlier years of the crossings, the conditions of weather were not propitious for pollen transfers, and it was found to be largely a matter of luck whether the seed set or not. In fact, it was beginning to be thought by us that the climate was not favorable to this line of experimenting. But in spite of bad weather, Mr. Robert M. Grey, the Superintendent in charge of the Station, succeeded in securing a fair number of desirable crosses. These seedlings have been transplanted into cane ground, and tests have been made of the content of sugar. Experiments show that the "Amber Cane" is still as good as any of the new varieties of our earlier series.

The last seasons have been better for the experimental work, being wholly exceptional in the recent annals of Cuban climate. Mr. Grey has been able to take advantage of the anomalous conditions and has succeeded far beyond our most hopeful expectations in obtaining new varieties. We now have at the Station about seven hundred sorts of cane seedlings, of the most varied parentage. It is believed that among this large number will be some which

will have a larger content of sugar and at the same time possess good powers of resistance to untoward influences. It is interesting to note that "Sereh" is not noted at the Station or on the Estate. Since it is the policy of the Station to place at the service of the Cubans the results of these experiments, improved varieties will be described at an early day.

Plants of various species which were brought by Mr. C. G. Pringle from Mexico direct to Cuba a few years ago and set out at once in the grounds of the Station, have done well with the exception of a few which were destroyed in a freshet which injured a part of our grounds. Most of them are now well established as stocks for experimental purposes.

During the past winter, Mr. Robert Cameron, Head Gardener of the Garden at Cambridge, made a long journey in the West Indies to secure certain fresh specimens of desirable economic plants for the Cuban Station. These have reached the grounds in good condition, and are nearly ready for crossing. To meet the demands for a wider range of soil for these new plants, additions have lately been made to the land used for study, and it is already found that our range of plants can now be materially increased. We have about all the sorts of soil and the kinds of exposure needed for our purposes.   G. L. G.

19. *Plant Response as a means of Physiological Investigation;* by JAGADIS CHUNDER BOSE, M.A., D.Sc., Professor, Presidency College, Calcutta (Longmans, Green and Co., London, New York, and Bombay, 1906).—This volume of more than 700 pages is a direct outgrowth of a previous work by the same author, entitled, " Response in the Living and Non-living," published in 1902. The first nine chapters in the earlier treatise were devoted to electric response, and response in plants, while the remainder of the work was given up to a consideration of response in inorganic matters. A great deal of that work was so interesting that it almost compelled a continuance of investigation along the same lines.

In the present volume the author attempts to prove by the use of extremely delicate multiplying apparatus, by which slight movements are increased many fold, that even those parts of living plants which have not hitherto been seen in motion possess a considerable power of response to external stimulation. The types of multipliers are for the most part unlike those previously employed in vegetable physiology, and, therefore, the paths struck out by the investigator are generally new. Whether the paths lead directly to the conclusions which the author adopts, must remain an open question until his researches have been many times repeated by others. But it may be unhesitatingly said that a careful reader of the present volume must be impressed by the ingenuity of device and the delicacy of manipulation obvious throughout the whole of the experimenting, and, further, one is struck by the apparent truthfulness of all the records. Assuming that the instruments work exactly as

described, it is difficult to reach conclusions which differ materially from those stated by Professor Bose.

The author has undertaken to show that the plant is a machine, the movements of which in response to external stimuli are "reducible to a fundamental unity of reaction." He says, "In analysing plant-movements the greatest complexity arises from the confusion of effects due to internal energy and external stimulus respectively. I have however been able to discriminate the characteristic expressions of these two factors and thus to disentangle the complex phenomena which result from their combined action. Another very obscure problem is found in the nature of so-called spontaneous or autonomous movements. By the discovery, however, of multiple response, and by the continuity which I have been able to establish as existing between multiple and autonomous responses, it has been found possible to demonstrate that there are, strictly speaking, no spontaneous movements, those being known by this name being really due to external stimulus previously absorbed by the organism. Thus all the experiments have tended to show that the phenomenon of life does not, as such, connote any intrusion into the realm of the organic of a force which would interfere with that law of the Conservation of Energy which is known to hold good in the inorganic world. The elucidation of the fact that such varied and obscure phenomena in the life processes in the plant, as, for instance, growth and the ascent of sap, are fundamentally due to the same excitatory reactions as are seen otherwise exemplified in the simple mechanical response now familiar to us, constituted a further result which, at the outset of the investigation, was little to be foreseen. It has been shown finally that there is no physiological response given by the most highly organised animal tissue that is not also to be met with in the plant."

In a further notice an analysis will be made of some of the chapters : the present is simply to call attention to the general character of a very suggestive work.   G. L. G.

20. *A Monograph of the British Desmidiaceae ;* by W. West and G. S. West. Vol. II, pp. 204 ; 32 colored plates. London, 1905 (printed for the Ray Society).—The first volume of this important monograph, published in 1904, has already been reviewed in this Journal (xviii, 473). The second volume maintains the high standard set for it by the first and continues the description of species. Only three genera receive treatment ; namely, Euastrum, with 46 species, Micrasterias, with 18 species, and Cosmarium, with 50 species. These genera include some of the most beautiful of the Desmids, and all three have a very wide geographical distribution. Of the species here described and figured nearly four-fifths have already been recorded from the United States.   A. W. E.

21. *Die Pflanzenfabel in der Weltliteratur ;* by Aug. Wünsche. Pp. 184. Akademischer Verlag für Kunst und Wissenschaft, Leipzig and Vienna, 1905.—The various fables in which plants

play an important part are discussed, with special reference to those found in the literature of Germany. The work is of literary rather than of scientific interest. A. W. E.

III. Miscellaneous Scientific Intelligence.

1. *Die Bahnbestimmung der Himmelskörper;* von Julius Bauschinger. Pp. 653, with 84 figures. Leipzig, 1906 (Wilhelm Engelmann).—The present volume is of particular interest since, coming from the hands of the able director of the Berlin Jahrbuch and Computation-bureau, the opportunities for practical testing of the methods have been unsurpassed. Also since the date of Watson's treatise of some 40 years and that of Oppolzer of some 20 years ago, which may be said to have covered the field of comet and asteroid orbit-computation at their epoch, and that of the less comprehensive but valuable works of Klinkerfues, Frischauf,* Moulton and others, a number of important contributions to this branch have been made. An especially interesting feature of Dr. Bauschinger's work are the historical sketches of the various phases of the problem.

The treatise is divided into seven parts, the first three of which treat of the coördinates, the heliocentrics and the geocentric motion of a body moving about the sun according to Kepler's laws.

Part four gives the solution of the problem of a first orbit and it is noteworthy to find that both for an ellipse from three observed positions and a parabola the methods presented in detail are substantially the Gauss-Encke and Gauss-Hansen for the former and the Lambert-Olbers-Gauss for the latter. The remarkable formulae of Gibbs, which are probably the most striking contribution of late years to the domain of orbit-computation, are briefly considered with modifications of Gibbs' original somewhat involved method; and reference is made to the ingenious methods of Weiss, Fabritius and others. For the exceptional case where four observations are requisite an expeditious method of the author is presented. The so-called direct methods, where three or any number of observations may be used, are briefly treated; the Laplace-Bruns method alone is given in full and reference only made to the work of Harzer, Leuschner and others.

Part five comprises the determination of a definitive orbit from all available observations by the method of least squares, and part six the theory of special perturbations, examples being given for the variation of constants and the perturbations in rectangular coördinates.

In part seven are found methods for orbits of meteors, satellites and binary stars.

Dr. Bauschinger has already published a collection of numerical tables for use in theoretical astronomy and the two works

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* To which an appendix with an application of Gibbs' principle has lately been issued by the same publishers.

together may be confidently recommended as a complete and practical presentation of the present status of orbit determination.

<div align="right">W. L. E.</div>

2. *Report of the United States National Museum under the direction of the Smithsonian Institution for the year ending June 30, 1904.* Pp. xvi, 780, with 66 plates and 142 text-figures. Washington, 1906.—The Assistant Secretary of the Smithsonian Institution, Mr. Richard Rathbun, gives in this volume a report of the present condition of the U. S. National Museum and the work done during the year named. This is supplemented by the reports of the Head Curators. Part II contains the History of American Geology by George P. Merrill, noticed on a preceding page (p. 467) ; also a description of the Howland Collection of Buddhist Religious Art in the Museum by I. M. Casanowicz, and of Flint Implements of the Fayum, Egypt, by H. W. Seton-Karr.

3. *The Dynamics of Living Matter;* by JACQUES LOEB. Pp. 233. New York, 1906. (The Columbia University Press, The Macmillan Company, Agents.)—The scope of this volume is clearly indicated by the introductory paragraph : " In these lectures we shall consider living organisms as chemical machines, consisting essentially of colloidal material, which possess the peculiarities of automatically developing, preserving, and reproducing themselves. The fact that the machines which can be created by man do not possess the power of automatic development, self-preservation, and reproduction constitutes for the present a fundamental difference between living machines and artificial machines. We must, however, admit that nothing contradicts the possibility that the artificial production of living matter may one day be accomplished. It is the purpose of these lectures to state to what extent we are able to control the phenomena of development, self-preservation, and reproduction."

The present book presents the same broad views of the fundamental problems of physiology as have dominated the earlier " Studies in General Physiology " and the " Comparative Physiology of the Brain " by the same author. It is impossible to read these comprehensive records, characterized as they are by the author's remarkable familiarity with the literature of comparative physiology and his unusual personal experience as an investigator, without immediate profit. His treatment of biological themes is as original as it is unique. The point of view may be unusual at times, but it is always suggestive. One may not always follow Professor Loeb with an enthusiasm equal to that with which some of his more radical views are championed. Nevertheless in such cases the critical reader will usually find that the pursuit of the new ideas stimulates, even if it fails to convince him.

To help in the construction of a mental picture of the make-up of living matter, Loeb has drawn aid from the newer discoveries of physical and chemical science. The topics: general chemistry of life phenomena, the general physical constitution of living matter, the rôle of electrolytes, tropisms, fertilization, heredity,

and regeneration will serve to indicate the range of the lectures. The chapters on tropisms, for example, are of exceptional general interest and show how trenchant the author's critique may become at times. In discussing a theme upon which so widely divergent views are held, he wisely says: "The more fertile a principle is, the more we can afford to be conservative in applying it." (p. 159.) Loeb mountains that the tropisms and tropism-like reactions will one day form the main contents of a scientific psychology of lower forms. The subject of fertilization, as might be anticipated, is discussed in a comprehensive way. Indeed the writer is far more successful in the treatment of general topics of this character than of more specific problems like those of secretion, for instance. The volume will be fruitful in awakening further interest in general physiology, and cannot fail to add to the author's influence on the progress of biological research and teaching in America.   L. B. M.

4. *Carnegie Institution of Washington.*—The following are recent publications of the Carnegie Institution :

No. 9.—The Collected Mathematical Works of George William Hill. Volume II, pp. 339. Containing memoirs Nos. 37–49. Volume III, pp. 577. Memoir No. 50, A new theory of Jupiter and Saturn.

No. 40.—The Nucleation of the Uncontaminated Atmosphere ; by CARL BARUS. Pp. xii, 152 ; with 104 figures.

5. *Brooklyn Institute of Arts and Sciences.*—Science Bulletin, vol. I, No. 7 (pp. 141–186) contains two papers by Chas. Schaeffer. The first describes some new Coleoptera from Brownsville, Texas, with notes on species now first recorded from the United States chiefly from the Huachuca Mts., Arizona ; the second paper gives a list of Bombycine moths collected in 1905 in the Huachuca Mts. A third paper by H. S. Dyar describes some new moths from Arizona.

Der Ablauf des Lebens ; Grundlegung zur Exakten Biologie ; von Wilhelm Fliess. Pp. 584. Leipzig und Wien, 1906.

Obituary.

Professor NATHANIEL S. SHALER, whose death on April 10 was announced in our last number, was born near Newport, Ky., on Feb. 20, 1841. He went to Harvard in 1859, enrolling in the Lawrence Scientific School and studying chiefly with Louis Agassiz. After receiving the degree of S.B. in 1862, he enlisted in the Fifth Kentucky Battery and saw active service in the Union army for two years. On returning to Harvard he was appointed lecturer in 1864, professor of paleontology in 1869, professor of geology in 1888, and dean of the Lawrence Scientific School in 1891. He was given the degree of LL.D. by Harvard in 1903. Shaler's lectures on geology were always popular; it is believed that he thus addressed some 7,000 students, probably a larger number than were ever taught geology by any other man. He was of marked individuality, inventiveness and activity, of

strong feelings and of unusually wide interests. The department of geology at Harvard flourished under his leadership, increasing greatly in number of teachers, subjects taught, students enrolled and equipment. The department of mining and metallurgy was developed under his initiative. The Scientific School was rehabilitated by his vigilant care as dean, and at the time of his death he saw the beginning of a consummation to which he had long looked forward : the establishment of a Graduate School of Applied Science at Harvard under the endowment of his long-time friend, Gordon Mackay. Shaler was director of the Kentucky Geological Survey from 1872 to 1879, geologist of the U. S. Geological Survey for a number of years, president of the Geological Society of America in 1895 ; he was frequently consulted on mining enterprises in the South and West, and was a member of Topographical Survey, Highway and Gipsy Moth commissions of Massachusetts. His writings covered many phases of geology, the brachiopods of the Ohio Valley, the caverns of Kentucky, glacial phenomena in New England, the structure of the Narragansett basin, the features of sea coasts, the face of the moon. In recent years, his thoughts turned towards social problems, as illustrated in three volumes, The Individual, The Citizen, and The Neighbor, and he found entertainment in writing on the Elizabethan period in blank verse. His death was caused by pneumonia following an operation for appendicitis ; it came upon him suddenly in the midst of work, his last official act being the preparation of a circular announcing the establishment of the new Graduate School of Applied Science and the associated changes in the administration of scientific work at Harvard. W. M. D.

ISRAEL COOK RUSSELL, Professor of Geology in the University of Michigan, died May 1st, in the 55th year of his age. His death coming in the middle of a busy life, is a blow, not only to the university which he had actively and efficiently served since his appointment in 1892, but to the science in this country which during many years he had so materially promoted by his work and publications. He was educated at New York University and Columbia College and soon became connected with the Government surveys of the West. His investigations of former Lake Lahontan, like those of Gilbert's Bonneville, produced results which have become classic in geologic literature. His explorations in Alaska and in the extreme northwestern states contributed knowledge of great interest and importance from little known regions, and laid the way for detailed investigations of the future. His interests tended largely to the physiographic side of geology, and his volumes, written in a popular way for instruction, on the volcanoes, glaciers, rivers and lakes of North America, have had a host of readers and have stimulated interest in geologic science. He also made the Triassic deposits of the east a field of special study, and his volume on the Newark formation is a standard work of reference on this subject. His genial disposition endeared him to all who knew him and he will be mourned by many friends. L. V. P.

INDEX TO VOLUME XXI.[*]

A

Abbe, C., obituary notice of S. P. Langley, 321.

Abbe, E., memorial to. 338.

Abraham, H., Ions, Electrons and Corpuscules, 466.

A c a d e m y, National, meeting at Washington, 406.

Agassiz, A., Albatross Expedition to Eastern Pacific, 257.

Alaska, Copper River region, geology, Mendenhall, 82 ; Mesozoic section in. Stanton and Martin, 181.

Albatross Expedition to the Eastern Pacific, Agassiz, 257.

Allen, E. T., polymorphic forms of calcium metasilicate, 89.

Arizona, Coon Butte, Barringer and Tilghman, 402 ; copper deposits, Lindgren, 332 ; stony meteorite. Mallet, 347.

Association, American, meeting at New Orleans, 188.

Auer burner, spectrum of, Rubens, 172.

B

Baker, R. H., solar eclipse of 1907, 245.

Ball, S. H., pre-Cambrian rocks of Georgetown, Col., 371.

Ballore, F. de M. de, les Tremblements de Terre, 331.

Barnes, C., nucleation of the atmosphere, 400.

Bauschinger, Bahnbestimmung, 478.

Berry, E. W., Prorosmarus alleni from Virginia, 444.

Birds, see **ZOOLOGY.**

Boltwood, B. B., radio-activity of salts of radium, 409 ; radio-activity of thorium minerals and salts, 415.

Bose, J. C., Plant response as a means of investigation, 476.

Boston Society of Natural History, Guide to Invertebrate Collection, Sheldon, 336, 475.

BOTANY.

Desmidiaceæ, British, West, 477.

Fungi, of N. America, Index, Vol. 1, pt. 1, Farlow, 87.

Pflanzenfabel in der Weltliteratur, Wünsche, 477.

Plant response as a means of physiological investigation, Bose, 476.

Plants, manganese as fertilizer, 248.

Rhizopoda, British freshwater, Cash and Hopkinson, 475.

Bradley, W. H., precipitates on asbestos, 453.

British Museum, catalogue of Glossopteris flora, Arber, 474 ; Madreporian corals, Bernard, 474.

— New Guinea, geological features, Maitland, 404.

Brooklyn Institute, bulletins, 479.

Brooks, W. R., The Oyster, 88.

Brown, J., interaction of hydrochloric acid and potassium permanganate, 41.

Buchanan, J. Y., determination of specific gravity of soluble salts, 25.

Bumstead, H. A., heating effects of Röntgen rays in different metals, 1.

C

California, Miocene foraminifera, Bagg, 253.

Canada, geol. survey, see **GEOLOGICAL SURVEYS.**

Carnegie Institution, publications, 258, 479.

C e y l o n minerals, Coomaraswamy, 186.

Chamberlin, T. C., geology, 400.

CHEMICAL WORKS.

Ammonia, liquid, as a solvent, Bronn, 79.

Chemistry, Conversations on, Ostwald, 248.

— Progress for 1904, Annual Report, 80.

Elements and Compounds, Affinities of, Martin, 79.

[*] 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.

CHEMISTRY.

Alkaline metals, boiling points of, Ruff and Johannsen, 78 ; hydrides of, Moissan, 77.

Ammonium sulphate, decomposition, Delépine, 247.

Antimony, modifications, Stock and Siebert, 170.

Asbestos, precipitates on, Penfield and Bradley, 453.

Bismuth, determination, Staehler and Schaffenberg, 171.

Bromine fluoride, Lebeau, 172.

Caesium chromates, Fraprie, 309.

Calcium hydride, gaseous in acetylene, 464 ; preparation, Jaubert, 464.

— metasilicate, polymorphic forms, Allen and White, 89.

Carbon oxybromide, von Bartel, 463.

suboxide, Diels and Wolf, 396.

Cyanogen, synthesis of, Wallis, 464.

Ferric chloride in the zinc reductor, Randall, 128.

Gold, colorimetric determination, Maxson, 270.

— distillation, Moissan, 171.

Grape sugar, determination, 325.

Halogens in organic compounds, determination, Vaubel and Schauer, 396.

Hydriodic acid, rapid preparation, Bodroux, 326.

Hydrochloric acid and potassium permanganate, interaction, Brown, 41.

Iron group, distillation of metals, Moissan, 397.

— rusting of, 78.

Iron-cyanogen compounds, cause of color, 78.

Manganese as a fertilizer for plants, Bertrand, 248.

Nitrous and nitric acids, determination, Weisenheimer and Heim, 170.

Organic substances, mechanical separation, Bordas and Tourplain, 398.

Platinum group, boiling of metals of, Moissan, 325.

Polonium, radio-activity of, Curie, 326.

Radium, see **Radium.**

Silicon, fluoroform, Ruff and Albert, 247.

Silver, electro chemical equivalent, Van Dijk, 326.

— vapor, molecular weight, Wartenberg, 463.

Sulphur in pyrites, determination, Hintz and Weber, 324.

Tellurous and telluric acids, Berg, 248.

Thorium, see **Thorium.**

Chwolson, O. D., Lehrbuch der Physik, 174.

Cirkel, F., asbestos, 255 ; mica, 405.

Coast Survey, report, Tittmann, 259.

Coherer, electrolytic, Gundry, 326.

Colorado, Georgetown, pre-Cambrian rocks, Ball, 371.

— red beds of southwestern, Cross and Howe, 328.

Colloidal solutions, electrically prepared, Burton, 399.

Condenser sparks, energy, duration, etc., Heydweiller, 465.

"Container," new form for Museums, Goodale, 451.

Corals, Madreporian in British Museum, Bernard, 474.

— Paleozoic, early stages, Gordon, 109.

Cross, W., red beds of southwestern Colorado, 328.

Crystallography, Groth, 185.

Crystals, drawing of, Penfield, 206.

Cuba, Harvard Botanical Station, 475.

D

Dadourian, H. M., radio-activity of thorium, 427.

DeLury, J. S., cobaltite in northern Ontario, 275.

Doelter, C., Petrogenesis, 472.

Dominica, Avifauna of, A. H. Verrill, 337.

Dresser, J. A., metamorphic rocks of St. Francis Valley, Quebec, 67.

Dynamics of Living Matter, Loeb, 479.

E

Earthquakes, de Ballore, 331.

Eastman, C. R., Dipnoan affinities of Arthrodires, 131.

Electrical conductivity of flames, Wilson and Gold, 399.

— radiation, Paetzold, 250.

— rectifier, Wehnelt, 250.

Electro-Chemistry, Hopkins, 249.

Electrolytic coherer, Gundry, 326.

Electron, constitution of, Kaufmann, 398.

Elektrische Kraftübertragung, Philippi, 81.

Ethnology, Bureau of American, publications, 260.

CONTENTS.

SCIENTIFIC INTELLIGENCE.