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Art. I.—*On Gravity Determinations at Sea*;* by L. A. Bauer.

A given mass changes its weight when transported over the Earth's surface. How shall we determine these alterations? It cannot be done with a balance; for a mass in one scale pan held in equilibrium by a set of weights in the other pan will remain in equilibrium all over the Earth, since the Earth's gravitational force within our limits of measurement acts alike on all substances. The variations in gravity are composed of three parts: one called the "normal part," varying simply with latitude; another the "anomaly," a more or less irregularly distributed part, and the third part dependent upon altitude of station above sea-level.

We might replace the beam of our balance by a pivoted magnetized steel bar or needle. Suppose we were to start out from Washington, where the magnetic dip is about 70·5°, with the beam made to lie horizontal by suspending a suitable weight on its south end; we have thus balanced the earth's gravitational force by the vertical component of the Earth's magnetic force. Were we now to proceed with this balance to some distant point, the beam might no longer be truly horizontal but make instead an angle with the horizon, the magnitude of which would depend upon the relation at that point between the earth's magnetic and its gravitational force. Knowing the value of the vertical magnetic component, it is then possible to determine, within certain limits, from the inclination of the beam how much the suspended mass has

* Presented before the Philosophical Society of Washington, November 5, 1910.

altered its weight, or in turn find the change in gravitational force. We have in fact such an instrument as here described, viz., the dip circle used in determining the total magnetic force by Lloyd's method, one operation consisting of measuring the angle of dip of a suspended magnetic needle having a load on one end. Observations made thus on the "Galilee" in the Pacific Ocean, covering a range in latitude from about 59° North to 42° South, showed that the variation in weight of the load over a large range in latitude might be taken into account. With such a dip circle, the latitude variation of gravity could just about be detected; however, for smaller gravity variations the instrument would not be sensitive enough, both because of its construction and our inability to determine the magnetic force with sufficient precision.

The method most commonly in use on land for determining the value of the linear acceleration of gravity, g, is by pendulum observations. But this method has not been found feasible on board ship. If, then, it is desired to extend a gravity survey so as to include the oceans as well as the land, other experimental means than swinging pendulums must be devised. The method thus far used to disclose gravity anomalies at sea is that known as the "boiling point, mercurial barometer method." The principle here is to measure the counterbalancing effect of the elastic pressure of a vapor on a column of mercury, once by reading the height of the mercurial column, the counterbalancing vapor being the atmosphere; next, by measuring the atmospheric pressure prevailing at the time by determining the temperature of the boiling point of pure water. Since the boiling point, other things being equal, depends solely upon the atmospheric pressure, it will not vary as we pass over the earth as long as the pressure is the same; however, the height of the mercurial column, under the same conditions, changes with variations in gravity. Hence the gravity anomaly is found by a direct comparison of the atmospheric pressure determined from the boiling point with that read off on the mercurial barometer. Prior to the boiling-point method for measuring the prevailing atmospheric pressure independently of gravitational force, the use of the aneroid was proposed; however, the latter instrument is found too variable and uncertain in its indications to possess the required sensitiveness.

Guillaume in 1894 was led to suggest the use of boiling point thermometers in place of the aneroid, but Mohn* has the credit of having made the first practical use of the method,

* Mohn, H.: Das Hypsometer als Luftdruckmesser und seine Anwendung zur Bestimmung der Schwerekorrektion. Christiania, Skr. Vid. Selsk. Math.-naturw. Kl. I, 1899, No. 2 (1–69).

in determining between 1896 and 1898 the gravity correction to observed barometric heights at various stations of the Meteorological Service in Norway. It was Mohn's success which led Helmert and Hecker to consider this method for ocean gravity observations.

Hecker, working under the direction of Helmert, has thus far made three expeditions, chiefly at the expense of the International Geodetic Association,—the first in 1901, in the Atlantic from Hamburg to Rio de Janeiro and return to Lisbon; next in 1904, a cruise extending over the Indian and Pacific Oceans, and finally in 1909 in the Black Sea. All of his work was executed in a most painstaking manner and a very elaborate instrumental outfit was used; the observations were made only on good-sized steamers of 5000 tons and upward. In his Black Sea cruise, of which the results have just appeared, the Russian cruiser "Pruth," of 5500 registered tonnage, was put at his disposal; his instrumental outfit consisted of six boiling point apparatuses, each provided with a thermometer and two sets of photographically registering barometers, one set having five mercurial barometers and the other four, or nine specially constructed barometers in all. The thermometers were read with a telescope magnifying twenty times, so that to the observer 0·001° appeared of the length $0 \cdot 4^{mm}$. The nine photo-barograms were independently read by two assistants and corrections for various sources of error were applied. Hecker also devised instruments for photographically recording the ship's motions, with the aid of which further corrections were determined. Finally, an elaborate adjustment by the method of least squares was made of the outstanding differences between the atmospheric pressure, *A*, derived from the boiling point work, and that, *B*, resulting from the barometric readings referred to standard temperature and normal gravity for latitude 45°; there were thus determined further corrections, as explained later in this paper.

The 1901 work was published in 1903, that of 1904 in 1908, and that of 1909 in 1910. In Hecker's last publication are given, in addition to the Black Sea results, the *revised* results of the work done in 1901 and 1904, so that the previous publications are superseded by this latest one. The revisions were made necessary by the correction pointed out by Baron Eötvös due to course and speed of vessel. Hecker's work in the Black Sea was done partly for the very purpose of testing whether his methods were of sufficient accuracy to detect this theoretical correction; he reaches an affirmative conclusion and, accordingly, revises his previous reductions. He now also excludes, in the least-square adjustments, observations in ports made on vessel at anchor; his present results for Δg differ at times from the previously published ones by $0{\cdot}15^{cm}$.

Suggestions have been received from various sources that it would be highly desirable to include, if possible, gravity work on the "Carnegie." At the request of President Woodward, I consulted in 1905 Professor Helmert, Director of the Geodetic Institute at Potsdam, as to the possibility of attempting the boiling-point method on the "Galilee," which had just been chartered for magnetic work in the Pacific Ocean. As the result of Hecker's experiences on vessels exceeding the tonnage of the "Galilee" by eight times and more, Helmert did not feel warranted in advising the undertaking of similar work on our vessel; he thought it best under all circumstances to await the conclusion of Hecker's labors. No attempt was accordingly made on the "Galilee."

However, on the "Carnegie" it was decided to include determinations of the temperature of the boiling point of water in the regular routine work aboard, the prime purpose being to obtain data for controlling the corrections of our aneroids. The instrumental equipment was in accordance with this aim; it consisted merely of two boiling apparatuses of the pattern described and figured in the British Antarctic Manual of 1901, p. 94, two specially constructed thermometers by Green, of Brooklyn, N. Y., graduated into one-hundredths of a degree centigrade from 97·6° to 107·7°, the length of one degree being about 40 millimeters, and one Green mercurial marine barometer. In all 106 determinations of the boiling point were secured on the First Cruise, between Sept. 1909 and Feb. 1910, four of which had to be rejected because of manifest errors, leaving 102 values and representing 75 different points. While a few observations were made at the very beginning of the cruise, by Mr. J. P. Ault, the navigating officer, the work did not begin regularly until the vessel left Falmouth on November 6, 1909, but thereafter to Madeira, thence to parallel 20° North and return to Brooklyn via Bermuda, the observations were made almost daily by Dr. C. C. Craft, and that too at times under very trying conditions of weather. A week's series or more was obtained at each of the ports,—Brooklyn, Falmouth, Funchal (Madeira), and Hamilton (Bermuda).

The two boiling-point thermometers were read visually, with the aid of a hand lens, to the nearest 0·001° by estimation of a tenth of a space $0{\cdot}4^{mm}$ long; and the mercurial barometer was read directly by vernier to 0·01 inch and by estimation to 0·005 inch or less. The pumping of the barometer, which is of the ordinary marine type, amounted at times under the severe conditions of sea encountered on the return trips to as much as

5^{mm}; several settings were made, and both the low and high readings were recorded. To reduce the pumping, Hecker had introduced a special capillary tube in about the middle part of his barometer, and, since his observations were made on large steamers, the pumping of his barometer was generally less than 0·5^{mm}. A careful scrutiny of our observations has encouraged me in the belief that it may be worth while to attempt also gravity work on the "Carnegie," which in her various cruises will have opportunity of getting data in regions not yet covered, and will also at times cut across Hecker's trips. Attention is accordingly being given to the question of refining the instrumental appliances and simplifying the method of reductions. As the best preparation it was thought well to review carefully Hecker's work in order that full advantage might be taken of his experiences in this pioneer work, as also to determine what were the various sources of error and their relative importance. (Cf. *Bestimmung der Schwerkraft auf dem Schwarzen Meere, etc.*, Berlin, 1910.)

Hecker's Ocean Gravity Observations.

Let us begin with the formulæ used, and the theoretical treatment applied to the observations.

Let A = atmospheric pressure deduced from the temperature of the boiling point of pure water with the aid of tables, as for example Wiebe's, given in the "Landolt–Börnstein Tabellen" for 1905;

B = the simultaneously observed atmospheric pressure with a mercurial barometer, reduced to standard temperature, to sea-level and to normal gravity for latitude, $\phi = 45°$;

then is $\beta = A - B$ in mms. mercury. (1)

Were there no errors of whatever kind attaching to A or B, then β would be the gravity anomaly sought. To convert into cms. of the acceleration of gravity, g, we must multiply equation (1) by the approximate factor, $980/760 = 1{\cdot}29$, hence

$$\Delta g = 1{\cdot}29\,(A - B) \text{ in cms. per second.} \quad (2)$$

The reduction of B to normal gravity is made with the aid of Helmert's formula of 1901*:

$$c = (-0{\cdot}002644 \cos 2\phi + 0{\cdot}000007 \cos^2 2\phi)\,B. \quad (3)$$

The coefficient of the second term was adopted by Helmert from the theoretical investigations of Wiechert and Darwin;

* See note next page.

however, the first coefficient, 0·002644, he deduced empirically* from a least-square discussion of nearly one-fourth of the available pendulum observations, selecting undisturbed coast and inland stations. This first coefficient gives for the ellipticity of the earth, 1/298·3; the value adopted in the Smithsonian Meteorological Tables, 1907, is 0·002662 as obtained by Professor Harkness in his work "The Solar Parallax and its Related Constants, Washington, 1901." For $B = 760^{mm}$, for example, the first corrective term for a point on the equator would be, $-2·0095^{mms}$ for Helmert's formula and $-2·0231^{mms}$ for the Smithsonian Tables; the second term for $B = 760^{mm}$ and the equator amounts to $+0·0053$, so that the total correction, according to Helmert, would be $-2·0042^{mms}$. For the poles, the corrections would be, $+2·0095$ and $+2·0231^{mms}$. In order, therefore, to detect by ocean observations the difference between the two formulæ, it would be necessary to secure an accuracy of about $0·01^{mm}$ mercury or $0·015^{mm}$ acceleration or about 1/100,000 part of g. This matter is mentioned here since one of the conclusions drawn by Hecker from his ocean observations is that they accord with Helmert's formula.

But A and B are subject to various sources of error, partly due to instrumental causes and observational errors and partly due to motion of the vessel. Of the disturbances caused by the vessel there are two which may readily be disposed of. First that due to the possible attractive effect of the mass of the vessel, since this even for a 100,000 ton vessel would only be on the order of 1/1,000,000 of g, is negligible; second, that due to the course and speed of the vessel. Only the motion in longitude counts—for a vessel sailing east along a certain parallel the instruments aboard are being transported around the axis of rotation of the Earth faster than is a fixed point in the same parallel and the force of gravity aboard is accordingly diminished and the mercury in the barometer made to stand correspondingly higher than it would were the vessel not moving. For a vessel sailing west, the effect is reversed. So that if at a certain point on the earth gravity is measured aboard a moving vehicle, once when moving eastwardly and next moving westwardly at the same rate of speed, the values of g at the two times would differ by twice an error, the exact amount of which may be computed from the following formula:

* Helmert, F. R. Der normale Theil der Schwerkraft im Meeresniveau. Sitzber. Akad. Wiss., Berlin, xiv, 1901. There is a misprint in Hecker's publication of 1908; at top of table, p. 226, Helmert's coefficient is given as 0·00244 instead of 0·002644.

Let c' = correction to an observed mercurial barometric height on account of speed and course of moving vessel,
v_0 = velocity of a point in the equator $= 4{\cdot}65 \times 10^4$ cm./sec.
v' = " " ship along a parallel of latitude.
R = earth's mean radius $= 6{\cdot}38 \times 10^8$ cm.

then is

$$c' = \mp \frac{760}{980} \cdot \frac{2v_0 v'}{R} \cos^2\phi = 0{\cdot}0146 \cos^2\phi \text{ in mm. mercury} \qquad (4)$$

— for vessel going east. + for vessel going west.

To get the correction in cms. g, multiply the tabular quantities by 1·29. For a vessel sailing east, for example, along the equator at the rate of 7 degrees or 420 knots a day, the atmospheric pressure observed on board with a mercurial barometer would have to be diminished by $0{\cdot}1^{mm}$. On the other hand, for the same vessel going west at the same speed, the barometer reading would have to be increased by $0{\cdot}1^{mm}$. In the first case g would be too low by $0{\cdot}15^{cm}$ and in the second too high by the same amount, or the resulting error, if not taken into account between the two occasions, would be $0{\cdot}30^{cm}$ or 1/3300 part of g—a respectable quantity. On the average, Hecker's corrections for the vessels on which he made his observations was about $\pm 0{\cdot}07^{cm}$ in g; for the "Carnegie" the correction would usually be less than $\pm 0{\cdot}03$. Since the correction is a perfectly definite one and can readily be computed, it is worth while applying.

But there are more troublesome sources of disturbance arising from a moving vessel not so readily disposed of as the preceding one—arising from the actual motions of the vessel, such as rolling and yawing, vibration due to machinery, and worst of all, pitching and accompanying vertical motions. Hecker, as above stated, undertook to determine these sources of error instrumentally with the aid of devices recording the ship's motions. He then determined the reducing coefficients for each effect by a least-square adjustment of all the observations made on any one cruise. The manner of mounting, as compared with those of the barometers, as well as an examination of the results of Hecker's laborious least-square adjustments, leads one to question the effectiveness of his devices for the elimination of the ship's effects.

Next are the errors due to purely instrumental causes, such as changes in the corrections of the thermometers with which the boiling point of pure water is determined, furthermore the relation of the zero of the boiling-point atmospheric pressure to that of the mercury barometer, and the variations in this relation, etc., etc.

Hecker's final observation equation is of the following form:

$$\beta + k_n + a\frac{dB}{dt} + bp + cr + ds + e(t - t_0) + k_2 = 0. \qquad (5)$$

I have substituted β for his quantity (Therm. — Bar. — computed gravity reduction to 45° — correction due to speed and course of vessel); it is the same as the quantity in equation (1) after having had the correction c' applied to B.

k_n = relation of the two zeros above + constant part of other corrections.

$\frac{adB}{dt}$ = correction to reduce the observations of boiling point and readings of barometer to same moment of time for any one set.

bp = correction due to pumping, p, of barometer.

cr = " " " rolling of vessel.

ds = " " " pitching " "

$e(t-t_0)$ = " " " time changes in instruments supposed to progress linearly.

k_2 = constant which enters into the equation only for deep sea observations, say for depths beginning with about 2000 meters.

There are thus in Hecker's complete equation seven unknowns, k_n, a, b, c, d, e, and k_2, which he determines by the method of least squares. Substituting next in each observation equation, of which there is one for each station, the derived values of the unknowns, a residual quantity, v, is obtained, supposed to be the gravity anomaly sought.

To get a clear understanding as to the assumption implied in his formula, let us suppose first that all the corrective terms in (5) except k_n and k_2, by a suitable scheme of observation and in a calm sea, reduce to negligible quantities, then we have for a shallow water station, s,

$$\beta_s = -k_n = \text{constant}, \qquad (6)$$

and for a deep water station, d,

$$\beta_d = -k_n - k_2 = \text{constant}, \qquad (7)$$

or

$$\beta_s - \beta_d = k_2 = \text{constant}. \qquad (8)$$

The same result (8) is obtained if we suppose, in passing from s to d, the corrective terms for each station were the same in magnitude and sign. But the difference $\beta s - \beta d$, under the conditions supposed, when multiplied by 1·29 (see equation 2) should be the difference in Δg at the two points, which of course would not, in general, be a constant. In other words β is composed of two distinct quantities, one, Δg, representing the gravity anomaly and the other the various sources of error, E, and so we have:

$$\beta = \frac{\Delta g}{1{\cdot}29} + E,$$

$$\text{or } \beta - \frac{\Delta g}{1{\cdot}29} - E = 0. \tag{9}$$

Comparing this equation with Hecker's (5), it must be evident that his corrective terms include the effects of the very quantities—the Δg's—to be determined. Since he applies the method of least squares to his equation, *Hecker must assume that during a cruise the local gravity anomalies*, *i.e.*, *the Δg's, partake of the nature of accidental errors*—that they either balance out in the long run or oscillate about a mean constant value, which enters into the constant terms of (5). But is not the proving whether such distributions of gravity anomalies exist, or do not exist, the very purpose of gravity surveys?

Furthermore, since Hecker adjusts each cruise by itself, then by the theory of least squares alone, the sum of his residuals or outstanding gravity anomalies must reduce to zero, or practically so, because of the presence of the constant terms in (5); hence his average computed β for the cruise must be *theoretically* equal to his average observed β, or in other words, *the average gravity anomaly of a whole cruise would be zero.* It must be evident then that as Hecker derives his unknowns they are not true values but are affected by the gravity anomalies over the areas for which the adjustment is made. They might be different, for example, for a cruise from New York to Liverpool than for one from Hamburg to Rio de Janeiro, even though all conditions remained precisely the same except that of difference in route followed. Manifestly then Hecker's method of adjustment is open to grave objections and it is a question as to how much of his resulting conclusions may not already be contained in his fundamental assumptions. Let us hope that the variations in the gravity anomalies at sea about an average value will be found to be of a sufficiently accidental nature to vitiate Hecker's main conclusions!

Strictly speaking, the values of the unknowns entering into equation (5) can only be derived from stations where there exist accurate gravity observations from which the anomaly Δg can be derived. This means, however, restriction to shore and harbor observation, but these are the very observations which above all Hecker has been unable to reduce satisfactorily and hence either omits entirely in his final tables or brackets as doubtful. In the first place the coefficients, *b*, *c* and *d*, can of course only be found from observation on a moving vessel. How poorly the Δg's from the harbor observations agree, in general, with those resulting from shore pendulum observations when the former are computed with the values of the unknowns obtained from the observations on the moving vessel, is shown by a table which Hecker gives on p. 159 of his 1910 publication. The differences amount at times to 1/6000 part of *g*. Hecker believes that the trouble arises chiefly from the fact that observations on a vessel moving and on one at rest are not comparable and, hence, require separate treatment, the difference arising chiefly from the dynamic conditions which enter in on the moving vessel. While he is undoubtedly in the main correct, still he does not appear to see that the unknowns as he derives them are not strictly instrumental or ship constants, but depend, as has been shown above, upon the area (extent and geographic position) from which they are derived. In any case, beyond revealing the discrepancies, he does not make known any attempt at a satisfactory reduction of the harbor observations. This is doubly unfortunate, first, because the harbor observations ought to furnish the best criteria possible of the absolute accuracy and possibilities of his method of observation, and secondly, since the connection of ocean results with land stations is correspondingly diminished in strength.

Every series of observations made by Hecker on shore or in port has been investigated, and not a single case of satisfactory reduction or adjustment was found. On his first cruise in 1901, in the Atlantic Ocean, from Hamburg to Rio de Janeiro and return to Lisbon, he made shore boiling-point observations at Rio de Janeiro and Lisbon at precisely the same places where he swung his pendulums. There was thus afforded a fine opportunity to test his boiling-point method and the behavior of his instrumental appliances. But he makes no attempt at such a comparison. Instead, he merely adjusts the series of shore observations at Rio de Janeiro, Aug. 24–Sept. 11, 1901, by itself and similarly the series at Lisbon, Oct. 12–17, 1901, again by itself. His observation equation is the same as (5) above with the omission of the terms involving *b*, *c*, *d*, and k_2, which apply only to observations at sea. While his adjustment improves the *individual* day's results at each of the two stations, it leaves unaltered the actual mean gravity anomaly observed at each station—in brief, he does not adjust Rio de Janeiro and Lisbon together, and the labor of his painstaking adjustments is practically for naught. Hence, if we take the quantities, as derived from Hecker's adjustments (or from the direct observations), we may see what the extent of *instrumental changes* may be during even such a brief interval as six weeks, during which, thermometers are subjected to frequent and protracted boiling. The mean Δg results for Rio de Janeiro–Lisbon derived from each of four barometers—two eye-reading ones and two photographically recording ones—differ from the pendulum value by $-0{\cdot}105$ to $+0{\cdot}200^{cm}$, thus exhibiting a range of 0·3. Even the two visual barometers give results from shore observations differing by 0·1 and this in spite of Hecker's laborious method of observation. The mean result here considered for any one barometer depended on 24 boiling point determinations and 8 barometric readings times the number of days, or for Rio de Janeiro, 360 B. Pts and 120 readings of each barometer and for Lisbon 216 B. Pts and 72 readings of each barometer!

Hecker made no shore observations by the B. P. method on any of his subsequent cruises, but he made a number in harbors on board vessels at anchor. These also exhibit most marked changes in but a few days, the effects of which if likewise experienced at sea, as must undoubtedly be the case, would exceed in importance the corrective terms in equation (5) due to motions of ship.

In his Black Sea work, Hecker had repeated trouble with his thermometers so as to be obliged to discard some series entirely. The thermometers were made by Fuess of Steglitz of Jena borosilicate glass 59 III. Looking over Hecker's scheme of observations, the suspicion is awakened that he "boiled" too often and too protractedly—a fact he himself began to suspect in his later work. What accuracy was supposed to be gained by excessive observing was lost in resulting instability of his thermometers. *The corrections for Hecker's thermometers were never re-determined after they had once been furnished by the German Physikalische Reichsanstalt.* Though some of the thermometers had been in use on the three cruises of 1901, 1904 and 1909, practically the same table of thermometric corrections is employed throughout. Three of them were provided with zero points but the zeros were never re-determined. *The corrections for the various barometers on a standard barometer for various barometric heights were never determined*, or if so, they were not used, the observer supposing that all instrumental changes—both of thermometers and of barometers—would fully be taken account of by a constant term (k_n equation 5) and by a term, $e\ (t-t_0)$, progressing linearly with the elapsed time. Let it be remembered that these two quantities k_n and e were not derived from observations at stations where Δg was known from pendulum work, but from the discussion of ocean observations for which a fictitious distribution of gravity anomalies had to be assumed in order that a least-square adjustment could be made.

The first point to be made, therefore, on the instrumental side is, that in order to secure desired accuracy in gravity determinations from boiling-point observations, it is essential that a method of observing be adopted which will protect, as nearly as possible, the instruments from changes of whatever kind, and next that the boiling-point thermometers be provided with zero points, the variations of which may be determined in the field with melting ice once a week or as often as may be found necessary. The next point is that the method of observations be such that they can be quickly reduced and that too in such a perfectly definite manner as to admit of no question with respect to the logical method of reduction to be employed. Hecker, as shown above, did not lay sufficient stress upon these vital points. It is believed that equally good, if not indeed superior results, can be obtained with less equipment than used by Hecker, using a simpler method of observation as well as of reduction. Hecker's cumbersome adjustments at times appear to have caused much needless labor. See, for example, his Black Sea adjustments, where he has attempted to derive his many unknowns from an insufficient range of conditions.

Another very important point introducing a source of error not considered by Hecker is with regard to the possible errors in the vapor tension tables used to convert boiling-point temperatures into corresponding atmospheric pressure. The latest of these tables are those of Wiebe's given in Landolt-Born-stein's "Physikalisch-Chemische Tabellen" for 1905. The most recent observations appear to be those of Holborn and Henning. For the purpose of gravity work, it is essential to be able to obtain accurately the atmospheric pressure for a comparatively limited range extending below and above 100° C.; the observations on which the tables are based were made at larger intervals and the interpolation is accordingly somewhat uncertain. It is quite possible that the atmospheric pressure as taken from the tables may be out by ·05 to $0·1^{mm}$, which corresponds to 0·065 to $0·135^{cm}$ in g. When dealing with only differential results, as we are in our case, the tabular errors are somewhat eliminated, though not wholly. *The problem of most accurate vapor-tension tables for water between 99° and 101° is here called to the attention of physicists.*

Hecker's Gravity Results.

From the explanatory statements on p. 150 of his 1910 publication, it is seen that Hecker uses a different plane of reference for the gravity anomalies, the Δg's, over each ocean, and that the planes refer strictly only to the parts of the respective oceans traversed. No direct comparison can in consequence be made in passing from one ocean to another and even for the same ocean, e.g., the Atlantic, it would not be possible to compare directly gravity anomalies between New York and Hamburg, with Hecker's between Hamburg, Rio de Janeiro and Lisbon. He does not explain completely how he actually connected ocean results with pendulum stations; for example, how he distributed the correction from one land station to another. Why he did not refer his Atlantic Ocean results likewise to his pendulum stations, e.g., at Rio de Janeiro and Lisbon, he does not say. All this confusion has come about because of Hecker's method of adjustment, as already explained, whereby he discards the shore and port boiling-point observations *ab initio* and gets his unknown coefficients from a least-square adjustment of ocean observations. Having done that, he finds that the port observations computed with these coefficients give results not only very discordant among themselves but also with the pendulum observations. He then has the difficult problem of connecting his ocean results with land pendulum stations by means of more or less discordant port and shallow water stations.

Tables I and II were drawn up from the figures in Hecker's 1910 publication; a plus sign means that g at the place in question is greater than it would be did the local disturbing cause not exist, and a minus sign means, of course, the reverse. It must be recalled that the tabulated Δg's are those as derived from Hecker's adjustments; if we may assume them correct, a mere glance shows at once that the disturbances in g are, in general, larger over the oceans than usually observed on land. Table I would show that the difference in Δg for two oceanic points may reach 0·4 and even $0{\cdot}67^{cm}$.

TABLE I.—THE AVERAGE, THE MAXIMUM, AND THE MINIMUM VALUES OF GRAVITY DISTURBANCES AS SHOWN BY HECKER'S OCEAN OBSERVATIONS.

(Revised figures 1910.)

Route	Date	No. of Obs'ns	Δg			
			Average	Maxi'um	Mini'um	Range
			cm	cm	cm	cm
Hamburg—Rio de Janeiro	1901	47	±0·048	+0·172	−0·095	0·267
Rio de Janeiro—Lisbon	1901	35	56	+0·142	−0·123	0·265
Spain—Suez—Colombo	1904	33	83	+0·289	−0·106	0·395
Colombo—Sydney	1904	28	61	+0·214	−0·106	0·320
Sydney—Honolulu—San Francisco	1904	41	106	+0·393	−0·273	0·666
San Francisco—Honolulu—Yokohama	1904	33	54	+0·310	−0·067	0·377
Black Sea (Odessa—Batum)	1909	15	31	+0·079	−0·052	0·131
Entire Work, 1901—1909		232	±0·066	+0·393	−0·273	0·666

TABLE II.—SOME LARGE GRAVITY DISTURBANCES SHOWN BY HECKER'S OBSERVATIONS, 1901–1909.—(Revised figures 1910.)

Cruise	Ye'r	Δg	Lat.	Long.	Depth	Region
		cm			m	
Hamburg—Rio de Janeiro	1901	+0·172	35° 02′ N	11° 56′ W	3600	Deep sea.
		+ ·148	8 36 S	34 53 W	40	Near Pernambuco.
		− ·095	11 44 N	26 59 W	5600	Deep sea.
Rio de Janeiro—Lisbon	1901	− ·123	11 35 S	36 49 W	3200	Deep sea } About 100 km. or more from Brazilian coast.
		+ ·123	6 23 S	33 20 W	5000	"
		+ ·142	2 15 N	29 33 W	2000	"
		+ ·123	1 04 N	30 08 W	2400	Near St. Paul.
Bremerhaven—Melbourne	1904	+ ·289	43 34 N	9 30 E	200	Med. Sea, N. of Corsica.
		+ ·235	12 34 N	55 45 E	3400	Near Socotra.
		+ ·214	35 49 N	129 54 E	5400	Steep gradient.
		+ ·346	33 49 S	151 54 E	200	"
		+ ·393	34 17 S	172 07 E	150	Near N. point N. Zealand.
		+ ·264	28 20 S	178 27? E	2700	Tonga Plateau.
		+ ·161	27 15 S	177 40? E	2700	"
		− ·196	23 12 S	174 47 E	8000	Tonga Deep.
		− ·273	22 07 S	174 13 E	6500	"
		− ·245	17 09 S	171 42 E	8500	"
		+ ·268	21 17 N	157 50 E	20	Roadstead of Honolulu.
San Francisco—Yokohama	1904	+ ·310	21 18 N	157 37 E	70	Near Oahu.
		+ ·304	21 17 N	158 17 E	1700	"
Black Sea	1909	+ ·079	44 51 N	32 46 E	150	Shallow water.
		− ·052	43 36 N	35 50 E	2200	Deep water.

Table III gives a comparison between Hecker's 1908 and 1910 values of Δg for certain characteristic points in the Pacific Ocean selected by Prof. J. F. Hayford in his paper before the meeting of the International Geodetic Association of 1909.* The last two columns are the differences between Hecker's values of g and those computed by Hayford with the aid of his new method; I have myself added the 1910 figures.

TABLE III.—COMPARISON OF SOME OCEAN GRAVITY ANOMALIES OBSERVED BY HECKER IN THE PACIFIC OCEAN WITH THOSE RESULTING FROM HAYFORD'S COMPUTATIONS.

No.	Name of Station	Depth in meters	Lat.	Long.	Hecker's Δg 1908	Hecker's Δg 1910	Hecker-Hayford 1908	Hecker-Hayford 1910
					cm	cm	cm	cm
1	Between Honolulu and San Francisco, at sea	5100	28° 10′ N	146° 35′ W	−0·001	−0·010	+0.003	−0·006
2	Tonga Plateau, at sea	2700	28 20 S	178 27 W	+ ·215	+ ·264	+ ·207	+ ·256
3	Tonga Plateau, at sea	2700	27 15 S	177 40 W	+ ·135	+ ·161	+ ·124	+ ·150
4	Tonga Deep, at sea	6500	22 07 S	174 13 W	− ·271	− ·273	− ·181	− ·183
5	Tonga Deep, at sea	8500	17 09 S	171 42 W	− ·248	− ·245	− ·162	− ·159
6	Near Hawaiian Islands, at sea	4000	22 50 N	160 23 W	+ ·034	+ ·062	+ ·023	+ ·051
7	Near Oahu, at sea	1700	21 17 N	158 17 W	+ ·273	+ ·304	+ ·203	+ ·234
	Mean with regard to sign				+0·020	+0·038	+0·031	+0·049
	Mean without regard to sign				0·168	0·188	0·129	0·148

*Hayford, J. F. The Effect of Topography and Isostatic Compensation upon the Intensity of Gravity. Cf. Report of the Int. Geod. Association for 1909, published in 1910, pp. 365–389.

In the first place it is seen that Hecker's mean Δg for the seven points here considered is larger for the 1910 figures than for the 1908 ones—whether the mean is taken with or without regard to sign. Next, the differences on Hayford are in every instance larger quantitatively for the 1910 figures than for the original ones of 1908 except for No. 5.

Furthermore the difference, Hecker-Hayford for station No. 2, viz., +0·207 for 1908 and +·256 for 1910, is greater than any residual thus far shown upon Hayford's computed g's. For 56 pendulum stations in the United States Hayford's computed values differed from the observed ones, on the average, by less than $0·02^{cm}$, the maximum difference being 0·094, this occurring at Seattle, known to be locally disturbed. Here are the differences for some very disturbed pendulum stations:

Table IV.—Some Very Disturbed Land Stations.

Station	Height above sea level	Latitude	Longitude	g_o-g_c
	m			cm
Honolulu	6	21° 18′ N	157° 52′ W	+0·053
Mauna Kea (volcano)	3981	19 49 N	155 29 W	+ ·184
Hachinohe (Japan)	21	40 31 N	141 30 E	+ ·111
St. Georges, Bermuda	2	32 21 N	64 40 W	+ ·019
Jamestown, St. Helena	10	15 55 S	5 44 W	+ ·059
Sörvaagen, Norway	19	67 54 N	13 02 E	+ ·147
Kala-i-Chumb, Turkestan	1345	38 27 N	70 46 E	– ·052
Gornergrat, Switzerland	3016	45 59 N	7 46 E	+ ·050
St. Maurice, Switzerland	419	46 13 N	7 00 E	+ ·004

It will be noted that only in the case of two very remarkable stations—the volcano Mauna Kea and Sörvaagen, Norway, Hayford's computed g_c differs from the observed g_0 by more than 0·11 and in both of these cases the differences are less than 0·2. But Hecker's revised figures of 1910 give five out of seven residuals over 0·1 and two above 0·2. Whether Hayford's method fails for such deep sea stations as here considered or whether we have thus afforded an indication of the absolute error of Hecker's values, it is not for me to say. It is curious, however, that Hecker's supposedly most correct values (those for 1910) accentuate the differences on Hayford.

Other detailed examinations made have not revealed any superiority of the 1910 method of adjustment over the previous one. The difficulty with some of the port observations, e.g., at San Francisco, was found to be chiefly due to *instrumental changes* (change in thermometer corrections). If the port observations are omitted, as Hecker desires, then the mean difference in Δg between his two computations without regard to sign is $0·022^{cm}$. The individual differences occasionally amount to $0·15^{cm}$. He finally says: "All conclusions drawn in the previous publications remain unaltered." These main conclusions are:

"The acceleration of gravity over the oceans traversed is approximately normal and conforms with Helmert's gravity formula of 1901. Pratt's hypothesis of isostatic adjustment of the masses of the earth's crust is thus, except for local anomalies, found to hold true generally. It can be regarded hence as proved that the lesser density of the water of the oceans is compensated for by the increased density of the masses below the ocean bottoms."

My contention is that this conclusion was already practically embodied in Hecker's method of adjustment. The conclusion may be true, but it can not be considered as proved by his mode of attack. Since no attempt was made to test whether another formula for normal gravity might not still better conform with the observations, the statement at the close of the first sentence does not seem warranted.

Observations on Hecker's Ocean Gravity Work.

1. No wholly satisfactory measure of the absolute accuracy of the existing ocean gravity results can be secured by a mere perusal of the publications. If an independent examination is made and such checks applied as are possible, and when all sources of error are considered, it will not be surprising if it be found that many of the most recently published results are in error by an amount approximating to $0·1^{cm}$, or about 1/10,000 part of g. In view of the pioneer nature of the work, it would have been desirable to have repeated observations, under different conditions, over all regions previously traversed.

2. One of the chief sources of error is to be ascribed to inconstancy of the corrections of the boiling-point thermometers caused by their continued and protracted use; the error thus arising may at times transcend in importance all other ones, an error in the temperature of 0·01° C. corresponding to about $0·35^{cm}$ in g. Insufficient attention was paid to purely instrumental changes and corrections. Thus, for example, corrections for the boiling-point thermometers of the Atlantic Ocean work of 1901 were used practically unaltered throughout the subsequent cruises of 1904 and 1909—after having once been supplied by the Physikalische Reichsanstalt, the corrections were never again redetermined. No separate examination of the barometers by comparison with standard barometers appears ever to have been made. The belief that such purely instrumental changes would be fully taken account of in the adjust-

ment is shown to be fallacious. A source of error also not considered is that due to possible imperfections of the vapor tension tables.

3. Insufficient evidence has been given to prove that, in the reduction of the observations, it is best to omit those made on board vessels at anchor. A method of adjustment which must assume practically what is to be proved, and which necessitates the rejection of data secured under supposedly the best conditions, weakening thereby the connecting link between the ocean results and the shore pendulum stations, can hardly be regarded as the best possible one. Instead some logical method of observation and of adjustment must be striven for, which will take advantage to the fullest possible extent of the shore and harbor results.

4. The problem of obtaining sufficiently reliable ocean gravity results still awaits solution.

Method to be Tried on the "Carnegie."

The method it is proposed to try on the "Carnegie," beginning, if possible, at Cape Town in about April of 1911, is practically the same as that employed in the magnetic work. At all ports visited there will be both shore and harbor observations, especially at those places where g has been observed with pendulums and where accordingly the anomaly Δg is known, thus permitting a logical determination of purely instrumental constants. Our provisional equation of condition for such stations will be of the following form, β having the same significance as in equation (1) above:

$$\beta - \frac{\Delta g}{1.29} = k + a\,(t - t_0) + b\,(B - B_0). \qquad (10)$$

$k = k_1 + k'_1 =$ constant part (k_1) of the relation between the zero of the thermometer and the zero of the barometer plus the constant part k'_1 of the errors of the vapor tension tables. It is hoped also by zero point determinations of the thermometers and by comparisons of barometers with port standards wherever there are such, to determine k_1 independently of k'_1 and thus gradually get some idea of the various errors.

$a\,(t - t_0)$ is to represent the change in instrumental constants with elapsed time from some mean epoch, t_0; it may later be found necessary to introduce a quadratic term, $a'\,(t - t_0)^2$, but it is believed that, with proper care of instruments and with sufficiently frequent zero determinations of the thermometers, this term may be avoided.

$b\,(B - B_0)$ is to take account of the variations not included in the time term, but dependent upon barometric height or upon boiling point; we may possibly find that this term can be taken account of by the special observations for k_1 as mentioned above.

Hecker's term $a\frac{dB}{dt}$ is to be eliminated partly by method of observation and partly by refinement of instrumental appliances. The three terms, $bp + cr + ds$ of his equation (No. 5), supposed to represent the effects of the ship's motions, we shall endeavor to make negligible as far as possible or reduce to one term, bp, partly by the manner and place of mounting and by construction of the barometers, and partly by the scheme of combination of the observations, so as to introduce varied conditions of motions of vessel. It is thus hoped to avoid any need of a laborious and time-consuming adjustment of the ocean resnlts, thereby enabling the observer to make as nearly a complete reduction of his observations aboard as may be possible, the determination of the effects from instrumental canses disclosed by the shore and harbor observations being left to the office compnter.

The various sonrces of instrumental error—thermometer and barometer—are at present being further examined. It is possible that the temperature of the boiling point will be determined both with mercurial thermometers of special construction and with electrical resistance thermometers. The chief difficulty now appears to be in the sufficient refinement of the barometric work. *The hope is entertained, however, that the great importance of getting values of* g *within the accuracy demanded by geodosists—about 0·02 or 0·03*^{cm}*—will lead some one to discover a method so superior as to eliminate the boiling point-barometer method altogether for ocean gravity work.*

Art. II.—*The Stratigraphy of a Deep Well at Waverly, Ohio*;* by R. S. Bassler.

Some months ago, in the course of routine work at the National Museum, the writer had occasion to identify a number of characteristic Eden fossils from a set of photographs sent for determination by Mr. Peru Hutt, of Waverly, Ohio. The occurrence of this fauna at Waverly, in a region of Mississipian strata more than 60 miles from the nearest outcrops of the Eden formation, led to a correspondence with Mr. Hutt, in which it was learned that the originals of the photographs had been obtained from a deep well drilled for oil at that place. Mr. Hutt had carefully saved enough samples from all of the material resulting from the boring to prepare two very detailed logs, which he was kind enough to forward for study. He is to be commended for his zeal in the matter, for, without his care, the following determinations, which are believed to be of some interest, concerning the underground stratigraphy could not have been made with any degree of accuracy.

The notes resulting from the study of the two series of samples were discussed with Dr. E. O. Ulrich at the time, and then set aside for future reference. Later the subject was mentioned by Dr. Ulrich to Professor Schuchert, who, in turn, deemed the section of sufficient importance to request a short article upon it for this Journal.

The well was drilled to a depth of 3,320 feet. The upper 1,100 feet were cased, so that the samples from this portion were little mixed and afforded an accurate idea of the various formations penetrated. The lower 2,220 feet, however, were left open, and the samples from this part required more careful study. Still, this latter portion was not difficult to decipher, since the predominating foreign material in the lowest samples was the blue limestone and shale of the Cincinnati group, which had fallen from above, and which, on account of lithologic characters totally different from those of the white magnesian limestone and sandstone of the lower formations, could easily be eliminated.

Instead of giving a detailed description of each of the many samples, the results of the study are arranged below in the form of a geologic section. Drilling commenced at a point 100 feet below the top of the sandstone quarries of the town, and the first 35 feet of the well passed through the lower portion of this sandstone. Then in descending order came the black Ohio shale, the limestones and sandstones of Devonian and Silurian ages, a good representation of the various Cincin-

* Published by permission of the Secretary of the Smithsonian Institution.

natian formations, a fair thickness of Trenton, Lowville, and Stones River, typical Saint Peter sandstone, and, finally, about 300 feet of rocks assigned to the Canadian. The various thicknesses given must be considered as only approximate, mainly because they were calculated from two distinct logs. For some reason the samples had been arranged in two sets, one measuring from the top to a depth of 2,020 feet, and the other from the bottom to a height of 2.200 feet. The two overlapping portions were correlated with little difficulty, because this part of the section was the most fossiliferous. The base of the well is of particular interest and will be discussed later.

Geologic Section at Waverly, Ohio.

	Thickness in feet.	Depth.
Mississippian:		
(b) Fine grained, drab "Waverly" sandstone exposed in hills of town above mouth of well	100	
Similar standstone forming lower part of Waverly series	35	0– 35
(a) Bituminous, fissile, black Ohio shale	450	35– 485
Devonian and Silurian:		
Mainly white, fine-grained sandstone with traces of white limestone. This material is so ground up by the drill that the limestone which it may have contained in some quantity has been mainly pulverized and washed away. The sandy material is evidently mostly from the Ohio Silurian formations. At the base of this portion are the red and brown calcareous sandstones of Clinton age	415	485– 900
Cincinnatian:		
(c) Blue shale with a few fragments of blue limestone. Fossils scarce, small portions of only *Dalmanella jugosa* being seen, but the strata are evidently of Richmond and Maysville age, with probably the Upper Eden shales represented	1065	900–1965
(b) Blue shales containing rather numerous Middle Eden fossils. The species identified are: *Rafinesquina alternata* (Eden variety), *Plectambonites sericeus*, *Dalmanella multisecta*, *Trematis millepunctata*, *Pholidops cincinnatiensis*, *Callopora sigillarioides*, *Climacograptus typicalis*, *Byssonychia vera*, *Protowarthia cancellata*, *Ceratopsis*		

	Thickness in feet.	Depth.
chambersi, *Bythocypris cylindrica*, *Trinucleus concentricus*, *Calymene callicephala*, *Proetus? spurlocki*, and *Nereidavus varians*. From this point to the bottom of the well, blue shale fragments holding this fauna were encountered, but, eliminating them, the remaining formations were, for the main part, clearly represented in the samples	55	1965–2020
(a) Unfossiliferous blue and greenish shale associated with the blue shale holding the overlying Middle Eden fauna. This portion probably represents the Lower Eden and Utica divisions	80	2020–2100
Mohawkian:		
Trenton formation.		
Blue clay and shale, with a few fragments of blue limestone. *Zygospira recurvirostris*, *Trinucleus concentricus*, and a species each of *Rhinidictya* and *Callopora*, known elsewhere from the Lower Trenton, were noted. At the base of this formation a small amount of glauconitic grains were present in the samples	125	2100–2225
Lowville and Stones River formations.		
Each of these formations is probably represented, but their lithology is so similar that no distinction could be made in the samples, which consisted mainly of white, clayey, and dove unfossiliferous limestone with blue argillaceous limestone at the bottom	600	2225–2825
St. Peter sandstone.		
White, saccharoidal sandstone	175	2825–3000
Canadian.		
This portion naturally contained the greatest mixture of materials, but after excluding all the rock formations of the overlying beds, a few fragments of white dolomitic limestone remained. These are quite similar to the Canadian rocks of the Appalachians, and for that reason and the absence of chert, which is more characteristic of the Ozarkian, as well as the stratigraphic position, the correlation was made as above. At the very base of the well a few small fragments of an igneous rock were detected	320	3000–3320

This section presents no new facts regarding the rocks younger than the Trenton, for between Waverly and Cincinnati, about 80 miles west, the same strata have been studied along numerous surface outcrops. The earlier Mohawkian formations are not exposed until central Kentucky, over 100 miles distant, is reached, while the Saint Peter sandstone and Canadian limestone are not known at all by surface outcrops in the Ohio valley.

The section of strata penetrated by a deep well at Oxford, Ohio, is of interest in this connection. A detailed description of the log of this well was given by Joseph F. James in volume X of the Journal of the Cincinnati Society of Natural History, but for present purposes only the general section determined by him is of interest. Arranged in the same form as the one given above, this section, with the formations as identified by James, but with the correlations of the present day inserted in brackets by the present writer, is as follows:

Geologic Section, Deep Well at Oxford, Ohio.

	Thickness in feet.
Cincinnati group:	
Blue limestone and shale [Richmond and Maysville]	360
Blue shale [Maysville and Eden]	380
Dark limestone [Trenton]	50
Trenton group:	
White limestone with magnesia [Lowville and Stones River]	495
Calciferous sandrock:	
White, arenaceous limestone [Saint Peter]	40

Unfortunately this well did not go deep enough to show the strata underlying the Saint Peter sandstone, nor did certain deep wells bored at Cincinnati pass beyond this formation. These Cincinnati wells showed the same stratigraphy and essentially the same thickness as in the Oxford well, so that the latter can be taken as typical for the region of the Cincinnati axis. Comparing the Oxford and Waverly sections, the following conclusions may be drawn:

(1) From observations on both sides of the Cincinnati axis, the Maysville and Richmond divisions of the Cincinnatian do not vary enough in thickness to suggest marked decrease of deposition across the apex of the axis. The Utica is seldom more than a few feet thick at Cincinnati. In northern Ohio it has become greatly thickened, as shown in the gas wells; it has likewise attained a considerable thickness in the Appalachians. The increased thickness of the Cincinnatian as a whole

in the Waverly well is thus probably due to the presence of greater deposits of Utica shale.

(2) The same eastward increase in thickness may be stated for the Trenton rocks with less doubt. At Cincinnati the lower 50 feet of the Trenton are exposed with the thin Utica shale resting upon its eroded surface. Proceeding southeast along the Ohio River, this thickness increases to over 100 feet, in a distance of 30 miles, by the addition of higher beds of the formation. The occurrence of 125 feet of Trenton strata at Waverly, 80 miles east, is therefore in line with the idea that the Trenton and the Utica are alike in having a minimum thickness along the Cincinnati axis. These same facts, among others, have convinced several of the students of Cincinnati geology that this axis did not pass along a northeast-southwest line 25 or 30 miles east of Cincinnati, as commonly believed, but close to the city itself.

Allowing for a certain amount of error in determination, the Stones River–Lowville sequence is practically the same in each section. At any rate, both the Stones River and Lowville are among the most widespread Ordovician formations, extending from Canada to Alabama, and from New York to the central Mississippi Valley. Both the Oxford and Waverly wells are interesting, therefore, in indicating the presence of both formations in the northern part of the Ohio Valley, where they have no surface outcrops.

The presence of such a typical fauna of Middle Eden species, a hundred or more miles from the shores of the sea of the time, is evidence for the shallowness of the early Paleozoic continental seas. Deep wells elsewhere have furnished abundant proof of this same fact, and the one at Waverly simply furnished an additional well-established example. This Eden fauna is well known in New York, in the Cincinnati uplift,and in the Appalachians, and not being pelagic, it could not have had such a dispersion had deep seas intervened between these several shore lines.

The occurrence of glauconitic material in the samples from the base of the Trenton is likewise noteworthy in indicating the unconformity between this formation and the underlying Lowville strata. Detailed studies of the early Paleozoic rocks have shown glauconite to be a common ingredient of the basal sediments of several overlapping formations.

Perhaps the most interesting fact brought out by this well is the presence of a few fragments of igneous rock at its very bottom. The importance of this occurrence was suggested at once by Doctor Ulrich, for the area about Waverly is on the northward extension of the uplift which he has named the Carter axis. The igneous nature of these fragments was verified by Dr. George P. Merrill, who determined them as peridotites which had become altered into serpentine. That the presence of this igneous rock is to be considered as indicating that the well passed through the base of the Paleozoic cannot be positively determined from the facts at hand, as the material may possibly have been derived as a bowlder from above. However the facts so far as known are highly significant, and it may be tentatively suggested that the Canadian rocks rest upon pre-Cambrian. Whether this area was a part of an axis of uplift, such as the Carter axis, or was included in a broad southern extension of the Laurentian shield during Cambrian and Ozarkian time, cannot be decided with the present evidence.

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ART. III.—*On Solid Solution in Minerals with Special Reference to Nephelite;* by H. W. FOOTE and W. M. BRADLEY.

IT is a fact well known to mineralogists that there are certain minerals to which no satisfactory chemical formulæ can be assigned which agree with the results of analysis. The reason for this in many cases, particularly where the mineral is rare and little investigated, is probably that the material is impure, containing included foreign matter, or else the analysis is incorrect. There appear to be cases, however, where the material has been so carefully selected that foreign matter could not be present except in traces, and where analyses have been made with the greatest care and still the formula cannot be definitely assigned. A case of this kind is that of the mineral nephelite, to which the formulæ $NaAlSiO_4$ and $Na_8Al_8Si_9O_{34}$ besides others more complicated have been given. An examination of several good analyses of this mineral will show that the analytical data do not support any one formula, but that there are considerable variations from it which are greater than can be accounted for by the ordinary errors of analysis.

In general the composition of a mineral as obtained in analysis varies from the composition of the ideal pure compound for two reasons, aside from errors of analysis. Either there is (*a*) isomorphous replacement of one element or radical by another, or (*b*) there are mechanical impurities present. Where there is merely isomorphous replacement, the formula of the pure compound can be derived from the analysis by the ordinary methods of calculation, which need not be considered here. The presence of mechanical impurities can usually be determined by other means, for instance, by the use of heavy solutions or by microscopic examination. We wish to call attention to another influence which must probably be taken into account in cases like that of nephelite. It appears to us necessary to assume that in certain cases a substance on crystallyzing forms a solid homogeneous solution with foreign matter which cannot be assumed to be isomorphous with any constituent, and which is not to be regarded as a mechanical mixture. It can be compared to the solution of salt in water, in which the salt takes on the appearance and form of the water without taking any part in the formula of the water. A case of this kind in minerals would not be a mechanical admixture of the foreign substance, comparable to the suspension of a solid in water, but would form a homogeneous mass with the rest of the mineral comparable to the salt solution. If such an impurity were present in appreciable amount, it is obvious that the formula of the pure compound could not be calculated correctly from the analysis. This type of solid solution must be clearly distinguished from isomorphous replacement, which is also commonly considered as solid solution. In the latter case, the formula of the compound can be derived directly from the analysis, as previously mentioned.

Before considering the application of these statements to nephelite, we wish to mention a simple case of solid solution which is known in artificial crystals. It has been shown by Roozeboom* that when ammonium chloride crystallizes from a solution containing ferric chloride, the crystals deposited are colored and may contain as much as seven per cent of ferric chloride. Here there can be no question of isomorphous replacement, and on the other hand the ferric chloride is not mechanically enclosed by the ammonium chloride. The latter point is proved partly by the fact that the crystals appear perfectly homogeneous, and it is proved much more definitely by the fact that the solubility of such crystals varies with their composition. If a mechanical mixture were present, the solubility would not vary with the composition of the mixed crystals, but there would be a definite solubility at a given temperature independent of the composition. The colored crystals are to be regarded as one homogeneous phase in which the ferric chloride is held in solid solution by the ammonium chloride. Similar occurrences have been noted in artificial minerals with a good deal of probability. Day and Shepherd† have observed an artificial calcium metasilicate crystallizing with tridymite which differs slightly in optical properties from the pure silicate. The variation appears to be due to the presence of silica taken up in solid solution by the metasilicate. The same metasilicate is also capable apparently of absorbing a considerable amount of the orthosilicate and still appear homogeneous. Again, Shepherd and Rankin‡ have shown that artificial corundum may take up a limited amount of sillimanite (or silica) in solid solution and also a small quantity of calcium oxide. We believe such cases also exist in certain minerals such as nephelite.

Several years ago, the late Prof. S. L. Penfield suggested to one of us (Bradley) that the reason for the variation in the composition of nephelite might be due to the presence of mechanical impurities and that if material of undoubted purity

* Zeitschr. f. phys. Chem., x, 145, 1892.
† This Journal (4), xxii, 265, 1906.
‡ This Journal (4), xxviii, 293, 1909.

could be obtained so far as mechanical admixture was concerned an analysis would show the correct formula of the mineral. A sample of nephelite from Eikaholmen, Norway, was chosen for analysis and freed from other minerals by use of acetylene tetrabromide. The sample used in analysis floated when the specific gravity of the liquid was 2·638 and sank when it was lowered to 2·632, so that variation in the density of the mineral was not more than ·006. The resulting nephelite contained a minute amount of albite which was insoluble in hydrochloric acid, but the quantity was so small that it could be neglected. The material obtained was, we believe, as pure as it is possible to obtain nephelite by mechanical means, since observations under the microscope showed the sample to be of excellent quality and practically homogeneous.

Two complete analyses and two other partial ones were made on this material with the greatest care (by Bradley). Only brief mention seems necessary of the methods employed in the chemical analysis. Silica was determined in the usual way, after dissolving the mineral in hydrochloric acid and by testing its purity traces of alumina were recovered. Alumina was precipitated as hydroxide and this was dissolved, reprecipitated and weighed in the usual manner. The small percentage of iron was determined volumetrically with potassium permanganate. A Smith's fusion was made for the alkalies. The results in detail with the ratios obtained are given below.

Table I.

Analyses of Nephelite (Bradley).

I

Nephelite from Eikaholmen, Norway.

	1	2	3	4	Average	Ratio	
SiO_2	44·59	44·31	44·37	44·59	44·46	·736	=2·23
Al_2O_3	33·29	33·02	33·41	32·71	33·11	·324	·330=1·00
Fe_2O_3	·96	·96	·96	·96*	·96	·006	
K_2O	5·62	5·62	....	5·59	5·61	·060	·323=0·98
Na_2O	16·59	16·31	....	16·06	16·32	·263	
H_2O	·38	·38*	....	·38*	·38		
	101·43	100·60		100·29	100·84		

The above analyses were not published at the time they were made, as the formula derived from them was complex, and the results could not be regarded as establishing the formula.

* Taken from anal. I.

The composition of nephelite was further investigated the following year by Morozewicz,* who also gives an excellent review of the literature on the subject. The author gives analyses of six different nephelites which were apparently made with the greatest care on carefully purified material. By his method of analysis, he was able to free his material from even a trace of albite. The results and the ratios derived are given below.

TABLE II.

Analyses of Nephelite (Morozewicz).

II

Nephelite (Elæolite) from Mariupol. Porphyritic Crystals.

		Ratio
SiO_2	43·65	2·21 (SiO₂ + TiO₂)
TiO_2	·10	
Al_2O_3	33·12	1·00 (Al₂O₃ + Fe₂O₃)
Fe_2O_3	0·48	
CaO	0·49	0·99 (CaO + K₂O + Na₂O)
K_2O	5·69	
Na_2O	15·91	
H_2O	0·74	
	100·18	

III

Nephelite (Elæolite) from Mariupol. Coarse and granular.

		Ratio
SiO_2	43·46	2·21 (SiO₂ + TiO₂)
TiO_2	·07	
Al_2O_3	32·82	1·00 (Al₂O₃ + Fe₂O₃)
Fe_2O_3	0·75	
CaO	0·31	0·99 (CaO + K₂O + Na₂O)
K_2O	5·55	
Na_2O	16·12	
H_2O	0·89	
	99·97	

IV

Nephelite (Elæolite) Mariupol. Reddish Crystals.

		Ratio
SiO_2	43·55	2·21 (SiO₂ + TiO₂)
TiO_2	·03	
Al_2O_3	32·96	1·00 (Al₂O₃ + Fe₂O₃)
Fe_2O_3	0·66	
CaO	0·25	1·00 (CaO + K₂O + Na₂O)
K_2O	6·09	
Na_2O	16·00	
H_2O	0·33	
	99·86	

V

Nephelite (Elæolite) from Miask.

		Ratio
SiO_2	42·71	2·12 (SiO₂ + TiO₂)
TiO_2	0·04	
Al_2O_3	33·83	1·00 (Al₂O₃ + Fe₂O₃)
Fe_2O_3	0·40	
CaO	0·32	1·00 (CaO + K₂O + Na₂O)
K_2O	5·86	
Na_2O	16·46	
H_2O	0·18	
MgO	trace	
Impurities	0·06	
	99·86	

* Bull. Acad. Sciences Cracovie, 958, 1907.

VI

Nephelite from Vesuvius.

		Ratio
SiO_2	42·53	2·11
TiO_2	0·01	
Al_2O_3	33·92	1·00
Fe_2O_3	0·30	
CaO	1·97	1·02
MgO	0·07	
K_2O	5·82	
Na_2O	15·12	
H_2O	0·13	
Impurities	0·24	
	100·11	

VII

Nephelite from Vesuvius.
Different specimen from VI.

		Ratio
SiO_2	43·34	2·15
TiO_2	trace	
Al_2O_3	33·75	1·00
Fe_2O_3	0·50	
CaO	2·20	1·03
MgO	0·24	
K_2O	4·34	
Na_2O	15·66	
H_2O	0·23	
	100·26	

We consider the seven analyses given above to be the best which have been made on nephelite. A considerable number of other analyses have been made, however, and we give below a summary of the ratios obtained from the analyses given in Dana's Mineralogy, page 425. The numbers are the same as in the Mineralogy.

TABLE III.

Ratios obtained from Analyses of Nephelite given in Dana's Mineralogy.

	SiO_2	Al_2O_5 etc.	Na_2O etc.
No. 1.	2·21	1·00	1·00
2.	2·25	"	·99
3.	2·17	"	1·00
4.	2·29	"	·95
5.	2·20	"	·91
6.	2·24	"	1·04
7.	2·18	"	1·02
8.	2·24	"	1·01
9.	2·31	"	·97
10.	2·60	"	1·16
11.	2·24	"	1·05
12.	2·06	"	·94
13.	2·14	"	·93
14.	2·29	"	·97
15.	2·19	"	·98

The summary of the ratios obtained in the seven analyses first given is as follows:

TABLE IV.

Summary of Ratios from Analyses by Bradley and Morozewicz.

No.	SiO_2	Al_2O_3 etc.	Na_2O etc.
I.	2·23	1·00	0·98
II.	2·21	"	0·99
III.	2·21	"	0·99
IV.	2·21	"	1·00
V.	2·12	"	1·00
VI.	2·11	"	1·02
VII.	2·15	"	1·03

In this table the ratio of $Na_2O:Al_2O_3$ is as nearly 1:1 as could be desired. There can be no question that soda and alumina are present in this proportion. The ratio for silica varies from 2·11 to 2·23, and this variation is greater than can be accounted for either from errors of analysis, or from the presence of impurities. For instance, analysis No. I contains more than two per cent excess of silica if the ratios were to be the same as in No. VI. There is no case known, we believe, where silica can be considered as replacing isomorphously either alumina or soda, and if it did in this case, the ratio between these two would not be simple. The same general conclusion as regards composition may be drawn from the ratios derived from older analyses given in Table III, though many of the analyses are probably not as good as the more recent ones.

Morozewicz* has shown that the nephelites may be considered as consisting of two series of compounds, a normal series and a basic one. The normal series should be represented by the formula $K_2Na_nAl_{n+2}Si_{n+3}O_{4n+10}$, in which $n=8$, 9, 10, and 11, and the basic series by the formula $K_4Na_{18}Al_{23}O_{90}$. By this series of variable formulæ, the variation in composition can be expressed. This method of representing the composition is open to the serious objection that a chemical compound, so far as we know, does not vary in type. Isomorphous replacement, for instance, varies the composition, but the type of compound remains the same.

If nephelite be considered a solid solution, the case becomes very different. A solution may be defined as a homogeneous mixture of substances which cannot be separated by mechanical means and whose composition varies continuously within certain limits. This definition distinguishes a solution from a suspension on the one hand and from a chemical compound on the other. It characterizes a solution of a salt in water, and a solid solution of ferric chloride in ammonium chloride and we

*Loc. cit.

can see no reason why nephelite should not be treated in the same class. This method of considering the composition of nephelite has the advantage of being much more simple than using a series of complicated formulæ, and it appears to us to agree with the facts. It need hardly be said that a chemical formula could be assigned to any solution but a different one would have to be used for each change in concentration of the solution, just as Moroscewicz uses a different formula for each nephelite.

From what has been said, we think it fair to consider that nephelite as it occurs in nature is not a pure compound but a solid solution analogous to the solid solution of ferric chloride in ammonium chloride. It then becomes of interest to consider the probable formula of the pure compound which forms the basis of nephelite. This appears to be the orthosilicate $NaAlSiO_4$. This formula is supported in two ways: (1) Nephelite has the same crystalline form as eucryptite $LiAlSiO_4$ and kaliophilite $KAlSiO_4$ which are in the same group, making it very probable that the type of formula is the same in all three cases. (2) Artificial nephelites have been prepared by Doelter* which have the same general characteristics as natural nephelite and vary in composition from the formula $NaAlSiO_4$ to compounds containing potash and an excess of silica corresponding to the mineral.

Perhaps the point should be emphasized that nothing whatever is known about the actual condition of the dissolved silica, whether it is present as dissolved albite or silica or leucite or in any other form, just as very little is known about the condition of dissolved substances in liquids as to whether they are combined with the solvent. It is certain, however, that the dissolved silica does not have the properties of either ordinary quartz or albite, since it is soluble in hydrochloric acid. In the same way, the properties of a dissolved salt are entirely different from the properties of the solid.

The excess of silica which can be taken up by nephelite to form a saturated solution can apparently be determined from the data given by Morozewicz and ourselves. Where albite is found intimately mixed with nephelite it is evident that the nephelite must be saturated with silica and the excess of the latter has formed albite.

In this case, therefore, the nephelite should have a constant ratio of silica to alumina, and these nephelites should contain the maximum amount of silica that can be taken up. The influence of temperature in determining the composition of the saturated solution can apparently be neglected. In our

*Zeitschr. f. Kryst., ix, 321, 1884.

own specimen, albite was associated with the nephelite, and Morozewicz states that albite was present in the specimens containing the nephelites of analyses II and III and microcline-microperthite, which would have a similar effect, in analysis IV. The ratio for silica in these four cases is 2·23, 2·21, 2·21 and 2·21, which is as nearly constant as could be desired. In analysis V, where the ratio for silica is only 2·12, the mineral is stated to be exceptionally pure, with biotite crystals on the outside. In VI or VII, where the ratios are 2·11 and 2·15, sanidine was present which might have the effect of albite, tending to raise the ratio to the saturation point, but in just these two cases (from Vesuvius) the nephelite appears to be a later growth on the sanidine and not intimately mixed with it. In these cases, then, where albite or its equivalent was not formed with nephelite, the ratio of silica to alumina shows that the nephelite has not taken up the maximum amount of silica. The most basic rock containing nephelite with which we are acquainted is an iolite described by Hackman.* This rock contains essentially pyroxene and nephelite with smaller amounts of titanite, apatite and ivaarite. There is no albite, quartz or feldspar present. The nephelite in this rock had the following composition and ratios:

		Ratio
SiO_2	43·98	2·13
Al_2O_3	34·93	1·00
CaO	0.36	
Na_2O	16·76	0·94 (CaO, Na_2O, K_2O)
K_2O	3·83	
	99·86	

Here, again, the silica is below what we may call the "saturation ratio" of 2·21.

It would be of considerable interest if nephelites could be found which closely approximated the formula $NaAlSiO_4$. From what has been said above, such an occurrence could only be expected where crystallization had taken place from a magma so deficient in silica that albite did not form.

In conclusion, the authors consider that the arguments advanced in the present article may be applicable to other minerals. Work has already been begun on the mineral pyrrhotite with the hope that similar deductions may be applied to this mineral.

Chemical and Mineralogical Laboratories of the Sheffield Scientific School of Yale University.
New Haven, Conn., October, 1910.

* Bull. de la Commis. Geol. de Finlande, 1900, p. 9.

Art. IV.—*Fossil Evidence of the Age of the Virginia Piedmont Slates;* by Thomas L. Watson and S. L. Powell.

Contents:

Introduction.

Recent detailed field study of the slate areas in the crystalline (Piedmont) region of Virginia by the State Geological Survey has resulted in much important information bearing on the lithologic characters, structural and age relations of the rocks, and on the sulphide ore-bodies (veins) associated with the slates of the northeastern belt. Of especial interest are: (1) discovery of fossils in the easternmost one of the slate areas; (2) recognition of volcano-sedimentary beds intimately associated with the slates in several of the areas; and (3) evidence of the age relations of a part at least of the sulphide veins in the northeastern portion of the crystalline region, which hitherto have been assumed to be pre-Cambrian.

The present paper treats only of the discovery of fossils in the Quantico slate belt, with a brief statement of its stratigraphic position, and of that of the other slate belts in the Virginia crystalline region. Discussion of the age relations of the sulphide veins and of the volcano-sedimentary beds associated with the slates will be treated in another paper, now in preparation.

Virginia Piedmont Province.

The Virginia Piedmont province (crystalline area) lies between the Coastal Plain and the Appalachian Mountains. It extends from the Blue Ridge eastward to the western margin of the Coastal Plain, and it widens southward (map, fig. 1). Its width increases from 40 miles in the northern portion along the Potomac River to nearly 175 miles along the Virginia–Carolina boundary. The rocks of this region are the oldest in the state, and, excepting the areas of Triassic rocks, they are all crystalline. They comprise both igneous and sedimentary masses, in many places so altered from metamorphism, chiefly pressure and recrystallization, that their original character is indistinguishable.

The region is made up of a complex of schists, gneisses, and granites, with which are associated some slates, quartzites and

Fig. 1.

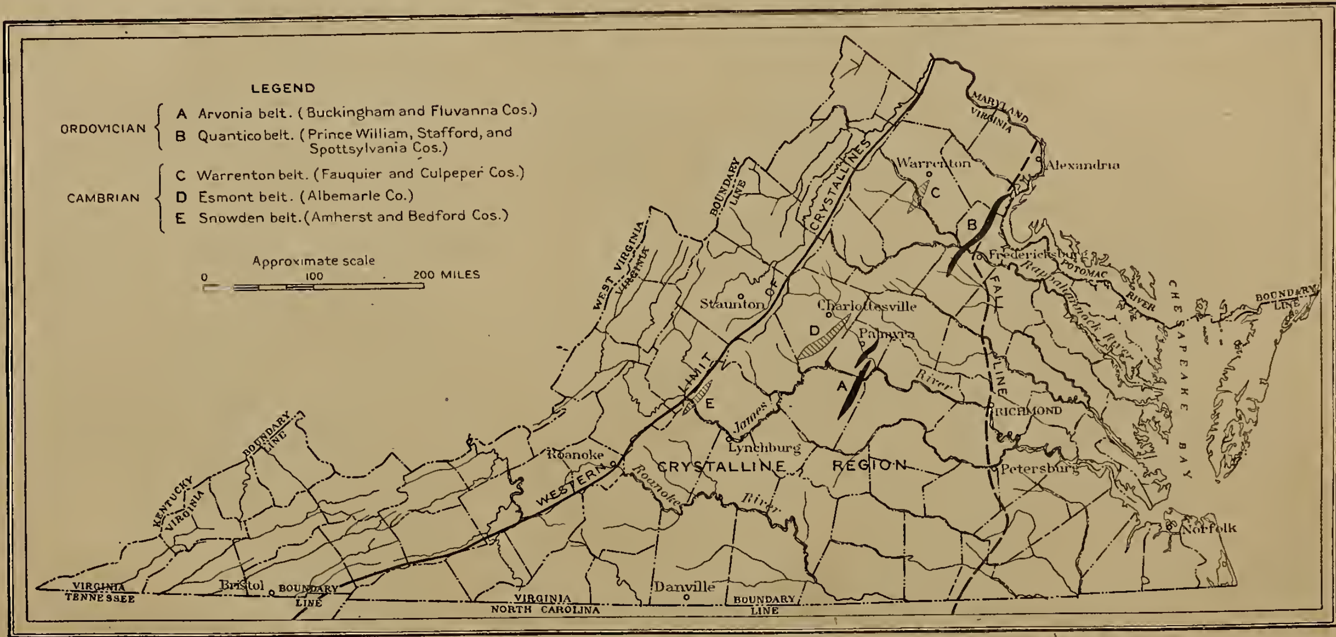


Fig. 1. Map of Virginia, showing distribution of slate areas in the crystalline region.

conglomerates, and crystalline limestones. These are metamorphosed and intruded by dikes and masses of diabase, diorite, and gabbro. Over parts of the eastern and central portions of the region are areas of altered volcano-sedimentary rocks, which extend southward into North Carolina.

Slate Areas of the Crystalline Region.

There are five principal slate areas occurring within the limits of the crystalline region of Virginia. These are shown on the accompanying map, figure 1. Named in the order of their present importance, the areas are: (1) the Arvonia belt in Buckingham and Fluvanna counties; (2) the Keswick–Esmont belt in Albemarle County; (3) the Snowden belt in Amherst and Bedford counties; (4) the Warrenton belt in Fauquier and Culpeper counties; and (5) the Quantico belt in Prince William, Stafford, and Spottsylvania counties.

The discovery of fossils in three of the areas (Snowden, Arvonia, and Quantico) has definitely determined their age—the Snowden area as Cambrian, and the Arvonia and Quantico areas as Ordovician. Fossils have not been found in either of the other two areas, Warrenton and Keswick–Esmont, but the relations of the slates to associated rocks of known age in or near these areas fix the age of the slates beyond reasonable doubt as Cambrian.

The Snowden slate area, flanking the southeast slope of the Blue Ridge in Amherst and Bedford counties, includes a series of beds of conglomerates, sandstones, and slate resting unconformably on a basement of igneous rocks. The sedimentary beds are in a highly metamorphosed condition, and were regarded by Rogers as Huronian, and by J. L. and H. D. Campbell as pre-Cambrian, but the discovery of fossils in them has definitely determined their age as Cambrian.* The sandstones of this series contain fossil borings of *Scolithus linearis*, which with the other data marks them as Cambrian in age. No fossils have been found in the slates of this series, but the *Scolithus* sandstone is observed to dip under the slates, which indicates that the latter cannot be older than Cambrian.†

The Warrenton slate area in Fauquier and Culpeper counties comprises a sedimentary series of rocks of Cambrian age (Loudoun) in close association with a pre-Cambrian (Algonkian) series of basic volcanic rocks (Catoctin schist) and their equivalent pyroclastics (tuffs). The sedimentary series (Loudoun formation) includes coarse arkoses, sandstones, quartzites,

* Pre-Cambrian Geology of North America; Bull. No. 360, U. S. Geol. Survey, 1909, p. 675. † Ibid., p. 694.

schists, conglomerates, and slates. No fossils have been found in the sedimentary rocks of this area, but their correlation with the Loudoun is conclusive, although the evidence cannot be presented here.

The Keswick–Esmont slate area in Albemarle County includes in its northern portion the following succession of rocks extending eastward from Charlottesville: Monticello schist (Catoctin schist of Keith), derived chiefly from a basic volcanic rock, basalt, of Algonkian age, followed by a series of sedimentary beds of fine and coarse conglomerate, sandstone, slates,

FIG. 2.

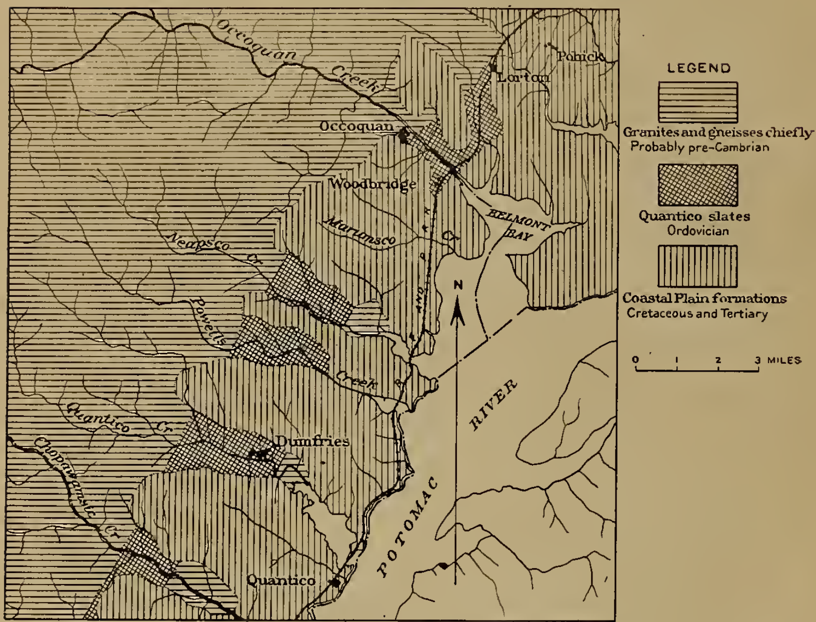


FIG. 2. Geologic map of northeastern Virginia, showing the northern half of the Quantico slate belt.

and limestones of Cambrian age. No fossils have been found in these beds, but the evidence strongly favors their being Cambrian in age, and they have been so mapped and described.*

Quantico Slate Belt.

The Quantico slate belt is so named from Quantico Creek in the southern part of Prince William County. It has been traced as a narrow belt averaging about one mile in thickness

*Lambeth, W. A. Notes on the Geology of the Monticello Area, Virginia. A Thesis, University of Virginia, June, 1901.

for a distance of 40 miles, extending in a southwest direction from Lorton, Prince William County, where it passes beneath the Coastal Plain formations, to Shady Grove, Spottsylvania County, five miles south of the Orange and Fredericksburg railroad. It lies partly in the three following counties: Prince William, Stafford, and Spottsylvania. The slates have not been traced continuously on the surface between the extreme limits given above, because of their concealment beneath the Coastal Plain sediments in the northern half of the belt, but they have been recognized in every section measured along the streams which cross from the crystalline rocks of the Piedmont onto the Coastal Plain sediments (map, fig. 2). The principal streams have carved narrow canyon-like gorges in the crystalline rocks of the northeastern Virginia Piedmont region, and they usually afford excellent exposures along their courses. North of Accakeek Creek the slates are concealed on the interstream areas by the Coastal Plain cover (map, fig. 2).

The slate belt varies from less than one mile to about 2 miles in width, with a probable average of about one mile. It is a part of the crystalline rocks of the Piedmont region, and northeastward from Accakeek Creek, Stafford County, it is the easternmost representative of the Piedmont crystallines. This part of the belt is bordered on the west by gneisses and granites, and on the east it is concealed beneath the cover of Coastal Plain sediments. Southwestward from Accakeek Creek the gneisses and granites are the limiting rocks on the east and west sides of the belt.

Structurally the slates show considerable variation in places both in dip and strike. With but few exceptions the dip is to the northwest, usually from 70° to vertical (see fig. 4); and the strike ranges from N. 20° E. to N. 60° E. The strike and dip are given below for the sections measured. They are:

Name of Section.	Strike.	Dip.	Remarks.
Occoquan Creek	N. 40° – 45° E.	70° N.W. to vertical.	
Marumsco Creek	N. 35° – 42° E.	Nearly vertical.	Variable.
Powells Creek	N. 20° E.	50°–70° N.W. to vertical.	
Quantico Creek	N. 30° – 35° E.	75° N.W. to vertical.	
Aquia Creek	N. 25° – 40° E.	70° N.W. to vertical.	
Austin Run	N. 30° – 45° E.	80° N.W. to vertical.	Variable.
Accakeek Creek	N. 38° – 60° E.	80° N.W. to vertical.	
Potomac Creek	N. 50° E.	35° – 59° N.W.	
Wilderness, one mile west	N. 20° E.	Nearly vertical.	
Brock Station	N. 38° E.	Vertical.	
Shady Grove	N. 25° E.	Vertical.	

In several sections, especially those of Occoquan and Quantico creeks, occasional steep southeasterly dips are observed. The general structure of the rocks suggests a series of closely compressed folds, probably of the isoclinal type.

The slates are not lithologically alike for the entire thickness of the belt in any section measured, but a variety of types

Fig. 3.

Fig. 3. Alternating light- and dark-gray slates, about ¾ mile S.E. of Occoquan village, on Occoquan Creek. The position of the slates is vertical. Some beds are tufaceous.

Fig. 4.

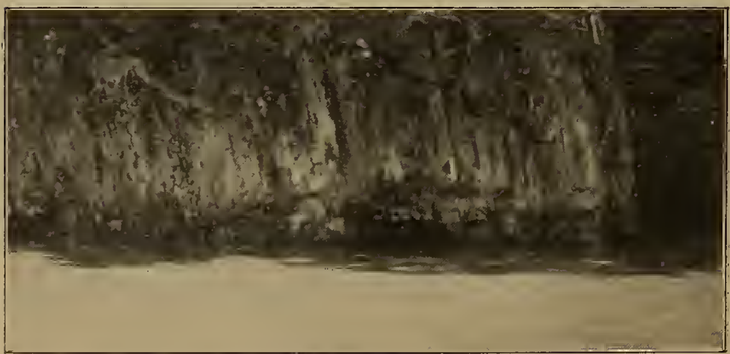


Fig. 4. Alternating light- and dark-gray slates, partly tufaceous, showing a steep dip to the southeast. About ½ mile S.E. of Occoquan village, on Occoquan Creek.

occur, grading one into the other. The belt comprises a probable average thickness of about one mile of alternating beds of gray to dark gray and black slates, with beds of green and maroon slates shown in some sections. Slaty cleavage is prominently developed in all the rocks of the belt. Variation is from dense, homogeneons, black graphitic slates of exceeding fine texture, having smooth cleavage surfaces, to rocks of fine granular texture having more or less curved or crumpled cleavage surfaces, and closely resembling phyllites.

Fig. 5.

Fig. 5. Granite falls in Occoquan Creek immediately west of Occoquan village, and about ¼ mile west of granite-slate contact.

The black graphitic slates near Dumfries in the Quantico section are reported to contain on analysis 3 per cent of graphite. These slates have been exploited for graphite in the Quantico Creek and Potomac Creek sections. In the Potomac Creek section the slates are considerably puckered and twisted.

The tufaceous character of a part of the beds for a considerable thickness of many of the sections is apparent to the naked eye. Beds of tufaceons character associated with the slates of the Arvonia district, further southwestward in Buckingham and Fluvanna counties, are even more conspicuously developed in places than in some sections of the Quantico belt.

The slates proper usually grade northwestward into true phyllites and schists, and are in contact with granites and gneisses which are in part at least of pre-Cambrian age. More or less pyrite in small and large crystals and in shapeless grains is disseminated through the slates, and frequently forms thin

Fig. 6.

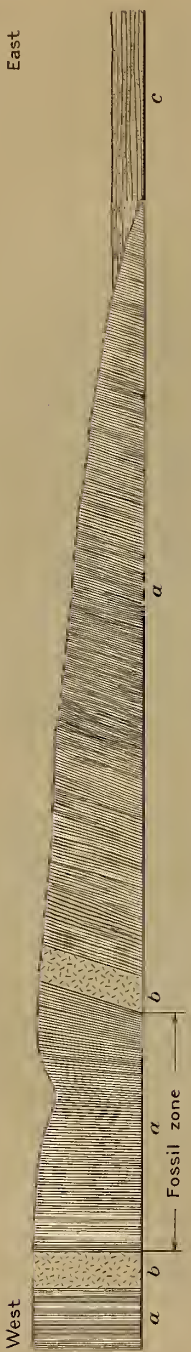


Fig. 6. Geologic section along Powells Creek, Prince William County, Virginia, from old telegraph road northwestward about one mile. *a*, dark gray to black graphitic slates; *b*, light-colored, dense-textured, altered rhyolite; *c*, Coastal Plain sediments.

films or veinlets in the cleavage. In a number of places the pyrite in the slates is sufficiently concentrated to encourage mining. Much quartz is present in the slates in places, occurring chiefly as eyes and stringers, sometimes as veins, which may coincide in direction with that of cleavage or may cut across it.

In several of the measured sections, Marumsco and Powells creeks in the Quantico slate belt, and south of James River in the Arvonia slate belt, a light gray, hard and dense-textured rock, which has been identified microscopically as an altered (metamorphosed) rhyolite, occurs interbedded with the slates (fig. 6). Thin sections of the rock show the following minerals: Quartz, sericite, biotite, chlorite, magnetite, tourmaline, apatite, zircon, and yellow glass. The exact thickness of this rock in the Quantico belt could not be ascertained because of lack of exposures, but in the Arvonia belt it is about 18 feet. It is strikingly uniform in lithology at every point observed. Except for small parallel elongated yellow specks and areas, which are identified as feldspathic (?) glass under the microscope, the fresh rock appears more massive than schistose, but partially weathered specimens of the rock invariably show pronounced schistosity. The longer axis of the yellow glass areas and the direction of schistosity are oriented in the same plane.

Occasional dikes of both basic and acid igneous rocks are intruded in the slates, as observed in the Occoquan and Quantico creeks sections (fig. 7).

Fossils.—During the summer of 1909, while studying the Powells Creek section, 3 miles north of Dumfries in Prince William County, the junior author found fossils in the smooth black graphitic slates, exposed

Fig. 7.

Fig. 7. Dike of igneous rock intruding slates parallel to the cleavage, west of Dumfries on Quantico Creek.

Fig. 8.

Fig. 8. Granite-gneiss exposed in Austin Run near contact of the slates on the northwest.

in a steep bluff on the south side of the stream one mile west of the old telegraph road (figs. 2 and 6). Figure 6 is a section along Powells Creek, in which the position of the fossiliferous beds is designated.

The specimens of slate containing organic remains collected from this locality were submitted to Dr. R. S. Bassler, of the U. S. National Museum, for identification, who kindly furnished the following statement regarding them: "The slates from northeastern Virginia contain numerous examples of a fairly well preserved pelecypod, closely related to the Cincinnatian forms of Pterinea, such as *P. demissa* Conrad. Associated with these are very imperfect remains of what may have been a linguloid shell, possibly a *Pholidops* or *Leptobolus*. The horizon is certainly Cincinnatian and most probably middle Cincinnatian."

It is a little disappointing not to have found definite evidence of the same species in the two slate areas (Quantico and Arvonia), and it is not improbable that more diligent search for fossils in the Quantico belt will be rewarded. It was thought at first that there was one species in common to the two areas, but after an examination of the U. S. National Museum collections from Arvonia, Bassler decided that the Arvonia species was not well enough defined for the most accurate determination. Concerning the correlation of the two areas on the basis of organic remains, Bassler says: "Although the present collections from the slates at Arvonia and from northeastern Virginia (Quantico slate belt) show no fossils in common, it appears most probable that the fossiliferous portion of each is of approximately the same age, indeed that the two slate belts themselves are synchronous."

The authors made a brief visit to the same locality during the past summer, but the conditions were such that no determinable organisms different from those collected in 1909 were found.

The same fossiliferous beds were exposed in a recent opening for pyrite near Marumsco Creek, 3 miles north of Powells Creek. Fossils were likewise noted here, chiefly replaced by pyrite, but the material was so disintegrated from weathering that no collections preserving them could be made.

The resemblance of the Quantico slates to the roofing slates of the Arvonia district on James River was noted by Darton as early as 1894,* but fossils had been found at that time only in the latter district (Arvonia). The two belts are aligned in the same direction of strike, similar lithologic types and associations are observed, and the metamorphic and structural rela-

*Fredericksburg Folio, No. 13, U. S. Geol. Survey, 1884.

tions of the slates are the same. Moreover, the slates in the two belts are alike in composition in being both graphitic and magnetitic.

There is in Louisa County and a part of Spottsylvania an area between the two belts, representing a distance of about 35 miles in direction of strike, in which the very dark gray to black graphitic slates have not been observed. While the true slates of this lithologic type have not been found in the small area between the two belts, the phyllites and schists, into which the slates of the Quantico belt grade, are traced continuously from the Quantico belt to the Arvonia belt, without change of structural relations indicated. It seems most likely therefore that the basin in which terrigenous and pyroclastic sediments were deposited during Ordovician times was a continuous one, and, so far as traced in Virginia, extended from the southern part of Buckingham County in a northeasterly direction to within 10 miles southeast of Alexandria, where the rocks pass beneath the Coastal Plain sediments of Cretaceous and Tertiary age.

The slates of these two belts, Quantico and Arvonia, in which upper Ordovician fossils have been found, represent the easternmost extension in Virginia of sedimentation during Ordovician time. West of the Blue Ridge the extensive areas of Martinsburg shale were laid down about the same time and are regarded as the probable equivalent of the Piedmont slates of the Quantico and Arvonia belts. Differential metamorphism has emphasized a fundamental difference in the eastern Piedmont slates and their equivalent Martinsburg shale, west of the Blue Ridge.

Arvonia Slate Belt.

In 1892,* Mr. N. H. Darton announced the discovery of organic remains in the roofing slate at Arvonia, Buckingham County, Virginia. The slabs collected by Mr. Darton were submitted to Dr. Walcott, who made the following statement regarding them:† "I have studied the specimens of slate showing crinoidal remains and come to the conclusion that they belong to the Trenton–Lorraine or upper portion of the Ordovician fauna. One of the large columns is closely allied to *Schizocrinus nodosus*, and some of the heads, although indistinct, approach closely to *Heterocrinus* and *Poterocrinus*. If these suggestions are correct, the slates are to be correlated with Lorraine or Hudson series and in the same horizon with the Peach Bottom slates of Pennsylvania."

* Darton, N. H. Fossils in the "Archæan" Rocks of Central Piedmont, Virginia. This Journal, vol. xliv, pp. 50, 52. †Ibid., p. 52.

Doctor R. S. Bassler furnishes the following statement of the fossils from the slates at Arvonia in the collections of the U. S. National Museum: "The collections of the U. S. National Museum contain twelve species of fossils from the slates at Arvonia, Buckingham County, Virginia. These are from the same horizon as the crinoid remains which resulted in Dr. Walcott referring the strata to either the Trenton or Hudson (Cincinnatian). The additional species make up an assemblage of forms which seems to be of middle Cincinnatian age. Most of the fossils are so distorted that their specific identification is necessarily uncertain. Many of the *Rafinesquinas*, for example, have a diameter of six inches, although the original shells were undoubtedly not more than two inches wide. The three species of echinoderms are numerously represented, a fact which is most unusual for Ordovician faunas. Indeed, if this fauna could be found well preserved, the general association of species would probably be very different from that of any Ordovician strata west of the Blue Ridge." The list follows:

Cyclocystoides sp. (one-third to one-half inch in diameter and with twelve to fourteen plates).
Protaster? sp.
Glyptocrinus cfr. *decadactylus.*
Calymene callicephala.
Trail resembling *Asaphoidichnus.*
Rafinesquina alternata (cfr. var. *ponderosa*).
Plectorthis cfr. *plicatella.*
Isotelus cfr. *gigas.*
Tentaculites sp.
Buthotrephis cfr. *gracilis.*
Buthotrephis cfr. *succulens.*
An indeterminable ramose bryozoan.

Five drawings of crinoids from these slates are reproduced by Darton in the paper published in 1892.*

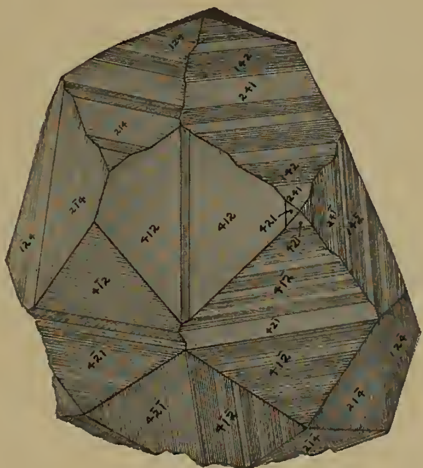
There are several specimens of a trilobite *Calymene callicephala* (Green) and an indeterminable crinoid, probably *Protaster* n. sp., in the collections of the University of Virginia, made by the senior author from the slates at Arvonia.

Brooks Museum, University of Virginia, October 18, 1910.

*This Journal, vol. xliv, p. 51.

ART. V. — *Native Gold from Gold Harbour, Queen Charlotte Islands;* by R. P. D. GRAHAM, Lecturer in Mineralogy, McGill University.

A BEAUTIFUL example of the crystallization of native gold has recently been presented to the McGill University Museum by Wm. Fleet Robertson, Esq., the Provincial Mineralogist of British Columbia, and on account of the comparative rarity of sharply defined crystals of this mineral it was thought that the occurrence merited a short note. The specimen is additionally interesting owing to the fact that it comes from Gold Harbour on Moresby Island, one of the Queen Charlotte Islands, which



locality, as Mr. Robertson informs me, was the scene of the very first gold excitement in British Columbia.

The gold, in the specimen examined, occurs as a cluster of crystals attached to colorless crystals of quartz, which also enclose specks of gold. With one exception the crystals are quite small, having a diameter of about 1^{mm}, but the remaining crystal stands out very prominently on the specimen and measures 4×3^{mm}, the elongation being along a trigonal axis; all are remarkably brilliant, and, both in luster and in the sharpness of their edges, they compare with even the brightest crystals of pyrite, from which mineral, however, they can at once be distinguished by the characteristic golden yellow color.

The form exhibited by the crystals is not at first sight obvious; the most striking feature of the habit is the arrangement of a number of almost square, four-faced pyramids, which lie very nearly, though not quite, in zones encircling the crystal. Parallel to the bases of these the faces are heavily striated, and in a great many cases there is a step-like structure; the occurrence of the accompanying reëntrant angles at the junction of neighboring pyramids causes these to stand out from one another more prominently, and is largely responsible for the pronounced "pyramidal" appearance.

From an inspection of the striæ it is easily possible to locate the various axes of symmetry and orientate the crystals; measurement of the large crystal on the telescope goniometer showed it to possess all the faces of the six-faced octahedron {421}, uncombined with any other form. The smaller crystals were not measured, but they are similar, so far as can be seen without removing them from the specimen; one was noticed which bore small faces of the dodecahedron, replacing the summits of the "four-faced pyramids" referred to above, and also of the cube. The general habit of the crystals is shown in the figure.

From the nature and distribution of the reëntrant angles, it was at first thought that the crystals might possibly be twinned, in which case they would have to be regarded as supplementary twins of some hemihedral form, such as the pentagonal icositetrahedron. As is well known, the holohedral symmetry of gold has been called in question by Helmhacker* and K. Martin,† who have described apparently tetrahedral forms of this substance: but, apart from this, it has been found that the crystals, however much distorted and misshapen, can always be referred to some form or combination of the holohedral class of the cubic system, and this is generally accepted as being the true symmetry of gold.

Although the evidence furnished by the reëntrant angles in the present crystals is suggestive, it is not, in itself, strong enough to warrant the assumption that they are hemihedral and twinned. Prof. E. S. Dana has very kindly examined the specimen, and is of opinion that the striæ and reëntrant angles are best to be regarded as the result, only, of an oscillatory repetition of the faces of the normal six-faced octahedron.

The specimen was collected by Mr. John McLennan, A.R.S.M., of Skidegate, from a quartz vein on his claim at Gold Harbour, and Mr. Robertson has kindly furnished the following particulars of the occurrence of gold in this neighborhood (see his Report for 1909, p. 76).

Gold (or Mitchell) Harbour is situated on the west coast of

* Tscherm. Min. Mitth., 1877, 1.
† Groth's Zeitschr., xxix, 278.

Moresby Island, which is the more southerly of the two principal members of the Queen Charlotte Islands. The discovery of gold in this locality would appear to have been originally made by Indians, since it was their possession of pieces of this metal that excited the curiosity of the Hudson Bay Company's traders, who induced the Indians to disclose the source; and this led to the prospecting expedition under the auspices of the H. B. Co. in 1852. Varying accounts have been given of the results of this expedition, but Major Wm. Downie, who examined the spot seven years later, states that he could not find anything worth working.

Since that date prospectors have been attracted to the vicinity at various times, and in 1906 McLennan discovered a new vein within about one hundred yards of the original H. B. Co.'s mine.

Mr. Robertson, who paid a visit to this locality in 1909, states in regard to the H. B. Co.'s mine, that "a trap dyke was found cutting through a diabase country rock in a N. 45° W. direction, with a nearly vertical dip. Following alongside the dyke is a crushed zone about 2 feet in width in which occurs a small vein of quartz, from one to four inches wide, somewhat irregular but quite persistent." The McLennan vein is similar, and being inclined to the other would intersect it under the harbour; both carry free gold in the form of small specks. A considerable amount of development work has recently been carried out on the property, and a stamp mill is now being erected for the treatment of the ore.

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Art. VI.—*Natramblygonite, a New Mineral;* by Waldemar T. Schaller.

Natramblygonite is, as the name indicates, a soda amblygonite, or a hydrofluo-phosphate of alumina and soda, with the soda in part replaced by lithia.

Occurrence.—The new mineral described in this paper was collected by me in 1908 in a large pegmatite mass four miles northwest of Canon City, Colorado. The presence of lithia minerals—lepidolite and pink tourmaline—had been noted in this pegmatite by Sterrett,* and it is owing to his favor and kindness, as well as to that of Mr. J. D. Endicott of Canon City that I was enabled to visit the locality and collect a suite of specimens from the pegmatite. As described by Sterrett, the occurrence of the tourmaline and associated minerals is on a low oval hill composed of pegmatite inclosed in contorted biotite and hornblende gneiss. Pink tourmaline and lepidolite are abundant though no cavities or pockets affording gem tourmaline were seen, the mineral being found only in the solid pegmatite.

Association.—The minerals associated with natramblygonite are few in number and do not possess any unusual properties. Tourmaline is abundant in black, pink or green crystals though no faces except those in the prism zone were seen on any of the crystals collected. A dark green, nearly black core with a pink shell seems to be a common color association for this locality. Small masses of minute bluish crystals and some larger green ones imbedded in muscovite were also noted. Most of the tourmaline is opaque and partly altered. The micas, muscovite and lepidolite, are also abundant. Lepidolite occurs in scaly pink masses, also as larger plates and in indefinite crystalline aggregates of pink or purplish colors. Albite generally is tabular in platy masses or in groupings of small crystals. The quartz and potash feldspars are massive and the single piece of natramblygonite found is also massive.

Description of new mineral.—The specimen of the new mineral measures about $7 \times 5 \times 3^{cms}$ and consists of a mass of cleavable natramblygonite surrounded by feldspar and lepidolite. Small veins and isolated masses of lepidolite are found scattered through the new mineral. Small amounts of pink tourmaline and of albite were also detected imbedded therein.

Three directions of cleavage can be detected, one more prominent than the other two. A section of the mineral cut parallel to the most prominent cleavage showed the other two

* Sterrett, D. B. The Production of Precious Stones in 1908; Mineral Resources 1908, U. S. Geol. Survey, 1909, p. 44.

cleavages intersecting at about 70°. In its general appearance the mineral very much resembles massive amblygonite. The hardness is 5·5 and the specific gravity lies between 3·01 and 3·06 with an average value of about 3·04. The luster is vitreous inclining slightly to greasy. The color is greyish white to white. In the hand specimen, it is translucent to opaque.

Examined in thin section under the microscope, inclusions of quartz, feldspar and mica were seen and also an irregular distribution of a kaolin-like dust. Two directions of polysynthetic twinning lamellæ intersecting at about 86° are prominent and lie at an angle against the cleavage cracks. The best cleavage is nearly normal to a bisectrix, and the section parallel to this cleavage shows a biaxial interference figure with a large angle. Its sign is negative.

Heated in a blowpipe flame, the mineral easily fuses, without decrepitation but with slight intumescence, to an opaque white enamel. The flame is colored yellow with no indication of red, due to lithium. In this particular, natramblygonite differs markedly from amblygonite and can thereby be distinguished from the common mineral. It would be well to test amblygonite from different localities by this flame test. Heated in a closed tube, water is given off and the mineral then quietly fuses without decrepitation to a blebby enamel firmly fused onto the glass tube.

Chemical composition.—Analysis of a selected sample of natramblygonite gave the values shown below. The sample was finely crushed and all visible impurities and doubtful looking pieces picked out by hand under a magnifying glass. The final sample all sank in Thoulet solution of density 3·01+ and all floated in solution of density 3·06. Beryllium was tested for but could not be detected. The mineral is difficultly soluble in H_2SO_4, in which solution no calcium could be found.

Analysis and ratios of natramblygonite.

P_2O_5	44·35	·312		1·00	
Al_2O_3	33·59	·329		1·06	
Li_2O	3·21	·107			
Na_2O	11·23	·181	·289	·93	
K_2O	·14	·001			
H_2O+	4·78	·266		·85	1·32
F	5·63	·296		·47F_2	
	102·93				
Less O for F	2·37				
	100·56				

The ratios yield the formula $P_2O_5.Al_2O_3.(Na,Li)_2O.(H_2O,F_2)$, which may be written more simply $AlNa(OH)PO_4$, with the Na partly replaced by Li and the (OH) by F. The ratios for water and fluorine are a little high, but this is probably to be ascribed to the difficulty of the fluorine determination. It is worthy of note, however, that the ratios for water and fluorine are also all high in Penfield's analyses of amblygonite.* The relations of natramblygonite to amblygonite are clear, the first being essentially the soda mineral and the second the lithia one.

Natramblygonite, $Na[Al(OH,F)]PO_4$.
Amblygonite, $Li[Al(OH,F)]PO_4$.

Nothing was seen which would indicate that the new mineral here described was originally the lithium compound which was afterwards changed to the sodium one. The alteration of amblygonite, described by Carnot and Lacroix†, yielded the mineral morinite which contains lime and soda without any lithia and much more water and fluorine than was present in the amblygonite.

Chemical Laboratory,
U. S. Geological Survey.

* Penfield, S. L. On the Chemical Composition of Amblygonite; this Journal, 3d ser., vol. xviii, pp. 295, 1879.

† Carnot, A., and Lacroix, A. The Chemical Composition of Morinite; Bull. Soc. franc. mineral, vol. xxxi, 1908, p. 149.

Art. VII.—*A New Emission Theory of Light;* by John Trowbridge.

It is interesting to imagine how Sir Isaac Newton would have rehabilitated his corpuscular Theory of Light if the Electron Theory had been enunciated during his lifetime. Might he not have answered the objection to his theory that light travels slower in fluids than in air by the assumption that the infinitely small electrons could pass between the atoms of the fluid and in so doing give up a portion of their energy to these atoms by setting them in vibration, thus producing absorption spectra which arise in all fluids on the transmission of light. Might he not, also, if the vortex theory of motion had engaged the attention of the mathematicians of his time, have provided his corpuscles with a whirling or vortical motion? In the periodic motion of the negative electron along a helical path, he could have supposed an apparent wave motion; and in the repulsion of neighboring vortices perhaps he could have abolished the conception of an elastic ether.

In thus imagining a new light dawning upon a mind which was capable of penetrating great secrets of the universe, I am emboldened to offer a hypothesis which may serve to lead us back to an emission theory of light, and at the same time enable us to relegate the ether to the phlogiston, the caloric, and the two fluid theories of electricity.

In the rough this theory supposes that negative electrons are shot forth from the sun in helical vortices, and in their progression provide an apparent periodic wave motion, giving, according to Maxwell's Electrodynamic Theory of Light, a pressure in the line of propagation and a tension at right angles to this line. A magnetic effect is a plane at right angles to the electrostatic effect, a repulsion between neighboring vortices which would simulate the supposed elasticity of an ether. The circular helices might become elliptical helices in passing through doubly refracting substances, and interference of light could be provided for. In support of this theory it may be urged that vortical motion is as common as rectilinear motion. The observer of the sun's surface is as conscious of vortex motion in the sun's spots as of the rectilinear uprush in the protuberances. The atomic theories are being recast to embrace the effect of supposed vortical motions. Speculation has gone so far as to suppose that atoms are mere whirls in a supposititious ether. A recent distinguished physicist has supposed that the negative electron is not matter and is provided with a vortex tail or tails to account for electrical lines of force. In this hypothesis, we appear to have two intangible essences tied together. Can we blame the metaphysicians for smiling, and saying "You physicists are coming into our ranks"? But are we not supplanting the hypothesis of a fluid which fills all space, a fluid which is thinner than any gas, a something which has no resemblance to anything of which we have cognizance and which is more elastic than steel, by another fantastic hypothesis? We have, however, given up the fluid theories in electricity and instead of media we have motions of electrons. Light is an electro-dynamic phenomenon, and the hypothesis I frame extends the motion of electrons from the confines of electrical circuits to the extent of space.

I have said that we have abandoned the fluid theories of electricity. This is true of the two fluid theories; but we see some merits still in Benjamin Franklin's one fluid theory, in the light of the electron theory. Franklin accounted for attraction and repulsion by an excess or diminution of a fluid. His theory could become an electron theory if instead of an excess or deficit of a fluid we read excess or deficit of negative electrons. The attachment or detachment of the negative electrons explain in a plausible manner the fundamental experiment of the attraction or repulsion of electrified pith-balls. Can we extend the modified Franklin theory to account for magnetism and diamagnetism? We should be able to do this, for as Maxwell remarks: "Every phenomenon in electrostatics has its analogy in magnetism."

To answer this question I am led to the subject of canal rays, which has greatly interested me;* for in this phenomenon we are brought into close consideration of what is perhaps the most important question in the theory of electricity: "What is positive electricity?"

The negative electron has been identified in the discharge from the negative cathode in Geissler tubes and the positive rays proceeding from orifices in the cathode—the so-called canal rays—are supposed to be a phenomenon of the positive electrons. To account for the positive rays we have a multitude of theories of combination and neutralization of single entities and doublets. From the cathode in a Geissler tube, at a suitable exhaustion, proceed negative electrons from every unit of surface both toward the positive terminal of the tube and toward or into the region where the canal rays manifest themselves, that is away from the positive terminal and back of the cathode. The canal rays appear to emanate from the canals or perforations in the cathode, and also proceed in both directions, one toward the positive terminal and the other in the direction away from the terminal.

*Proc. Am. Acad., xlv, No. 19. Ibid., xliii, No. 20.

We find that the negative electrons exhibit the greatest penetrating and impulsive effects. They are extraordinarily sensitive to a magnetic field; whereas, the positive rays are comparatively insensitive and require a strong magnetic field to affect them, which is in the opposite direction to that taken by the cathode rays or streams of negative electrons.

If we adopt Franklin's hypothesis of excess and deficit and make the assumption that all space is filled with negative electrons, which pass through matter, modifying atomic movements, we might suppose that the positive discharge in a Geissler tube is due to an effort of the electrons of space to re-establish an electrical equilibrium disturbed by chemical action of a battery or the motion of a dynamo. This disturbance appears to be shown in more Protean ways at the cathode than at the anode. The stream of negative electrons in passing through the glass of the Geissler tube communicate some of their energy to the atoms of the rarified gas, aiding perhaps the cathode electrons in driving the atoms in both directions from the perforations in the cathode, thus causing the Doppler effect, and transforming their ultra-violet radiations into longer wave lengths, and the diminished velocity of the wave lengths of the visible spectrum. The positive column of the discharge in Geissler tubes may also be regarded as the effect on the atoms of the gas of the electrons entering from outer space to reëstablish the electrical equilibrium, disturbed by the agency which produced the electric discharge in the tube.

But how shall we explain the effect of a magnetic field on the positive rays? The electrons of the cathode do not appear to affect the canal rays, although the directions of both the retrograde canal rays and the direct canal rays coincide with the directions of the cathode rays from the two surfaces of the cathode. Experimenters have always been careful to drive the cathode rays out of the field before applying a magnetic field to the positive rays. Is it not possible, however, that negative electrons can be so entangled among the atoms of the gas that the effect of a magnetic field on the motion of these atoms and the effect on the electrons of the environment which come from outer space, and not from the local electrical disturbance, might produce a deflection of the atoms in a direction opposite from that taken by the cathode rays? We appear to have an analogy in magnetism and dia-magnetism. We can suppose that the magnetic metals afford a greater receptivity to the vortical motion of the negative electron of space than the non-magnetic metals, or that the energy of the electrons is less consumed in iron than in copper. The strong magnetic effect necessary to produce an apparent effect in deflecting non-magnetic metals may be regarded, as in the case of the canal rays, of a balance between the effect on the atomic motions and the effect on the environment. The difference of phosphorescent effect of cathode and positive* rays is mainly a question of energy and not a difference in kind.

As I have previously remarked, our experiments on electrons in Geissler tubes are conducted in an environment filled, on my hypothesis, with electrons. The magnetism of the field is also an exhibition of a certain selectivity of path of the electrons of outer space.

If the sun is constantly throwing forth negative electrons, it is, according to Franklin's hypothesis, being positively charged every instant, and recharged, perhaps from the electrons of outer space. Every flame throws off negative electrons and is constantly being reduced to a positive state. Perhaps in this interchange we can trace the intermittent action, amounting to billows of pulses, of the waves of light. If we examine the tendencies of Physical Science from the time of Sir Isaac Newton, we see a tendency to abandon intangible media and to base all phenomena upon the motion of matter. Indeed, I am tempted to paraphrase Tyndall's much-quoted remark, that we may be led to discern "in matter the promise and potency of all terrestrial life" † by substituting motion and matter for "in matter." It has become a serious question, how the physicist, in entertaining a belief in an intangible ether, the whirls of which constitute matter,—a belief that electricity is another intangible something not matter, in an electron which is an essence with an essential tail tied to it by a knot of something thinner than any gas, — can escape being welcomed into the ranks of the metaphysician and philosopher. To escape this suppression of his identity, I believe the physicist must resolutely cling to a belief in both motion and matter.

* It may be suggested that the effect of magnetic fields on non-magnetic metals is feebler than that on the positive rays. An atom of gas, however, has a finer suspension than any we can accomplish in the case of a metallic filament.

† Belfast address.

ART. VIII.—*The Origin and Peopling of the Deep Sea*; by Prof. Dr. JOHANNES WALTHER.*

THE ocean covers two-thirds of the earth's surface. Five continents and numberless islands rise out of it and divide the ocean into separate parts, but nowhere is there to be found a barrier which can permanently prevent the intermingling of the waters. The ever-moving and restlessly intermingling sea water shows therefore a very marked uniformity in its chemical composition. At Pole as at Equator, in the upper surface as in the depth of the sea, the salt content amounts to about 3·5 per cent and the proportion of chloride, sulphate and carbonate remains on an average the same in brackish bays or at the mouths of great rivers.

It is known that the astronomical position of the earth with relation to the sun causes marked climatic zones which are arranged in almost parallel girdles perpendicular to the earth's axis, and we notice on the mainland a steady decrease of organic life the farther we proceed from the warm equatorial region toward the cold polar circle.

The surface of the sea is also girt about with climatic zones, which, corresponding to the continental temperature belts, reach from one coast to the other. In the equatorial region, the water has a warmth of 30° C.; toward the poles its temperature sinks, and since salt water first freezes at −2·5° C., the polar shores are laved by very cold water. One would then believe that hand in hand with this decrease in temperature a diminishing of the organic life in the sea would be noted, but quite the opposite is the case. In the polar seas, the plankton net is filled with a veritable jelly of floating plants and animals which serve as food for the numberless fish swarms and the giant whales, and if the naturalist has drawn the dragnet over the sea bottom, it is filled with a vast multitude of echinoderms, mollusks and crabs.

In order to understand this striking fact, we must keep clearly in mind that almost all sea animals belong to cold-blooded forms whose own warmth changes as the temperature of their surroundings changes. *Pecten islandicus* thrives as well in a sea temperature of zero centigrade as does *Pecten jacobæus* in 10° C., or as the tropical *Pecten sanguinolentus* in the water of the coral seas with a temperature of 25° C. Consequently, the absolute degree of temperature is of no influence on the richness in forms of the sea fauna.

We know that the climate of a continent undergoes very

* Translated from the German (*Naturwissenschaftliche Wochenschrift*, 1904) by Clara Mae LeVene, Peabody Museum, Yale University.

noticeable changes in the same geographical latitude if the land is raised into mountains. Kilimanjaro lies in the tropical zone and still its peak is covered with eternal snow and "polar" glaciers.

Just as the climate of the continent with increasing topographical altitude becomes more like polar climate, so we notice in the sea with increasing depth a constant lowering of temperature. Even at 120 meters* the daily and yearly fluctuations of the warmth of the water cease as a rule, and under the surface water, with a warmth of 30° C. in the equatorial region, we find even at 200 meters a temperature of 12° C. and at 1200 meters one of 5° C. From here to the bottom reigns an unvarying temperature of zero to 5° C., which in the southern Atlantic sinks even to —2° C.

But while on the land the colder regions occupy only scanty space, the contrary condition rules in the sea bottom. For even in the equatorial regions, the warm water is restricted to very narrow zones parallel to the coasts and the whole expanse of the true deep sea bottom is covered with ice-cold water. A gigantic but immeasurably slow stream of cold south polar water flows toward the equatorial region in the depths and projects the thermal characteristics of the southern ice seas to the deep sea bottom.

By examination of a world chart, we do not get the correct impression of the relation of the sea to the continents, because the border region of the continental mass is washed over by the sea, and consequently around almost all coasts extends a broad shallow-water zone, whose depth very slowly sinks to 200 to 300 meters. The whole North sea, the Irish sea and the ocean for 300 kilometers west of Ireland belong to this so-called continental shelf, and not until beyond them does the sea bottom sink suddenly to 4000 meters.

But even if we consider the continental shelf as the submerged edges of the continents, still half the earth's surface belongs to the area of the deep sea, with an average depth of 4000 meters and a maximum depth of 8 to 10 kilometers. This vast region, embracing half of the globe, is so significant in the natural history of the earth to-day that one can well understand the important rôle it has also played in the geologic past. But in order to discern the past history of the deep sea, we must point out still another important characteristic of the present deep sea.

Waves and currents were produced by passing or periodical winds and set in motion only the upper water strata. In a depth of 1000 meters, even the Gulf Stream is scarcely noticeable and farther down all measurable water movements cease.

*For the sake of simplicity the figures are given in round numbers.

Only imperceptibly slow diffusion streams constantly mix the waters.

Just as the sun's heat can only warm the upper water strata, so the sunlight, even in clear water, penetrates only to a depth of about 400 meters. Photographic plates which were exposed at such a depth at Nice show no influence of light. Only the delicate shimmer of phosphorescent animals lights the dark abyss. The consumption of carbon dioxide, so important for the life of plants, is only possible in sunlight; therefore we need not wonder that the deep sea harbors no single plant and that with their absence fail also the plant-eating animals.

To sum up the characteristics of the abyssal region so far noted,—a uniformly low temperature, quiet water of normal salinity disturbed by no noticeable movement, no light and no plant life: these are the bionomically important characteristics of the deep sea.

These conditions of existence are, moreover, very constant over vast areas and cause the world-wide distribution of most of the deep-sea dwellers. The fauna of the deep sea is undoubtedly poorer than that of the shallower parts of the sea, but if we consider that all light-hungry and plant-eating animals are lacking there as well as all inhabitants of the moving and warm sea water, we are still astonished at the animal world of the abyss. For each dragnet brings up deep sea animals and even the small bottom samples of the sounding apparatus have afforded traces of organic life at the maximum depth of more than 8000 meters.

Ten years ago, Sir John Murray gathered the results of the earlier deep sea expeditions and thereby showed that

down to	200	meters	about	4200	kinds	of	bottom-dwelling	animals	exist
down to	2000	"	"	600	"	"	"	"	"
at	4000	"	"	400	"	"	"	"	"
below	5000	"	"	150	"	"	"	"	"

To this must be added the great number of animals floating and swimming in the deeper water strata. But, while in shallow water a great number of individuals of each species are captured in each cast of the net, the deeper strata are rich in species, but poor in individuals. A cast of the dragnet in 1000 meters depth still gave 100 examples of the same animal, but in greater depths there were often in a net only 2 examples each of 10 different species.

It is difficult to point out a peculiar characteristic of the known deep-sea animals without giving a specific description of individual forms. But one can safely state that they mostly possess very weak structures. Their hard parts are rare or very frail. Some are blind, others distinguished by telescopic eyes or wonderful concave mirror-like sight organs. Many live on decaying deep sea ooze and have therefore lost their organs for the mastication of food, others are robbers with strongly developed jaws. Many forms show wonderful contrivances for the care of the young, while others seem to multiply with extraordinary rapidity; but almost all are provided with phosphorescent light organs which unite with their gay, soft radiance, that in some cases can be photographed after capture, to transform the dark depths into a magic garden.

If we inquire into the conditions of existence of this animal world so rich in forms, a peculiar problem arises: we know that organic life is only maintained by the constant introduction of inorganic elements into the cycle of life and that the force which in great measure is able to maintain life is the carbon dioxide consumption by the plants. Only when sunlight falls on brightly colored plant parts are carbonic acid and water separated into their elements and from these the complex protoplasmic molecule built up. Where sunlight and green plants are wanting, there can no new life arise and no organic life be maintained. So the animal life in the deep sea of to-day could not be maintained if a stream of cold south polar water did not pour oxygen and food down into the abyssal depths.

The deep sea resembles, speaking in terms of national ecology, a purely industrial state without agriculture dependent for its existence upon lands pursuing agriculture and stock-raising. Hence it follows as a necessary consequence that the fauna of the deep sea cannot have originated there, but must have wandered down into the dark depths from the sun-lit strata rich in plants.

As soon as we have made clear this indisputable fact, a very significant geological problem confronts us. We ask, When did the deep sea become peopled? and when did the deep sea basin originate?

To be able to solve these questions, we must describe in few words the character of the sediments of the present deep sea, for only by knowing these well is it possible to examine an old rock as to the history of its origin.

All deposits of the coast region and the shallow continental shelf had their origin on the mainland of the continental areas. The bowlders on the rocky shore, the sand of the dune regions, and the blue or green ooze of the shallow sea are either washed from the strand by the sea waves or borne into the ocean by rivers. The mighty delta masses of the Nile, Ganges or Mississippi bear witness to the vast quantities of continental muds that are carried into the sea.

But the salty sea water has the peculiar property of clarifying muddy river water in a short time and of precipitating all ooze to the bottom. In this way all the river mud is deposited in the shallow sea region and no fragment of quartz reaches the abyss.

Sir John Murray, after the completion of the Challenger expedition, examined all the known samples of deep-sea bottom and showed that in these depths sediments of a very peculiar character exist. The mightiest rôle in their composition is played by the floating organisms of the sea. The chalky shells of frail Globigerina cement together the main mass of the so-called Globigerina ooze, which covers about half of the entire deep sea bottom. This cream-yellow when fresh, soft, liquid lime-ooze is connected with the continental muds of the coast zones by transition stages, and passes, by decrease of its chalk content, into the so-called Red Clay of the deep sea, which covers about one-fourth of the earth's surface. To it are joined isolated areas which are completely strewn over by the delicate microscopic siliceous tests of Radiolaria. The Red Clay of the deep sea originates from transformed volcanic ashes and through the solution of organic calcareous skeletons.

With certain exceptions the above named deep sea sediments and other associated deposits of the abyssal regions are distinguished by the following characteristics:

1. They contain neither quartz nor other fragments of continental rocks.
2. They contain no plant residue which is brown or black in color.
3. They are piled in horizontal layers and are spread over marvelous distances.
4. They contain no remains of shallow sea animals or plant-eaters.
5. By very slow and gradual transitions they are connected with the shallow water sediments of another origin.

The geologic examination of the continental masses has given the remarkable result that from the oldest times of earth history to the present day almost every part was repeatedly sea bottom. The present position and limits of the ocean are a transitory appearance, and while it was formerly believed that it was possible to measure and gauge the height of the land by the fixed level of the sea surface, it has been known for twenty-five years that the sea level is variable. Now, if each part of the present dry land was one or more times sea bottom, we must first ask whether we know deposits in the earth crust which by their lithologic and faunal character can be considered as formerly sea bottom.

I have busied myself much with recent deep sea sediments, have studied those of the Challenger expedition, and in my geologic studies have considered again and again whether anywhere a fossil rock possesses abyssal characteristics, and can state that nowhere have I met with a rock either from Paleozoic or Mesozoic deposits that by its structure and nature of deposition corresponds to the present sediments of the deep sea. Even the radiolarian rocks made known through Dr. Rüst's careful studies contain no likeness to the radiolarian ooze of the present deep sea. Their coal wealth, the mass of terrigenous material, and their stratigraphic connection with undoubted littoral sediments make it impossible to see in them the deposits of the deep sea. We are much more reminded of the tripoli of Sicily and the oceanographic conditions in the straits of Messina. Here rushes upward a mighty stream of cold deep sea water, bringing deep sea fishes, crabs and radiolarians to the surface of the sea where they, mingled with the dwellers of the upper water strata, give rise to the richness of the sea fauna here so well known to all zoologists. John Murray attained the same result after he had applied to a number of geologists with the request to send him fossil "deep sea rocks." The microscopic examination showed that only on a few small islands like Malta, Barbados, and Christmas island occurs true Tertiary deep sea ooze, and the local distribution of these unmistakably indicates that local upheavals of former deep sea bottom formed the nuclei of these islands. Although almost the entire areas of the continents of to-day have been wholly or partly and repeatedly overflowed by the ocean since the Cambrian, yet we know here only such deposits as are now forming in the shallow seas or in depths not below 1000 to 2000 meters.

Herewith we confirm by geologic proof a view which has long been asserted on the ground of theoretical speculations and which centers in the statement: the deep sea of to-day has been deep sea for a long period and it has not essentially shifted its place on the earth's sphere since its origin. The deep sea basins appear to us as the original regions of ocean origin, from which the sea periodically transgresses upon the continents, only to flow back again into the gigantic gathering-reservoir.

Geologically it can be shown with certainty that former continents have been sea bottom. Thus, we find in Devonian time on both sides of the Atlantic ocean, in North America and Spitzbergen as well as in Scotland and Russia, deposits of great fresh-water basins with a very characteristic fish fauna. In the Carboniferous as well as in the Jurassic and Cretaceous the same land and plant animals lived in North America as in

North Europe. All this points to the conclusion that during these long periods an Atlantic land connection existed between both continents which to-day is in part deep sea bottom. Similar facts force the acceptance of the opinion that the present Indian ocean throughout long periods possessed a land bridge from Africa to India and Australia. Finally, how can we explain the occurrence of entire skeletons of hippopotamus and African elephants in very ancient bone caverns at Palermo except by the conclusion that Sicily was once joined with Africa, although now a deep sea exists between the two shores? For a passive transportation of these gigantic animals is not to be considered.

Aside from a few local exceptions where deep sea bottom has again become land, there are numerous cases in all parts of the earth where we can show that great portions of the firm earth crust through sinking have become changed into sea bottom. In other words, the deep sea has grown at the expense of the shallow sea and the mainland.

The great interest of geologists in the investigation of the deep sea arose when the elder Sars discovered in the Lofotens at a depth of 1000 meters a small sea lily, *Rhizocrinus lofotensis.* The stalked sea lilies up to this time had been held as an entirely extinct group which in the geologic past had possessed a great significance, inhabiting the former seas in hundreds of genera now extinct. Out of the deep sea there was then drawn such an ancient animal still living and at once then arose the hope of obtaining by methodical dredging of the deep sea bottom other animal species also believed to be extinct. It was one of the more important tasks of the Challenger expedition to seek after these very ancient types.

A number of expeditions have now explored the bottom of the deep sea and we know very well the systematic interrelation of the present deep sea fauna and its characteristics acquired by adaptation to the peculiar environmental conditions; and it seems a praiseworthy task to prove the geologic age of this fauna, just as paleontologists do in determining the age of an extinct fauna. It is well known that in each period of the earth's history different sea animals have lived; let us now compare the present deep sea fauna with the chronologically arranged faunas of the past.

To this end we must first point out that not a single animal characteristic of the Paleozoic is found in the present deep sea. The Archæocyathidæ, Tetracoralla, Tabulata, Stromatopora, Spiriferidæ, Graptolithidæ, Cystidea, Blastoidea, Paleocrinoidea, Orthoceratidæ, and Trilobitæ are completely lacking. We might then perhaps surmise that in general no Paleozoic forms still live. Therefore we must also point out that in the present shallow sea there actually live a number of uncommonly long enduring Paleozoic genera:

Of brachiopods, *Lingula*, *Rhynchonella*
Of bivalves, *Arca*, *Avicula*, *Astarte*, *Leda*, *Mytilus*
Of univalves, *Capulus*, *Pleurotomaria*
Of cephalopods, *Nautilus*
Of worms, *Serpula*
Of starfishes, *Astropecten*.

Limulus, the last representative of Silurian horseshoe crabs, is a coast dweller, and *Ceratodus*, rooted in the Devonian, still lives in Australian rivers.

We must thereto also add a number of forms without skeletons which are phylogenetically very old and which must have had their origin in the pre-Cambrian faunas. *Hydra* and *Amphioxus* as well as the Asconia sponges, Planarians and Holothurians are mostly dwellers in very shallow water, and all these forms reach back into the oldest part of the earth's history.

Only the Cambrian genus *Discina*, some Silurian bivalves such as *Arca* and *Nucula*, univalves such as *Dentalium* and the Devonian *Terebratula*, have descended into the deep sea, but it is naturally very easy to suppose that they first began this migration at a later time. Mustering now the remaining animals with skeletons living below 2000 meters and with a clear understanding as to their paleontologic position, there can be no doubt that the oldest genera date from the Triassic and Jurassic periods.

The Euretidæ among the hexactinellid siliceous sponges, the turbinolids among the corals, *Pentacrinus* among the crinoids, *Ophioglypha* and *Asterias* among the starfishes, *Echinus* among the sea urchins and *Penæus* among the crabs are forms whose oldest kin belong to the Mesozoic age. Their migration into the deep sea can therefore at best date from the Triassic.

Very close is the relationship of the present deep sea fauna to the animal world of the Jurassic and Cretaceous periods. The German Valdivia expedition found the nearest kin of the upper Jurassic *Eryon* in the characteristic deep sea crabs *Pentacheles*, *Willemœsia* and *Polycheles*, and A. Agassiz has shown that most of the deep sea urchins are related to Cretaceous genera.

The deep sea corals belong almost entirely to Cretaceous genera. It is further noteworthy that typical Tertiary forms are very rare in the deep sea. The migration must therefore in general have ceased in the Tertiary.

Were the present deep sea fauna laid before a paleontologist "without designation of locality," he would on the basis of the more fundamental relationships have to consider it as Mesozoic and would refer the majority of the forms to Cretaceous and Jurassic genera and others to genera of the Triassic. The few Paleozoic genera occurring at all water depths would thereby gain no significance because all specific forms of Paleozoic time are wanting in the deep sea, whereas, on the other hand, many representatives of the same are found living in the present shallow sea.

General considerations as to the life habitats of the deep sea have led us to the conviction that its fauna must have migrated from the shallow sea; the comparison of the deep sea fauna with the fossil faunas has shown us that it has a Mesozoic character; therefrom the conclusion necessarily follows that the peopling of the deep sea can be traced at the earliest to the Triassic.

The deep sea basins represent the greatest inequalities of the earth's crust. While the average height of the mainland amounts to only 700 meters, the average depth of the oceans is 3500 meters, but the average depth of the deep sea basins amounts to about 5000 meters. It is only the Tibetan highland that rises to this amount above the mainland, while one-half of the entire earth's surface is depressed below this level.

In different periods of the earth's history great land areas have sunk beneath the surface of the sea to be united to the deep sea; into the new depressions the water flowed and left the former shallow sea regions. Since the Jurassic, North America and Europe have in this way gained land, and even in Asia we see the land growing at the expense of the shallow sea. The intensive development of mammals, birds and insects since the Eocene seems to stand in the closest causal connection thereto.

The fact, recurring in all great sea basins, that the greatest depths occur nearest the coasts, can be explained only by the assumption that these deep channels represent local exaggerated deepenings of a general deepening process.

From the study of newer and older mountains it is now seen that hand in hand with the elevation of the mountain chains extensive depressions have occurred. The Alpine folding continues into the depressed plain of Lombardy just as the chains of the Himalayas are connected with the Bengal depression and the South American Cordillera finds in the bottom of the Pacific ocean its downward-directed compensation. With the elevation of the Black Forest and Vosges the plain of the Rhine valley sank into the depths, and the sinking of the Dead Sea corresponds to the elevation of the Lebanon.

We must also expect the beginnings of those immense depression areas to be connected with the powerful processes manifested in mountain-building, and have to examine as well whether in the earth's history there is discernible an increased folding of the crust at the end of the Paleozoic..

Everyone who is at all familiar with the events of that epoch knows that at no other period did there arise anything equalling the extent and grandeur of the mountain ranges of the time between the Carboniferous and Triassic periods. A gigantic range of mountain folds can be traced from Ireland through all of France to the banks of the Rhone; a second range extended from the Rhine northeast through Germany to the Carpathians. The eastern Alps were mountain land and in Switzerland as well are to be seen undoubted traces of a former mountain range. In the same epoch arose the Urals and simultaneously the Appalachians were thrust together in North America. In the Sudan there probably arose a mountain fold with great granite stocks at the termination of the Paleozoic and in South America the Permian age of extensive mountain folding was definitely established! Even in eastern Asia keen scientific explorers have been able to trace a Permian period of folding from China to Japan and through the interior of India to Sumatra.

But where are to be sought the complementary movements of this same time directed toward the center of the earth?

An answer to these questions is not difficult to find. For if the present deep sea fauna contains predominantly Mesozoic types and in accordance with its whole character must be considered as a migration from the shallow sea; if therein almost all Paleozoic elements are lacking although such are represented rather numerously in the present shallow sea; then the deep sea must have originated at the end of Paleozoic time.

And if in the same period of time we find that mighty mountains have arisen almost everywhere on the earth, then it is easy to bring the depressions of the deep sea basins into direct connection with these folding processes.

General biological grounds, the stratigraphic position of the present deep sea fauna as well as tectonic investigations, force us to the conclusion that the deep sea as a life-region is not a characteristic of the earth in its oldest periods, and that its origin falls in the time when in all parts of the present continents began tectonic folding movements which so decidedly changed the relief of the earth's surface.

Art. IX.—*The Camels of the Harrison Beds, with Three New Species;* by F. B. Loomis.

During the deposition of the Upper and Lower Harrison beds of Lower Miocene age there was probably no more abundant or varied group of vertebrates in that region than the camels. Already six species belonging to two genera have been described, and in this paper three more will be added to the number; but even then the collectors in that region, judging from the varied toe bones, etc., are confident that there are yet several species to be added. The deposits are typically those of an upland country, those of the Lower Harrison being fluviatile, and those of the Upper Harrison, in a considerable proportion at least, eolian. The fauna points in the same direction, being entirely composed of plains types and river-frequenting animals, like the rhinoceroses, Diceratherium and Aceratherium.

In 1908 both Yale University and Amherst College had parties working together along Muddy Creek and in the "breaks" to the south of the Raw Hide Buttes in Converse Co., Wyo.; and it is the camel material of these two expeditions which is the basis of this paper, the authorities of the Yale Museum having generously loaned all of theirs for this purpose.

In the Lower Harrison beds the camels which are most abundant belong to the genus Stenomylus, forms characterized by their very hypsodont dentition and slender build. Of these there are three species as differentiated further on. Then one species of Oxydactylus has been described by Mr. Cook from these beds, making four known species. It is in these horizons that there are doubtless several more species. In the Upper Harrison beds two species of Oxydactylus have been described by Peterson, the genus being characterized by a brachyodont complete dentition and elongated limbs. To these will be added two more species of Oxydactylus and one of Protomeryx, which differs from the foregoing by not having the excessive development of limbs and still retaining the brachyodont dentition. In both divisions of the Harrison it will be seen that the camels are specialized and further that they are of the open country or plains types. The more generalized genus Protomeryx is strikingly scarce, being only represented by the one species, which in its turn is the slenderest representative of the genus.

The genus Oxydactylus is the dominant one, containing five different species, the representatives of which are also among the most frequently found. It is characterized by i. 3/3 c. 1/1 pm. 4/4 m. 3/3 brachyodont teeth, the upper incisors being but little reduced, the third incisor being caniniform and often of considerable size, occasionally larger than the canine. The first premolar in both upper and lower jaw is double-rooted. Limbs are long and metacarpals free, metatarsals also separate except at the palmar process. The skull is usually small and specific variations are perhaps best seen in the relative development of the snout as shown by the spacing either side of the canine and first premolar. The relative size of the canine and third incisor are also characteristic. *O. longipes* is the largest of the known species and most fully described so that it can conveniently be used as a standard for comparisons.

Oxydactylus longipes Peterson

Ann. Carnegie Museum, vol. ii, pp. 435–468, 1904.

This largest species of the genus is also comparatively abundant in the Upper Harrison beds; and is characterized by a moderately short snout, and by the third incisor being equal to or slightly larger than the canine.

Oxydactylus brachyodontus Peterson

Ann. Carnegie Museum, vol. ii, pp. 469–471, 1904.

This species is the most abundant of the Upper Harrison camels, is slightly smaller than *O. longipes*, and has a much more elongated and narrower snout, the third incisor being smaller than the canine.

Oxydactylus lulli sp. nov.

The type of this species is number 10327 of the Yale Museum, found by Prof. R. S. Lull in the "breaks," about five miles south of the Raw Hide Buttes, Converse Co., Wyo. The type consists of a skull complete as to the jaws and dentition, but lacking the major part of the brain case and being considerably crushed laterally, and also of incomplete limb and foot bones. Beside the type there are three other specimens, all from the Upper Harrison beds, but none showing the brain case. This species is nearest to *O. brachyodontus* but is smaller and of very different proportions. The facial portion of the skull is as long as that of *O. brachyodontus* but much lower throughout. The back part of the skull, especially in the region of the premolar and molar series of teeth, is considerably shorter than the foregoing. The third upper incisor is much smaller than the canine, though caniniform in shape. In the upper jaw the diastema between incisor 3 and the canine is only 12^{mm}, which makes the canine seem very far forward. Similarly in the lower jaw the first premolar is placed well forward, being but 15^{mm} from the canine. This first premolar is unusually stocky and two-rooted. Premolars 2–4 in the lower jaw are entirely simple and do not resemble the molars.

FIG. 1.

FIG. 1. Type of *Oxydactylus lulli*. Dotted outlines are put in from a second specimen. Nat. size.

Oxydactylus gibbi sp. nov.

The type of this species is number 10328 in the Yale Museum, found by Mr. Hugh Gibb on Muddy Creek, about opposite the spring associated with the "Spanish diggings." The type consists of the palate and lower jaws with complete dentition, except that the third molar is lacking in each jaw. In the measurements given it is estimated as being of the same

FIG. 2.

FIG. 2. Upper and lower jaws used as type of *Oxydactylus gibbi*. Half nat. size.

proportions as that of the other members of the genus. Beside the type there are two other specimens from the same general region, all from the Upper Harrison beds. One of the two aeeompanying specimens eonsists of the major portion of the skull and some limb bones, but the individual is so young as to still be using the milk dentition although molars 1 and 2 are up in the jaw.

This speeies is smaller than the preeeding one, in faet is the smallest Oxydaetylus yet deseribed. Its snout is moderately long and the speeies is easily distinguished by the great size of upper ineisor 3, whieh is nearly twiee the size of the redueed eanine. The first premolar is also a large, strong tooth, and less reduced than in other speeies. The lower jaw is stoeky, the eanine being mueh enlarged. The first premolar stands eonsiderably nearer to the eanine than to the seeond premolar. The skull of the young individual shows wide projeeting arehes over the orbits and a rather wide but short brain ease. The limb material is only eomplete enough to show that the form had long limbs typieal of the genus.

Oxydactylus campestris H. J. Cook

Amer. Naturalist, xliii, p. 188, 1909.

This speeies oeeurs in the Lower Harrison beds, is intermediate in size between *O. brachyodontus* and *O. lulli*, and elearly distinguished by the very short snout, and by the large size of upper ineisor 3, whieh is larger than the eanine. The short snout would indieate a less advaneed type than those in the Upper Harrison beds.

Protomeryx leonardi sp. nov.

The type of this speeies is number 2004 in the Amherst College Museum, and was found in the Upper Harrison beds on Muddy Creek, about three miles below the "Spanish Diggings" spring, by Mr. E. N. Leonard. Part of the skull of a very young individual was also found in the same beds some five miles further up the Muddy Creek and is 10326 of the Yale Museum. Heretofore this genus has not been reported from the Harrison beds. This speeies is eharaeterized by the slender proportions of the lower jaw, whieh is all that was found of the adult animal. The full set of teeth is present in the lower jaw, the teeth being rather high erowned, but not enough so to be designated hypsodont. In the lower jaw there is a short diastema behind the third ineisor (as shown by the young jaw). The canine is a slender, eompressed tooth whieh rises to an unusual height and projeets somewhat forward. The first premolar is redueed, being but $4\frac{1}{2}^{mm}$ wide, the diastema between it and the eanine being 15^{mm}, while the interval behind it, i. e. between premolar 1 and premolar 2, is very considerable, 17mm. The premolar series is simple, there being no crescent on any of the teeth, and premolars 2–4 measuring 23mm. The three molars are those typical of the genus, but rather high crowned, and together extending 45mm. The jaw is very slender and with a short coronoid process. It measures but $12\frac{1}{2}$mm in depth under the first premolar, and 17mm under the second molar.

FIG. 3.

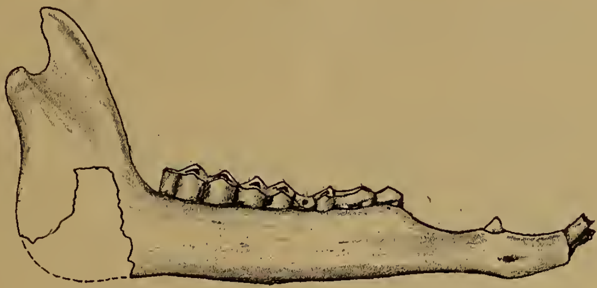

FIG. 3. Lower jaw used as type of *Protomeryx leonardi*. Nat. size.

The following table is arranged to show the relative size of the different species of Oxydactylus, and especially to show the variations in the proportions of the snout and in the positions of the canine and first premolar teeth:

		Length of skull	Diastema $i^3 - c$	Diastema $c - p^1$	Diastema $p^1 - p^2$	Length $p^2 - m^3$	Diastema $\overline{c} - \overline{p^1}$	Diastema $\overline{p^1} - \overline{p^2}$	Length $\overline{p^2} - \overline{m^3}$
O. longipes------	U. Harrison	340	13	14	18	102	17	17	104
O. brachyodontus	U. Harrison	---	14*	18*	19*	93	17*	22*	100
O. lulli ---------	U. Harrison	275	12	19	19	85	15	20	91
O. gibbi --------	U. Harrison	---	10	16	18	72†	12	24	77†
O. campestris ---	L. Harrison	290	--	--	--	70	--	--	--

The genus Stenomylus contains the other Harrison camels and is distinguished by having a complete dentition of very hypsodont teeth, by the upper canines being partly and the lower wholly incisiform, and by the slender build. Three

* These measurements are taken from the figure.
† The last molar being absent, it is estimated as being normal to the genus.

species are described, of which *S. hitchcocki* is commonest and known by the most complete material, so may be used for a standard for comparisons.

Stenomylus hitchcocki Loomis

This Journal, vol. xxix, 298–318, 1910.

This species, known by several complete skeletons, has so far been found only at one point, in a quarry near Agate, Neb., in the Lower Harrison beds. It is characterized by the small size, narrow molars, lower canine completely incisiform, lower jaw deep, metacarpals separated the entire length.

Stenomylus gracilis Peterson

Ann. Carnegie Museum, vol. iv, p. 41, 1906, and p. 286, 1906.

A larger species, rather rare, with narrow upper molars, lower canine less incisiform, lower jaw slenderer, and metacarpals coössified a part of their length. Occurs in the Lower Harrison beds.

Stenomylus crassipes Loomis

This Journal, vol. xxix, p. 319, 1910.

About the size of the preceding, but with lower canine completely incisiform, and the limbs much shorter and the skeleton throughout much heavier. This form occurs in the uppermost beds of the Lower Harrison.

WILLIAM HENRY BREWER.

Professor William Henry Brewer was born September 14, 1828, at Poughkeepsie, N. Y., and while he was still an infant his family moved to Enfield, about six miles from Ithaca. Here Brewer's childhood and youth were spent on his father's prosperous farm, where the boy took his part in all kinds of farm work, from the clearing of the forest to the marketing of special crops. He went to the village school and later to a private academy in Ithaca, intending after his "schooling" was done to follow his father's business.

Early in life he had a strong taste for natural science, particularly botany and chemistry. The published letters of Prof. J. P. Norton, who was studying with Johnstone, the Scotch agricultural chemist, and of Prof. Horsford, a student of Liebig's, fixed his attention on the application of chemistry to agriculture, and the reading of Liebig's letters on the subject determined his career. It was the spark that fired him, that "educated him away from the farm," and though he left it for a year to prepare himself to be a better farmer, with no thought but to live and die there, he was drawn to the ends of the earth,—as a botanist, a chemist, a sanitarian and an explorer, the servant of all men and friend of all the world.

In 1848 he came to New Haven, to learn from Prof. J. P. Norton, of Yale College, how to analyze the soils of that hilltop farm near Cayuga Lake and by it to learn how to make them more productive. On the same day that Brewer reached New Haven there also came George J. Brush, and then began between these two an acquaintance which ripened into a companionship for many years in the work of the Sheffield Scientific School, and into a friendship which was lifelong.

Just when young Brewer definitely decided to leave the farm for the work of study and teaching is uncertain. After study in Yale College and two years of teaching natural science in the state of New York, he came again to New Haven, passed his examinations and received his degree with the class of 1852, the first to be graduated by the Sheffield Scientific School.

After some further time spent in teaching, he went abroad and studied in Paris, Heidelberg and Munich.

In 1858 he became professor of natural science in Washington College, Pa. From 1860 to 1864 he was first assistant on the California State Survey and in the last of these years was a professor of natural science in the University of California. In 1864 he was appointed professor of agriculture in the Sheffield Scientific School of Yale and served in this position until 1903, when he became professor emeritus.

A catalogue of Professor Brewer's publications and a summary of the strictly scientific work which he did is left for some fuller biographic notice than can be given here. We choose rather to notice some of the public services which Professor Brewer rendered freely and often at personal sacrifice,—services which needed a man scrupulously honest, with scientific training, a careful observer, with strong common sense and willingness to give time and strength freely to the public service. Such a man was Brewer. He was of the noble race of scientific men who were the forerunners of specialists in science,—men with a clear knowledge of the scientific method, inspired with the scientific spirit and not being called to the profound study of some narrow specialty, yet were the apostles of science and justified it by showing its help in practical matters. No one connected with Yale University within the last forty years has been called so continuously and in so many ways for service outside the college world as Professor Brewer; and he has met these various calls with a mixture of scientific knowledge and common sense which has commended science to the laity and common sense to the specialist.

Thus for seventeen years he was a member of the local health board and for twelve years its president.

For thirty-one years he was on the State Board of Health, from the time it was organized until he resigned because of failing strength, and for sixteen years he presided over the Board.

This Board began its duties when the public had very little understanding of the value of public health work. Violent opposition developed through ignorance, as well as through evil intent. There was little help at that time to be got from the experience of other states. Brewer's knowledge of sanitary science, his vast fund of information on many related matters, his influence as a public speaker and his common sense were never more helpful than in guiding the growth of a state health board from a distrusted experiment into an indispensable public service.

He was chairman of the Commission which managed the topographical survey of Connecticut, from 1889 to its completion in 1895. His experience as a geographer in the survey of California fitted him for this work and the popular knowledge of his character and ability left no room for the criticism of those who, with more or less reason, always suspect that a public commission will be made a private graft.

He was a member of the United States Forestry Commission in 1896, which visited and reported upon forest conditions in the west.

At the age of 66 he joined an exploring expedition on the steamer Miranda, which went up the coast of Greenland and was wrecked near the Arctic Circle. After much danger and great exposure and discomfort, the party was rescued by a small schooner "built to accommodate 18, that could carry 22, but came back with 90 people on board," who were forced to sail the North Atlantic in her for fifteen days.

Interested in the problems of animal breeding, he made special researches in the evolution of the horse, particularly in the matter of speed, gathering and discussing the very voluminous data which had never been thus treated. His prediction from this discussion, of the time of the coming of the two-minute racing horse, was verified.

He was fond of travel, not for rest, but for the recreation which he found in careful observation and record of facts in all departments of human interest. To observe and gather was his delight all the days of his life. Even the signs of waning strength and the coming of old age interested him as a new class of facts to be studied and noted. Afraid of nothing, he observed in himself these things in the detached way that a physician might watch a hospital patient. It is the one regret of those who knew him that to arrange, discuss and publish his work was hard and almost impossible for him.

"Educated away from the farm" in his youth, his sympathy with farm interests was always active. He was a professor of agriculture, not only in the Sheffield School, but throughout the state. His addresses at farm meetings, through many years, which were published in the reports of the State Board of Agriculture, did much to make its early reports sought after everywhere as an encyclopædia of farming. All the various work of the farm was familiar to him. On practical matters he spoke to practical men as one having authority, in homely language and with that kind of humor which is indigenous to country life.

He labored, with his associate and friend, Prof. S. W. Johnson, for the establishment of an agricultural experiment station in Connecticut, and saw it established, the first one to be organized in the United States. He was a member of its Board of Control from 1877 until he died, and his last public appearance was at a meeting of this Board a few days before his death.

He was a member of the Connecticut Academy of Sciences, the American Public Health Association and the National Academy of Sciences.

From Washington and Jefferson College he received the degree of Ph.D., in 1880; the degree of LL.D. from Yale, in 1903, and the same degree from the University of California, at its fiftieth anniversary, in 1910.

He was married twice and leaves a daughter and three sons. After a brief illness he died at his home in New Haven, Nov. 2, 1910.

By the public he will be remembered for his public service. To those who knew him well a memory better and more useful than that of the things which he did will be the recollection of his genial companionship, his broad, unselfish nature, and his clean, helpful life.

EDWARD H. JENKINS.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The Preparation of Metallic Radium.*—The successful preparation by Mme. Curie of a small quantity of this metal was noticed in the last number of this Journal, but, nevertheless, the preparation of barium-radium metal by a different method appears to be worthy of mention. E. Ebler considered the preparation of the metal an important matter, as he conceived the possibility that radium might not be an element at all, but a comparatively stable radical, possibly a radical containing helium, and that the salts of this radical resemble barium salts in the same way that ammonium salts resemble those of potassium. It was his view also that the preparation of radium amalgam, which had been effected by Coehn, did not contradict this radical theory on account of the well-known formation of ammonium amalgam. Ebler's method of preparing the metal was by slowly heating the mixed barium and radium azides, $Ba(N_3)_2$ and $Ra(N_3)_2$, since it had been shown by Curtius and Rissom that the metals calcium, strontium and barium may thus be produced from their azides. The method appears to be preferable to that used by Mme. Curie, as the azide is stable and, as Ebler has shown, it does not appear to be decomposed by the radium radioactivity. Ebler found that the mixture of metals produced in this way gave the same γ radiation as the original salt, and he concludes that metallic radium is capable of existence, and is analogous to metallic barium.—*Berichte*, xliii, 2613. H. L. W.

2. *The Reduction of Oxide of Iron by Solid Carbon.*—Charpy and Bonnerot have studied the interesting question concerning the action of the solids under consideration in the absence of gases. They employed carefully purified ferric oxide and graphide which had been heated separately to 1000°. The materials were then finely pulverized and mixed in an agate mortar, and the mixture was agglomerated at a pressure of several thousand atmospheres. Since it appeared to be impossible to heat the mixture in the absence of every trace of gas, even by the use of a mercury pump, the matter was studied by observing the rapidity of the reaction, measured by the amount of gas given off, at varying, very low pressures. As an example, a series of experiments carried on at 950° C. gave the following results :

Pressure in millimeters of mercury	Volume of gas given off per hour, ccm.
0·01	0·10
0·1	0·14
1·	0·31
2·	0·56
4·	0·80
8·	1·07

From these results the conclusion is reached, since the rapidity of the reaction diminishes rapidly with the pressure of the gas in the apparatus, that solid carbon does not reduce oxide of iron, at least at 950° C., although it has been previously supposed that this reduction commences at 450°.—*Comptes Rendus*, cli, 644.

H. L. W.

3. *Action of Light upon an Electric Cell.*—H. Pélabon has observed that if two rods, one of pure antimony and the other of an alloy of antimony and selenium, are plunged into a hydrochloric acid solution of antimony trichloride, a cell is obtained in which the pure antimony acts as the negative pole. This cell has curious properties. If it is kept in darkness its electromotive force, in open circuit, attains a constant value in a few days, provided that the temperature remains constant. Upon suddenly illuminating the positive pole, the electromotive force, originally E_0, increases at once to a much higher value, E_1, and then, the illumination being maintained, it diminishes, and in the course of about 20 minutes reaches the original value E_0, which remains constant under these conditions. Then when the illumination is cut off the electromotive force diminishes to a value E_2, when it increases slowly and in about an hour reaches the original value E_0, which is maintained continuously in darkness. The same phenomenon is observed, whatever may be the proportion of selenium in the positive electrode, but alloys low in selenium appear to be the most sensitive. Tellurium and sulphur when alloyed with antimony do not give this behavior. The nature of the metal influences enormously the delicacy of this phenomenon. Almost all the metals with their selenides give cells which are sensitive to light.—*Comptes Rendus*, cli, 641. H. L. W.

4. *Sterilization of Large Quantities of Water by Ultra-violet Rays.*—Helbronner and Recklinghausen have devised an apparatus for the treatment of water on a large scale with the rays of the quartz-mercury-vapor lamp. The lamp is placed in a box, three sides of which are composed of quartz plates, and the current of water in the apparatus flows against each of these plates in succession. In this way more than three-quarters of the rays emitted by the lamp are utilized. It was found that the transparency of the treated water is of the greatest importance and that it is desirable to filter the water to clarify it before the treatment. The authors have installed a practical apparatus treating about 160,000 gallons per day, which gave most satisfactory results for a period of six weeks. Before passing through the apparatus the water contained from 30 to 300 germs per cubic centimeter, including 50 to 1000 of *bacillus coli* per liter. After the treatment the water contained an average of one germ per cubic centimeter, and not a single *bacillus coli*. The lamp employed was of the Westinghouse-Cooper-Hewitt type of 220 volts and 3 amperes, so that the electricity employed amounted only to about 100 watts-hour per 1000 gallons.—*Comptes Rendus*, cli, 677. H. L. W.

5. *Refrigeration by Mixtures of Liquids.*—The mixture of two liquids is often accompanied by a lowering of temperature. For instance, with carbon bisulphide and methyl formate the variation of temperature is 16° C. For practical refrigeration such mixtures have never been used on account of their cost and low effect in comparison with the solution of a salt, such as ammonium nitrate, in water. J. Duclaux has devised an ingenious application of the two liquids method for the production of very low and nearly constant temperatures. He allows the liquids to flow through two long tubes, and after mixing they flow back around the exterior of the tubes. In this way the cooling effect is accumulated. The tubes used were very small, about 1^{mm} in diameter, delivering one or two drops of liquid per second. The most satisfactory liquids employed, on account of economy and ease of recovery, are carbon bisulphide and acetone. which produce quickly a temperature of −48° C. by this method, When the apparatus is protected by a double-walled, silvered tube it is easy to produce a practically constant low temperature for a long time. It is a simple matter to recover the liquids nearly pure by shaking the mixture three times with half its volume of water and distilling the products.—*Comptes Rendus*, cli, 715.

H. L. W.

6. *The Relations between Chemical Constitution and Some Physical Properties;* by Samuel Smiles, D.Sc. 12mo, pp. 583. London, 1910 (Longmans, Green & Co.).—This is one of the text books of physical chemistry edited by Sir William Ramsay. As the title indicates, the aim has been to show the relations that exist between certain physical properties and the chemical constitution of compounds, particularly of organic compounds. The various properties are dealt with under the general headings of mechanical, thermal, optical and electrical properties and these are further subdivided. Under mechanical properties, for instance, are included capillarity, viscosity and volume relations. There is a short historical introduction to each property, followed by the common methods of determination and ending with a discussion of the results obtained. References to the literature appear to be excellent and the book will be found useful as a work of reference. H. W. F.

7. *Positive Rays.*—W. Wien contributes a very full paper on this subject accompanied by many diagrams. His previous investigations had shown that the manifestations of canal rays are dependent not only upon conditions of immediate excitation but also upon length of path pursued and upon the conditions of voltage and other circumstances in the escape of the positive ions from one receptacle to another. The author does not agree with Sir J. J. Thomson in regard to the non-dependence of the deviation of the rays under magnetic and electric fields, upon voltage, nor with the latter's assumption that the velocity of the rays depends on the atomic energy or upon cathode rays instead of upon the voltage.—*Ann. der Physik*, No. 15, 1910, pp. 871–927.

J. T.

8. *Deflections by Electrostatic and Magnetic Fields of Radium B after Recoil from Radium A.*—These deflections have been measured—the electrostatics, by Sidney Russ and Walter Makower; the magnetic by W. Makower and E. F. Evans, and estimations of the value of $\frac{e}{m}$ and the atomic weight of radium were made. The value of 194 was obtained for the latter, which the authors regard as good agreement with the theoretical value 214.—*Phil. Mag.*, No. 15, 1910, pp. 875–886. J. T.

9. *Energy Distribution of Diffraction Gratings.*—Professors Augustus Trowbridge and R. W. Wood continue their investigations on the energy of distribution from definite forms of grooves—wedge shaped—in gratings with few rulings which are called echelettes. They show that these gratings give the highest resolving power that has yet been brought to bear upon the infra-red.—*Phil. Mag.*, Nov. 1910, pp. 886–901. J. T.

10. *Modification in Magnetic Fields of Lines of the Light emitted by the Electric Spark.*—G. A. Hemsalech finds that magnetic fields modify the intensity of light. On the sun such fields may produce a diminution of light, showing thus an apparent absorption of light coming from the photosphere and a reinforcement of certain lines in the solar spots.—*Comptes Rendus*, Nov. 21, 1910, pp. 938–941. J. T.

11. *Electric Motors;* by Henry M. Hobart. Pp. xxiv, 748, with 798 illustrations. New York, 1910 (The Macmillan Co.).—This is the second edition, entirely rewritten and enlarged, of a volume which first appeared in 1904. It treats the theory and construction of continuous, polyphase and single phase motors; the section on the latter accounting in large part for the increased size of the present edition. A useful table of the properties of copper wire for standard wire gauge is given in the Appendix.

D. A. K.

II. Geology and Natural History.

1. *Grundzüge der Paläontologie;* by Karl A. von Zittel, 1. Abteilung, third edition, revised by F. Broili, 1414 text figs., 607 pages with an index. Munich, 1910 (Oldenbourg).—This well known German text-book, the classic of Invertebrate Paleontology by a great past master, is here revised by one of his students. The reviser has added about 70 new figures and on many of the old ones letters have been affixed permitting of more direct descriptions of the structural parts. There are about 90 pages of new matter over the first edition, and about 50 pages more than in the second edition.

The revision and additions are chiefly important in matter of detail and the classification adopted is practically that of the former editions. Even Treptostomata Bryozoa or the monticuliporids still remain here as in former editions with the Tabulate corals. Beecher's classification of the Brachiopoda and Trilobita, while mentioned, are not accepted. This conservatism is also seen in the geological column and particularly in the Paleozoic, where Silurian system is retained for the Ordovician and Silurian, and the Carbon system embraces our Pennsylvanian and Mississippian systems. The book is nevertheless the best so far in the German language and should be used by teachers of paleontology in connection with the Zittel-Eastman English translation of the first edition, entitled Text-Book of Paleontology. C. S.

2. *Notes on Ordovician Trilobites*, parts II, III and IV; by PERCY E. RAYMOND. Annals Carnegie Mus., vol. VII, No. 1, 1910; 35–80, pls. XIV–XIX.—The author, now a member of the Geological Survey of Canada, revises the trilobites of the New York–Vermont Chazy, and the Asaphidæ of the Beekmantown, Lowville and Black River formations bordering the Adirondacks. A number of new species are described along with the following new genera or subgenera,—*Isoteloides, Hemigyraspis*, and *Vogdesia.*

The following European genera are for the first time recognized in this country,—*Asaphellus, Basilicus*, and *Onchometopus.*

Two new subfamilies of Asaphidæ are erected,—(1) *Ogyginæ* for Ogygia, Niobe, Asaphellus, Symphysurus, Nileus, Vogdesia, Illænurus, Megalaspis, and Megalaspides; and (2) *Asaphinæ* for Basilicus, Ptychopyge, Pseudasaphus, Asaphus, Onchometopus, Isotelus, and Isoteloides. The author is well acquainted with the European literature and is making decided efforts to get entire specimens so that even fragments may be of value in stratigraphy. C. S.

3. *A Preliminary List of the Fauna of the Allegheny and Conemaugh Series in Western Pennsylvania;* by PERCY E. RAYMOND. Annals Carnegie Mus., Vol. VII, No. 1, 1910: 144–158, pls. XXIV–XXVIII.—For several years the author has been gathering the marine fossils in the Pennsylvanian of central western Pennsylvania, resulting in 97 species here listed according to the various zones from which they were taken. Of these 28 are restricted to the Allegheny series and 52 to the Conemaugh. Three new species are described and a new chiton genus *Glaphurochiton.* C. S.

4. *The British Carboniferous Orthotetinae;* by IVOR THOMAS. Mem. Geol. Surv. Great Britain, Pal. I, 1910; 83–134, pl. 13.—A very important revision of the various brachiopod genera of this subfamily and of the British Carboniferous species. The author recognizes two groups of genera, (1) having a ventral septum in the muscular area as in Orthotetes, Derbyia (has not the same generic characters as Ortholetes as heretofore supposed), and Geyerella; and (2) without such a septum as in Schuchertella, Streptorhynchus, and Meekella (Places here both plicate and non-plicate species). As the genus is based on plicate forms having a very different general aspect from the two new English

non-plicate species, these had best be restored to Orthothetina, a name here abandoned), and *Schellwienella* (new, genotype *Spirifera crenistria* Phillips, heretofore thought to have the internal characters of Orthotetes). Six new species are described.

C. S.

5. *Geological Excursion in the Grand Canyon District;* by D W. Johnson. Proc. Bost. Soc. Nat. Hist., vol. xxxiv, p. 135–161, 1909.—This presents a study of faulting in a part of the Grand Canyon district and is of considerable interest in showing for how long a period movements have continued in the region. Thus the author finds that three periods of faulting are shown in the area of the San Francisco Plateau, along the same plane; the first and second periods separated by a long era of base-levelling, while the second and third were divided by a shorter, but yet distinct, interval of erosion. In the main the faults of the region are of ancient date. The paper is illustrated by a number of excellent half-tone cuts of photographs. L. V. P.

6. *Aufbau des Gebirges in der Umgebung der Strassburger Hütte an der Scesaplana;* von W. von Seidlitz. Festschr. 25-jahr. Best. d. Sekt. Strass. i. E. d. deut. u. österreich. Alpenver. Pp. 45–68, 1910, Strassburg.—This is a small geological guide, well planned and excellently carried out. It describes the geology surrounding an elevated point in the Raetikon Alps, on the border between the Tyrol and Switzerland. It is an excellent lesson in tectonics, folding, faulting, and thrusting being visible on a gigantic scale. A large panorama, well drawn and geologically colored, is a prominent feature of the work, which is also illustrated by a number of sections and photogravure plates of the scenery. L. V. P.

7. *Granites of the Southeastern Atlantic States;* by T. L. Watson. Bull. 246 U. S. Geol. Surv., pp. 282, 1910.—The author has given in this work a general description of the granite areas in the region mentioned, extending from Maine to Georgia, and including Tennessee and Alabama. The petrographic, physical, and chemical properties of the varied occurrences are stated, and especial emphasis is laid upon their technical exploitation and use. The work is illustrated with many maps, diagrams, and photographs, the latter chiefly of granite quarries. While its value is mostly on the economic side, and it should prove of great service in the granite quarrying industry, it has none the less scientific interest and is a useful work of reference for geologists and petrographers. L. V. P.

8. *The Volcanic Rocks of Victoria;* by E. W. Skeats. Address by the Pres. Sec. C, Aust. Assoc. Adv. Sci., 1909.—This paper contains a general account (and a full bibliography) of the igneous rocks in this part of Australia; it will undoubtedly prove of considerable local service, and to the general reader it emphasizes once more what a wide distribution the alkalic rocks have in Australia. The brief descriptions are materially aided by the considerable number of analyses which are quoted. The article is accompanied by several sections and a map. L. V. P.

9. *Analcite Rocks.*—In a recent paper Mr. G. W. Tyrrell of Glasgow University has shown that among the numerous intrusions of igneous rocks that penetrate the Paleozoic strata of the west and south of Scotland there are numerous types of alkalic nature, which are of interest to petrologists. Thus he describes teschenites of several types, essexites, trachytes, etc., along with other varieties. Among these in the south of Scotland are rocks containing much analcite which, for several reasons, he considers as a primary constituent. In a letter to the reviewer he says, in addition, that "the group contains rocks of the analcite series corresponding to the nepheline series,—from nephelite-syenite to ijolite. The analcite syenite is a remarkably fresh rock composed principally of soda-orthoclase, albite, and analcite, with purple titanaugite, barkevikite, and aegirine. The latter is inclosed in the analcite, which is very abundant. Another remarkable rock is one composed principally of analcite, with a little nepheline, crowded with perfect euhedral barkevikite, sometimes with a little titanaugite and plagioclase." These appear to be remarkable and novel rock types, and Mr. Tyrrell's forthcoming paper upon them, in which full details are promised, will be awaited with much interest by petrologists.—*Trans. Geol. Soc. Glasgow*, vol. xiii, Pt. III, p. 299, 1909. L. V. P.

10. *Morganite, a Rose-colored Beryl.*—In a paper read before the New York Academy of Science on December 5th, 1910, Dr. George Kunz described some new and remarkable gems which had been cut from a rose-colored beryl found in Madagascar. He proposed the name morganite for them in honor of Mr. John Pierpont Morgan of New York City.

The beryl, together with other gem minerals, is found at Maharita in the valley of Sahatony, an affluent of the Manandora which passes along the western slope of Mount Bity, Madagascar. The minerals occur in numerous veins of pegmatite which penetrate the alternating layers of limestone, mica schist, and quartzite. The veins often attain a thickness of nearly one hundred feet and consist of quartz, amazonite often in fine colors, albite, lithia, tourmaline, lepidolite in deep shades, etc. In these veins magnificent crystals of tourmaline, beryl, and kunzite have been found.

The pink beryl, morganite, has also been found associated with kunzite at Pala, San Diego Co., California, in large but pale crystals and sometimes more of a salmon color. At the Madagascar locality, however, it is found in magnificent specimens of gem quality, some which weighed 98½ carats. Its color is a true rose-pink, a pure, clear color with less of the magenta tint than is found in even a pale tourmaline and lacking the lilac of the kunzite. It is obtained in larger, finer stones than any other pink gem mineral we have ever had.

When exposed to the Röntgen rays the new beryl assumed a brilliant cerise color under a tube of moderately low vacuum with about twelve or fifteen amperes through the tube. When the current was increased the brilliancy of the stones increased accordingly. Under the mercury light it became a pale lilac.

This beryl has been found by Ford* to contain 4·98 per cent of alkalies, distributed as follows: Na_2O, 1·60; Li_2O, 1·68; Cs_2O, 1·70. Along with this unusual amount of alkalies goes a slightly higher specific gravity (2·79) and an increase in the mean refractive index and the amount of birefringence. W. E. F.

11. *Tables for the Determination of Minerals by Physical Properties*, ascertainable with the aid of a few Field Instruments, based on the system of the late Prof. Dr. A. WEISBACH; by PERSIFOR FRAZER and AMOS PEASLEE BROWN. Sixth edition. Pp. xiii, 125. Philadelphia, 1910 (J. B. Lippincott Co.).—This is a new edition of a well-known work, which has filled a highly useful place, both in Germany and as translated into English.

12. *The Subantarctic Islands of New Zealand:* Reports on the Geo-physics, Geology, Zoology, and Botany of the Islands lying to the South of New Zealand, based mainly on Observations and Collections made during an Expedition in the Government Steamer "Hinemoa" (Captain J. Bollons) in November, 1907. Edited by CHAS. CHILTON. Published by the Philosophical Institute of Canterbury. Two volumes: Vol. I, pp. xxxv, 388, with 20 plates and many figures. Vol. II, pp. 389–848, with numerous illustrations (John Mackay, Wellington, N. Z., 1909).—This work consists of thirty-five separate articles, written by specialists in various parts of the world, and based on the collections obtained by the members of the scientific staff which accompanied the magnetic survey expedition to Auckland and Campbell Islands. Three of the papers relate to geo-physics, 3 to geology, 22 to the various groups of animals, 6 to plants; while the concluding article, by the editor, presents a summary of the results and discusses the biological relations of the islands. Many new species of invertebrates were discovered, and are here described and figured. The only mammals found about the islands are seals and cetaceans. There are no reptiles of any kind. Seabirds, of which the species of albatross and penguin are most conspicuous, are abundant. Of these there are several excellent reproductions of photographs showing the nesting habits. There are a few kinds of land birds, in addition to several species of British birds, including the English sparrow, goldfinch, starling, thrush and blackbird which have reached the islands from New Zealand. A comparison of the animals and plants found on these islands offers strong evidence of a former connection with the Antarctic continent. W. R. C.

13. *British Nudibranchiate Mollusca, with Figures of the Species; Part viii, Supplementary.* Figures by the late JOSHUA ALDER and the late ALBANY HANCOCK and Others, text by SIR CHARLES ELIOT. Quarto, 197 pp., with 8 colored plates. London, 1910 (Ray Society).—This supplementary volume to Alder and Hancock's classic monograph, published in 1845–1855,

* This Journal, xxx, 128, 1910.

consists in part of the drawings and notes which they had made some years ago with a view to issuing a supplementary volume to include such rare, inconspicuous, or little known species as had been found on the British coast during the many years that had elapsed since the publication of their monograph. After their death Sir Charles Eliot undertook the preparation of the volume, and the great value of the work is largely due to the lucid discussion of the general anatomical features and relationships of this group of animals from his pen. The chapters on variation and distribution, bionomics, embryology and larval stages, and classification, are treated on such broad biological lines as to be of general interest, while the concluding chapter contains a synopsis of the families, genera and species which occur in the Northeastern Atlantic region, and brings up to date the nomenclature of the forms which have been recorded during the more than half century since the publication of the first seven parts of the work. Of the 68 figures, 45 are reproduced from the drawings of Alder and Hancock, while the remaining 23 have been drawn, mainly from living animals, especially for the present volume. W. R. C.

14. *Medusae of the World;* by Alfred Goldsborough Mayer. 3 volumes, quarto. Washington, 1910. (Published by the Carnegie Institution.)—Volume I, pp. 230 + xv, with 29 colored plates and 119 text figures, and Volume II, pp. 231 to 498 + xv, with 26 plates and 208 text figures, contain descriptions of all the known Hydromedusae of the world and of such hydroids as are known to produce medusae. Volume III, on the Scyphomedusae, contains pp. 499-735, with 21 plates and 101 text figures. This splendid monograph is by no means a systematic treatise only, for it includes a discussion of all known facts regarding the embryology, cytology and physiology of each species. The large number of beautifully executed drawings on the colored plates illustrate alike the artistic ability and tireless energy of the author. W. R. C.

15. *An Introduction to Zoology;* by Robert W. Hegner. Pp. xii, 350, with 161 figures. New York, 1910 (Macmillan Company).—This book represents a wide departure from the customary plan of an elementary book in zoology in that its aim is to illustrate the important biological principles by a comparatively thorough study of a very few types rather than by a superficial study of a representative of each of the principal phyla. A general discussion of the principles of biology, the phenomena of life, the cell, and cell theory is followed by a comprehensive study of the structure and life processes of Amœba and Paramœcium, with reference to certain other protozoa. The hydra, worms, crayfish, and the honeybee represent the metazoa and are treated with a special reference to the physiological peculiarities of their various organ systems. An interesting chapter on the history of zoology, with portraits of several of the earlier investigators, and a final chapter on the more important zoological theories and the facts on which they are based, emphasize the

bearing of zoology on human thought and progress. The book is cordially recommended as giving a thorough preparation for advanced courses in the subject. W. R. C.

16. *Animal Study: with Directions for Laboratory and Field Work;* by W. H. D. MEIER. Boston and New York, 1910 (Ginn & Co.).—A loose-leaf laboratory note book of convenient size, and well arranged for the use of elementary classes in Zoology. The type system, for both invertebrates and vertebrates, is employed. The directions for work and questions to be answered are printed on the top of each sheet, with blank space for drawings beneath. Additional sheets of drawing and note paper are provided to be inserted in place as required. The directions for work are at once clear and suggestive and the questions stimulative of interest outside the classroom.

W. R. C.

17. *Methods of Attracting Birds;* by GILBERT H. TRAFTON. With illustrations; pp. xv, 171. Boston and New York, 1910 (Houghton Mifflin Company).—The desirability of encouraging the feeding and nesting of birds around the home, garden, or orchard is here discussed, and such methods of accomplishing this end as have been found practicable either in this or other countries are described and illustrated. Suggestions are made for the protection of our native birds from the rigors of winter, from cats and other enemies, and especially from their arch enemy, the English sparrow. W. R. C.

18. *Second Report on the Hymeniales of Connecticut;* by EDWARD ALBERT WHITE. Pp. 70, with 28 plates. State of Connecticut, Geological and Natural History Survey. Bulletin No. 15, Hartford, Conn., 1910.—This is properly a supplement to Bulletin No. 3 of the Survey, containing a preliminary report, by the same author, on the fleshy and woody fungi of the State. Some of these are edible mushrooms, while others are extremely poisonous. The first part of the present Bulletin gives analytical keys for the identification of Connecticut species of *Agaricaceæ.* This is accompanied by a series of excellent half-tone plates from original photographs by the author. The second part describes the edible species of the group, while the third gives a list of the species reported since July, 1905, and hence not included in Bulletin No. 3.

Copies of this Bulletin may be obtained from the State Librarian, Geo. S. Godard; the price, including postage, is 35 cents, but it will be sent gratuitously to scientific men, teachers, and others, particularly citizens of the State, who require it for their special use.

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[FOURTH SERIES.]

Art. X.—*On an Adjustment for the Plane Grating Similar to Rowland's Method for the Concave Grating*;* by Carl Barus and Maxwell Barus.

1. *Apparatus.*—The remarkable refinement which has been attained (notably by Mr. Ives and others) in the construction of celluloid replicas of the plane grating, makes it desirable to construct a simple apparatus whereby the spectrum may be shown and the measurement of wave-length made, in a way that does justice to the astonishing performance of the grating. We have, therefore, thought it not superfluous to devise the following inexpensive contrivance, in which the wave-length is strictly proportional to the shift of the carriage at the eye-piece; which, for the case of a good 2-meter scale divided into centimeters, admits of a measurement of wave-length to a few Ångström units and with a millimeter scale should go much further.

Observations are throughout made on both sides of the incident rays and from the mean result most of the usual errors should be eliminated by symmetry. It is also shown that the symmetrical method may be adapted to the concave grating.

In fig. 1, A and B are two double slides, like a lathe bed, 155^{cm} long and 11^{cm} apart, which happened to be available for optical purposes, in the laboratory. They were, therefore, used, although single slides at right angles to each other, similar to Rowland's, would have been preferable. The carriages C and D, 30^{cm} long, kept at a fixed distance apart by the rod aRb, are in practice a length of $\frac{1}{4}$-inch gas pipe,

* The greater part of this work was done by my son and myself and contributed to the Proceedings of the American Philosophical Society, April 24, 1909, from which the present paper is abridged. I have since added some other matter at the end.—C. B.

swivelled at a and b, 169·4 centimeters apart, and capable of sliding right and left and to and fro, normally to each other.

The swivelling joint, which functioned excellently, is made very simply of $\frac{1}{4}$-inch gas pipe T's and nipples, as shown in

FIG. 1.

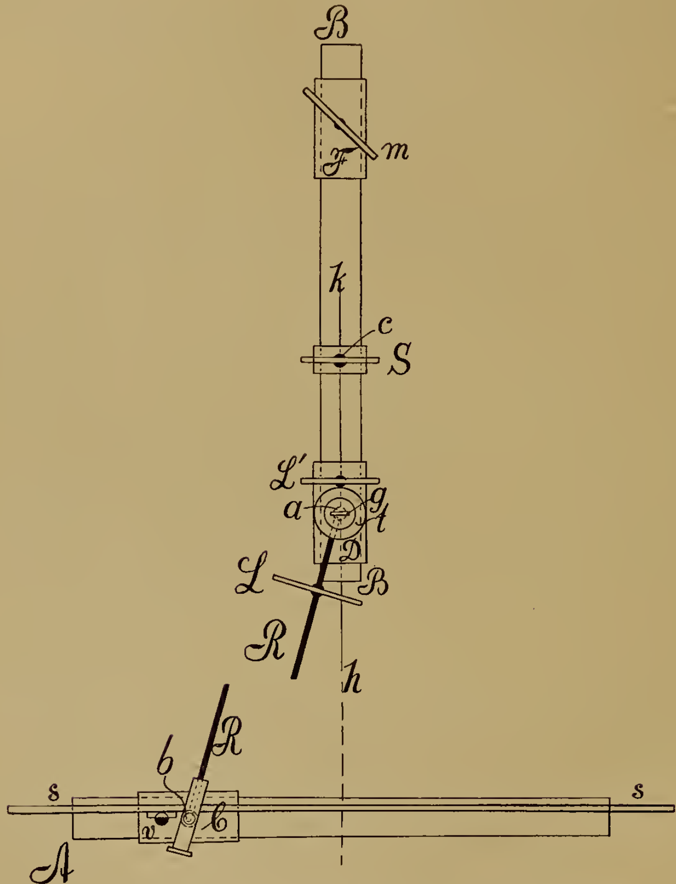


FIG. 1. Plan of apparatus. *AA*, *BB*, slides; *CD*, carriages; *R*, connecting rod.

fig. 2. The lower nipple N is screwed tight into the T, but all but tight into the carriage D, so that the rod ab turns in the screw N, kept oiled. Similarly the nipple N'' is either screwed tight into the T (in one method, revoluble grating),

or all but tight (in another method, stationary grating), so that the table *tt*, which carries the grating *g*, may be fixed while the nipple *N''* swivels in the T. Any ordinary laboratory clamp *K* and a similar one on the upright *c* (screwed into the carriage *S*) secures a small rod *k* for this purpose. Again, a hole may be drilled through the standards at *K* and *c* and provided with set screws to fix a horizontal rod *k* or check. The rod *k* should be long enough to similarly fix the standard on the slide *S* carrying the slit and be prolonged further toward the rear to carry the flame or Geissler tube apparatus.

Fig. 2.

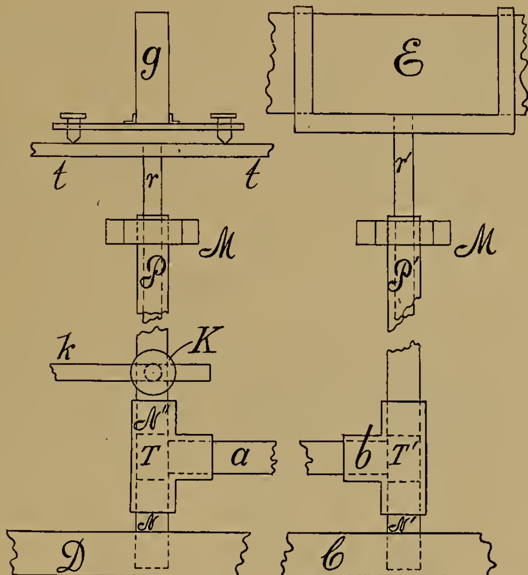


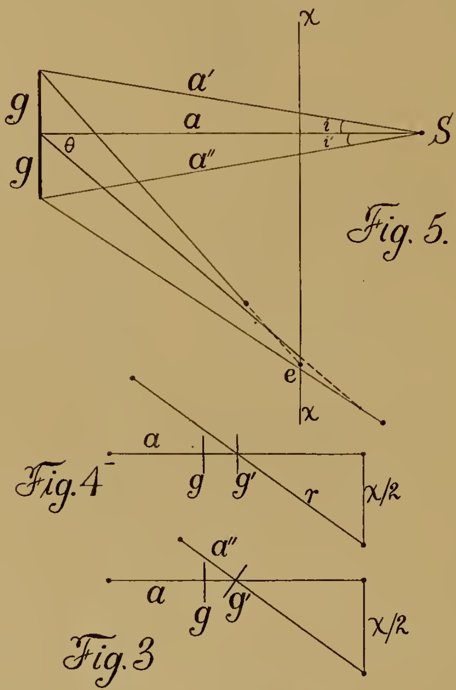
Fig. 2. Elevation of the grating (*g*) and the eye-piece (*E*) standards.

The table *tt* is revoluble on a brass rod fitting within the gas pipe, which has been slotted across so that the conical nut *M* may hold it firmly. The axis passes through the middle of the grating, which is fastened centrally to the table *tt* with the usual tripod adjustment.

2. *Single Focusing Lens in Front of Grating.*—I shall describe three methods in succession, beginning with the first. Here a large lens, *L*, of about 56^{cm} focal distance and about 10^{cm} in diameter, is placed just in front of the grating, properly screened and throwing an image of the slit *S* upon the cross-hairs of the eye-piece *E*, the line of sight of which is always parallel to the rod *ab*, the end *b* swivelled in the carriage *C*, as stated (see fig. 2). An ordinary lens of 5 to 10^{cm}

focal distance, with an appropriate diaphragm, is adequate and in many ways preferable to stronger eye-pieces. The slit *S*, carried on its own slide and capable of being clamped to *c* when necessary, as stated, is additionally provided with a long rod *hh* lying underneath the carriage, so that the slit *S* may be put accurately in focus by the observer at *C*. *F* is a carriage for the mirror or the flame or other source of light whose

FIGS. 3, 4, 5.



FIGS. 3, 4, 5. Diagrams.

spectrum is to be examined; or the source may be adjustable on the rear of the rod by which *D* and *S* are locked together.

Finally the slide *AB* is provided with a scale *ss* and the position of the carriage *C* read off by aid of the vernier *v*. A good wooden scale graduated in centimeters happened to be available, the vernier reading to within one millimeter. For more accurate work a brass scale in millimeters with an appropriate vernier should of course be used.

Eye-piece *E*, slit *S*, flame *F*, etc., may be raised and lowered by the split tube device shown as at *M* and *M′* in fig. 2.

3. *Adjustments.*—The first general test which places slit, grating and its spectra and the two positions of the eye-piece in one plane, is preferably made with a narrow beam of sunlight, though lamplight suffices in the dark. Thereafter let the slit be focused with the eye-piece on the right marking the position of the slit; next focus the slit for the eye-piece on the left; then place the slit midway between these positions and now focus by slowly rotating the grating. The slit will then be found in focus for both positions and the grating, which acts as a concave lens counteracting L, will be symmetrical with respect to both positions.

Let the grating be thus adjusted when fixed normally to the slide B or parallel to A. Then for the first order of the spectra the wave-length $\lambda = d \sin \theta$, where d is the grating space and θ the angle of diffraction. The angle of incidence i is zero.

Again let the grating, adjusted for symmetry, be free to rotate with the rod ab. Then θ is zero and $\lambda = d \sin i$.

In both cases however if $2x$ be the distance apart of the carriage C, measured on the scale ss, for the effective length of rod $ab = r$ between axis and axis,

$$\lambda = dx/r \text{ or } (d/2r)\, 2x,$$

so that in either case λ and x are proportional quantities.

The whole spectrum is not however clearly in focus at one time, though the focusing by aid of the rod hh is not difficult. For extreme positions a pulley adjustment operating on the ends of h is a convenience, the cords running around the slide AA. In fact if the slit is in focus when the eye-piece is at the center ($\theta = 0$, $i = 0$) at a distance a from the grating, then for the fixed grating, fig. 4,

$$a' = a\frac{r^2}{r^2 - x^2},$$

where a' is the distance between grating and slit for the diffraction corresponding to x. Hence the focal distance of the grating regarded as a concave lens is $f' = ar^2/x^2$. For the fixed grating and a given color, it frequently happens that the undeviated ray and the diffracted rays of the same color are simultaneously in focus, though this does not follow from the equation.

Again for the rotating grating, fig. 3, if a'' is the distance between slit and grating

$$a'' = a\frac{r^2 - x^2}{r^2},$$

so that its focal distance is

$$f = a\frac{r^2 - x^2}{x^2},$$

It follows also that $a' \times a'' = a^2$. For $a = 80^{cm}$ and sodium light, the adjustment showed roughly $f' = 650^{cm}$, $f'' = 570$, the behavior being that of weak concave lenses. The same $a = 80^{cm}$ and sodium light showed furthermore $a' = 91$ and $a'' = 70·3$.

Finally there is a correction needed for the lateral shift of rays, due to the fact that the grating film is enclosed between two moderately thick plates of glass (total thickness $t = ·99^{cm}$) of the index of refraction n. Moreover, since this shift is on the rear side of the lens L, its effect on the eye-piece beyond will be (if f is the principal focal distance and b the conjugate focal distance between lens and eye-piece, remembering that the shift must be resolved parallel to the scale ss)

$$e = \frac{tx}{r}\left(\frac{1}{\sqrt{1 - x^2/r^2}} - \frac{1}{\sqrt{n^2 - x^2/r^2}}\right)\left(\frac{b}{f} - 1\right),$$

where the correction e is to be added to $2x$, and is positive for the rotating grating and negative for the stationary grating.

Hence in the mean values of $2x$ for stationary and rotating grating the effect of e is eliminated. For a given lens at a fixed distance from the eye-piece $(b/f - 1)$ is constant.

4. *Data for Single Lens in Front of Grating.*—In conclusion we select a few results taken at random from the notes.

TABLE I.

Grating	Line	Observed $2x'$	Shift	Corrected $2x$.
Stationary	C	132·60	—·26	132·34
	D_2	118·90	—·23	118·67
	F	98·23	—·19	98·04
	Hydrogen Violet	87·87	—·16	87·71
Rotating	C	132·10	+·26	132·36
	D_2	118·45	·23	118·68
	F	97·90	·19	98·09
	H. Violet	87·50	·16	87·66

The real test is to be sought in the corresponding values of $2x$ for the stationary and rotating cases, and these are very satisfactory, remembering that a centimeter scale on wood and a vernier reading to millimeters only was used for measurement.

5. *Single Focusing Lens Behind the Grating.*—The lens L', which should be achromatic, is placed in the standard behind g. The light which passes through the grating is now convergent, whereas it was divergent in §2. Hence the focal points at distances a', a'' lie in front of the grating; but in

other respects the conditions are similar but reversed. Apart from signs, for the stationary grating

$$a' = a\frac{r^2-x^2}{r^2},$$

and for the rotating grating

$$a'' = a\frac{r^2}{r^2-x^2}.$$

The correction for shift loses the factor $(b/f-1)$ and becomes

$$e = \frac{tx}{r}\left(\frac{1}{\sqrt{1-x^2/r^2}} - \frac{1}{\sqrt{n^2-x^2/r^2}}\right).$$

As intimated, it is negative for the rotating grating and positive for the stationary grating. It is eliminated in the mean values.

6. *Data. Single Lens Behind the Grating.*—An example of the results will suffice. Different parts of the spectrum require focusing.

Grating	Line	$2x'$	Shift	$2x$
Stationary	D_2	118·40	+·13	118·53
Rotating	D_2	118·65	−·13	118·52

The values of $2x$, remembering that a centimeter scale was used, are again surprisingly good. The shift is computed by the above equation. It may be eliminated in the mean of the two methods. The lens L' may be more easily and firmly fixed than L.

7. *Collimator Method.*—The objection to the above single-lens methods is the fact that the whole spectrum is not in sharp focus at once. Their advantage is the simplicity of the means employed. If a lens at L' and at L are used together, the former as a collimator (achromatic) and with a focal distance of about 50^{cm}, and the latter (focal distance to be large, say 150^{cm}) as the objective of a telescope, all the above difficulties disappear and the magnification may be made even excessively large. The whole spectrum is brilliantly in focus at once and the corrections for the shift of lines due to the plates of the grating vanish. Both methods for stationary and rotating gratings give identical results. The adjustments are easy and certain, for with sunlight (or lamplight in the dark) the image of the slit may be reflected back from the plate of the grating on the plane of the slit itself, while at the same time the transmitted image may be equally sharply adjusted on the focal plane of the eye-piece. It is, therefore, merely necessary to place the plane of spectra horizontal. Clearly a' and a'' are all infinite.

In this method the slide S and D are clamped at the focal distance apart, so that flame, etc., slit, collimator lens and grating move together. The grating may or may not be revoluble with the lens L on the axis a.

8. *Data for the Collimator Method.*—The following data chosen at random may be discussed. The results were obtained at different times and under different conditions. The grating nominally contained about 15,050 lines per inch. The efficient rod length ab was $R = 169{\cdot}4^{cm}$. Hence if $1/C = 15{,}050 \times {\cdot}3937 \times 338{\cdot}8$, the wave-length $\lambda = C \cdot 2x^{cm}$.

Grating	Lines	$2x'$	$2x$
Stationary	D_2	118·30	118·19
Rotating	D_2	118·08	118·19
Stationary	D_2	118·27	118·16
Rotating	D_2	118·05	118·16

Rowland's value of D_2 is $58{\cdot}92 \times 10^{-6\,cm}$; the mean of the two values of $2x$ just stated will give $58{\cdot}87 \times 10^{-6\,cm}$. The difference may be due either to the assumed grating space, or to the value of R inserted, neither of which were reliable absolutely to much within ·1 per cent.

Curious enough an apparent shift effect remains in the values of $2x$ for stationary and rotating grating, as if the collimation were imperfect. The reason for this is not clear, though it must in any case be eliminated in the mean result. Possibly the friction involved in the simultaneous motion of three slides is not negligible and may leave the system under slight strain equivalent to a small lateral shift of the slit.

9. *Discussion.*—The chief discrepancy is the difference of values for $2x$ in the single lens system (for D_2, 118·7 and $118{\cdot}5^{cm}$, respectively) as compared with a double lens system (for D_2, $118{\cdot}2^{cm}$) amounting to ·2 to ·4 per cent. For any given method this difference is consistently maintained. It does not, therefore, seem to be mere chance. The detailed investigation, which must be omitted here,* made it clear that the effect of focusing is without influence on the diffraction angle and much within the limits of observation. It is, therefore, probable that the residual discrepancy in the three methods is referable to a lateral motion of the slit itself due to insufficient symmetry of the slides AA and BB in the above adjustment. This agrees, moreover, with the residual shift observed in the case of parallel rays in § 8.

10. *Reflecting Grating.*—The adjustment of the plane grating if cut on specular metal is nearly identical to the above, except that the collimator is fixed as a whole in front of the grating, either to the slide carrying the standard of the grating, B, or else quite in front of the cross slide AA, fig. 5 above,

* See Proc. Am. Phil. Soc., l. c.

so as to give clearance for the to and fro motion of the rail, R. This admits of measurement of x on both sides of the slit, so that $2x$, the distance apart of the two symmetrical positions for a given spectrum line, is again observed.

11. *Rowland's Concave Grating.*—For the case of the *concave* grating, the accurate adjustment for symmetrical measurement on *both* sides of the slit is not feasible, because the slit and eye-piece would have to pass through each other. It is possible, however, to find conjugate foci at different distances from the grating in the normal position, which approximately answer the purposes of measurement. Rowland's equation

$$(\cos i / \rho - 1 / R) \cos i + (\cos \theta / \rho' - 1 / \rho') \cos \theta = 0$$

where ρ and ρ' are the conjugate focal distances for angles of incidence and deviation i and θ, may for $\theta = 0$ be written

$$\frac{1}{\rho / \cos^2 i} - \frac{1}{R / \cos i} = \frac{1}{\rho_0} - \frac{1}{R}$$

where ρ_0 is the normal distance of the eyepiece, so that

$$\frac{1}{\rho_0} - \frac{1}{\rho_0'} = \frac{2}{R}.$$

If in figure 6, the slit S is put at $\rho' > R$ from the grating G (normal position), the image is at E at the end of ρ_0 from G, where $\rho_0 < R < \rho'$. If ρ_0 be used as a rail instead of R and put at an angle of incidence i, for the eye-piece at E' or E'', $\rho_0 \cos i > \rho$. But this excess need not be so large as to interfere with adequately sharp focusing.

The following table gives an example, in which the difference of ρ_0 and ρ_0' in the normal position is even over 1 foot, an excessive amount, as the distance necessary for clearance need not be more than a few inches. The grating has 14436 lines to the inch and a radius about $R = 191^{cm}$.

TABLE II.

Conjugate foci of the concave grating. $R = 191^{cm}$, 14436 lines to inch, 5683 lines to cm. $D = \cdot 000{,}176$.
$\rho_0 = 166^{cm}$. $\rho = 198^{cm}$. $\rho - \rho_0 = 32^{cm}$. $1/\rho_0 - 1/R = \cdot 000788$. $\theta = 0$, $\sin i = \lambda/D$.

$i°$	ρ cm.	$\rho_0 \cos i$	Diff. cm.	$(\rho/\cos i)^2$	Fraunhofer Lines	i
0°	166·0	166·0	·0	27500	*B*	22° 59′
5	165·3	165·3	·0	27500	*C*	21° 54′
10	163·2	163·5	− ·3	27400	*D*	19° 34′
{ 15	159·6	160·3	− ·7	27300	*E*	17° 26′
{ 20	154·7	156·0	−1·3	27100	*F*	16° 02′
25	148·5	150·4	−1·9	26800	*G*	14° 10′
30	140·9	143·7	−2·8	26500		
35	132·2	136·0	−3·8	26000		
40	122·3	127·1	−4·8	25500		

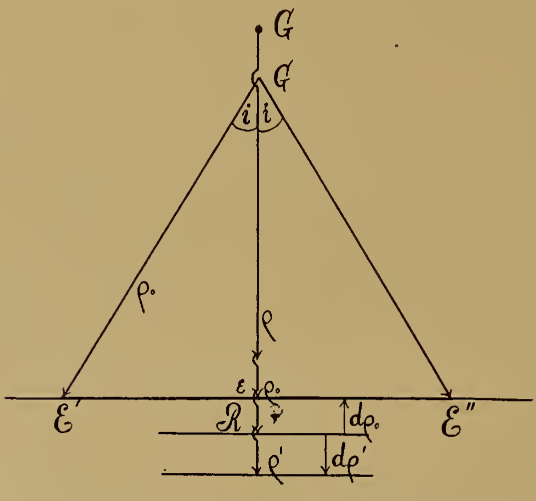
The greater part of the visible spectrum is thus contained between $i = 15°$ and $i = 20°$. It follows that the excess of $\rho_0 \cos i - \rho$ lies between 7 and 13^{mm}. Hence the eye-piece may be placed at a mean position corresponding to 10^{mm} and give very good definition of the whole spectrum without refocusing, as I found by actual trial. Within 1^{cm} the focus is sharp enough for most practical purposes. If the distances ρ_0 and ρ_0' are selected so that eye-piece and slit just clear each other the definition is quite sharp.

The diffraction equation is not modified and if $2x$ corresponds to the positions $+ i$ and $- i$ for the same spectrum line,

$$2\lambda = (D/R)\ 2x.$$

It is, therefore, not necessary to touch the eye-piece, and this is contributory to accuracy.

FIG. 6.



If Rowland's equation is differentiated relatively to ρ and ρ'

$$- d\rho = \left(\frac{\rho}{\rho_0' \cos i}\right)^2 d\rho_0',$$ where the $d\rho_0'/\rho_0^2$ factor is constant. Hence $- d\rho$ varies as $(\rho/\cos i)^2$, given in the table. If furthermore a comparison is made between $d\rho_0$ and $d\rho$ this equation reduces to

$$\sqrt{d\rho_0/d\rho} = [(R-\rho_0)(1-\cos i)]/R \cos i$$

which becomes unity either for $i=0$ or for $\rho_0=R$ (Rowland's case).

12. *Summary.*—By using two slides symmetrically normal to each other and observing on both sides of the point of

interference, it is shown that many of the errors are eliminated by the symmetrical adjustments in question. The slide carrying the grating may be provided with a focusing lens in front or again behind it, if the means are at hand for actuating the slit which is not sharply in focus on the plane of the eye-piece carried by a second slide throughout the spectrum at a given time. It is thus best to use both lenses conjointly, the latter as a collimator and the former as an objective of the telescope in connection with the eye-piece. It is shown that a centimeter scale parallel to the eye-piece slide with a vernier reading to millimeters is sufficient to measure the wave lengths of light to few Ångström units, while the wave lengths are throughout strictly proportional to the displacements along the scale. The errors of the three available methods and their counterparts are discussed in detail. The method is applicable both to the transparent and the reflecting grating.

It is furthermore shown that in case of Rowland's concave grating observation may be made symmetrically on both sides of the slit, or for reasonable clearance of slit and eye-piece passing across each other, although one conjugate focal distance is now not quite the projection of the other.

Brown University, Providence, R. I.

Art. XI.—*Determination of the Hardness of Minerals, II*; by H. Z. Kip.

In the issue of this Journal for July, 1907, an article by the writer on the subject of mineral hardness appeared, whose threefold object was outlined as follows: 1. To invite general acceptance of a single definition of hardness. 2. To establish theoretically in conformity with the definition the best method of investigation. 3. To put this method in practice by means of suitable apparatus and adequate mathematical calculation.

Inasmuch as it is my present purpose to act as my own critic as well as to publish the results obtained in carrying out the investigations indicated above under 3, it will be found excuseable, perhaps, if I depart from the general practice of contributors to the extent of speaking in the first person instead of the third.*

In regard to the formula for determining hardness, established in my previous paper, $H=\sqrt{x^2+y^2}$, I may say that no mineralogist or physicist who has favored me with his opinion has taken exception to this equation. Indeed so long as the generally accepted definition of hardness prevails (resistance to abrasion) this is, and can be, the only adequate formula.

If in what follows I appear to view my own results with some scepticism, I wish it to be understood that this is not the result of a lack of faith in the method employed, but merely an acknowledgment of the difficulty of dealing accurately with molecular forces by mechanical means, such means, at least, as I have had at my disposal.

The apparatus employed was described in its general principles in my previous paper. As actually constructed it differed from the description given in two points only. A pulley and weight were substituted for the spring scale (see fig. 3, loc. cit.) in determining y (lateral force), the mineral and carriage, meanwhile, remaining immovable. This made it necessary to determine x (vertical force) and y in two separate operations, which, however, proved to be rather an advantage than a disadvantage. Likewise two arms were substituted for four in the frame carrying the diamond point. These arms were bent and continued down beneath the level of the surface of the mineral so that the frame and point remained in equilibrium even when no weight was attached. The method

* This is rendered the more necessary by the fact that it is my duty, no less than my privilege, to make due acknowledgment in this place to the trustees of the Elizabeth Thompson Science Fund (Boston) for the appropriation (Grant No. 136) without which these investigations would hardly have been undertaken.

of applying the vertical force by means of a weight suspended beneath the diamond point, with the necessary consequence that this force, at least, is expended solely in the abrasion of the mineral, proved itself to be even more efficacious than was anticipated, and while experimenters are notoriously devoted to their own mechanical devices, I cannot but believe that this feature will be adopted in the sclerometer of the future, provided this instrument is ever standardized.

The values obtained for *x*, *y*, and H for Nos. 3 to 9, inclusive, in Mohs's scale are given in the subjoined table. Values for talc and selenite could not be obtained for the reason that these two minerals yielded to the diamond point even when the latter was balanced merely by the weight of the frame in which it was mounted.

	x	*y*	H
Calcite	1870 mg.	250 mg.	1887 mg.
Fluorite	3300	1180	3505
Apatite	5010	500	5035
Orthoclase	13566	1292	13627
Quartz	22135	2128	22237
Topaz	20197	1539	20255
Corundum	24130	2774	24289

Two diamond points were used in these tests, the first weighing in its frame 784 mg., and the second 2723 mg. The former was used on calcite, fluorite and apatite; the second, and sharper, point on apatite and the remaining members of the scale up to and including corundum. It was found that the force required to produce abrasion on apatite with point No. 1 was 3·8 times that required with point No. 2. The values obtained, therefore, with point No. 2 for orthoclase, quartz, topaz and corundum were raised in this proportion and so appear in the table.

It would, of course, give more reliable results if one and the same abrading instrument were used throughout. But neither of the diamond points prepared at my request by Messrs. Richard Müller-Uri & Cie. (Braunschweig) seemed suited for all of the minerals tested, and with the time and funds at my disposal it was not possible to reconstruct the apparatus and repeat the tests. Future experimenters, it is hoped, will avoid this error from the start. The relatively high value for *y* on fluorite is doubtless due to the fact that a polished specimen of this mineral was used, no cleavage surface being found among the specimens at hand sufficiently smooth to be available. For the other minerals only natural cleavage or crystalline faces were tested. A polished surface is an artificial product and has, in my opinion, no place in investigations which deal solely with surface phenomena.

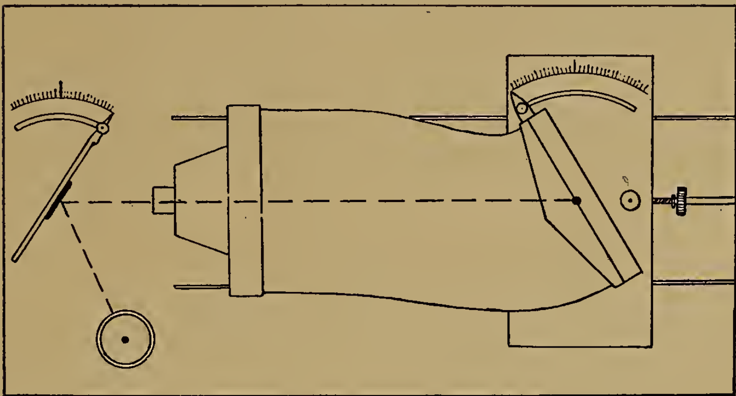
While I do not claim or consider the values given in the above table as final, I wish to call particular attention to the fact that the hardness value shown for quartz is greater than that for topaz. Similar values for these two minerals were obtained by Rosiwal in 1892; quartz, 149: topaz, 138 (corundum being placed at 1000), although his unsupported testimony seems to have failed to shake the traditional faith of mineralogists in the infallibility of Mohs's scale. As a result of my experiments I am fully convinced that Rosiwal is correct in stating that quartz is harder than topaz, but that the difference between the two minerals in this regard is comparatively slight. It should be observed that Pfaff, Prof. Jaggar and others who have arrived at the opposite conclusion have failed to eliminate the factor of density in carrying out their tests. In other words, while regarding hardness as resistance to abrasion they have sought to determine its value on the theory that it was to be measured in terms of resistance to excavation. This fact, of course, should also be borne in mind in comparing all the values presented by Rosiwal and the writer with those obtained by investigators who are satisfied to measure only one of the forces employed in producing abrasion and who disregard density as a possible factor in the problem. The idea that the minerals at the upper end of Mohs's scale are almost infinitely harder than those at the lower end is, in my opinion, erroneous. They may appear so when tested by the method usually employed in the laboratory, in which the hardness of the constantly changing abrading agent is perhaps not greatly superior to that of the mineral under investigation. The nearer the rigidity and hardness of the instrument of abrasion approaches the ideal, the less will the differences in hardness of the various minerals be found to be.

Vanderbilt University, Nashville, Tenn.

Art. XII.—*Photographing Fossils by Reflected Light;* by Lancaster D. Burling.

The successful photography of fossil organisms is not easy, and when the specimens have no relief and are hardly to be distinguished, except by reflected light, from the rock on which they rest, the problem becomes one of great difficulty. Several thousand such specimens were collected by Dr. Chas. D. Walcott in the Canadian Rockies, and Dr. R. S. Bassler, Mr. J. M. Jessup, and the writer have been working upon a method of photographing them by reflected light. The

Fig. 1.



scheme developed seems to yield excellent results, is believed to be new, and may be generally valuable in photographic reproduction.

The back of an ordinary enlarging and reducing camera was pivoted so that it would revolve about a vertical line passing through the center of the groundglass or plate, and the rack upon which the specimens are mounted was made to revolve about a vertical line passing through the center of the specimen. Suitable scales were so attached to both the specimen rack and the back of the camera that each might be clamped at any desired angle. In practice the specimen is placed in position, the lens is removed, and the relative position of the light and the angular position of the specimen are manipulated to secure the most favorable illumination.* In order to elimi-

* Experience has shown that variations in the intensity of the reflected light are necessary to bring out the particular features of different specimens and that the degree of illumination required can best be determined by direct observation through the camera, rather than upon the groundglass.

nate distortion, the back of the camera is then revolved through an angle corresponding to that indicated by the scale on the specimen rack, the lens is replaced, and the specimen is focused and photographed. The best resnlts have been obtained with lenses having a focal length of at least six or seven inches, or long enough to eliminate any errors arising in the adjustment of the camera.

Figure 1 is a plan of the camera showing its arrangement. The light used is a screened arc lamp, snspended by a pulley from the ceiling, the camera stand is movable, and the specimen rack and the back of the camera are each free to move through an arc of 60 degrees. The box-like projection into which the bellows may be compressed has been cut away to increase the angle through which the back of the camera may be revolved.

Art. XIII.—*Synthesis of the Paleogeography of North America;* by Edward Suess.*

It is only now, after more than four months of fatigue, that I can sit down to answer your kind letter of April 20 and thank you for the transmittal of your great paleogeographic memoir [The Paleogeography of North America] and the honour of having my name on the title page beside that of your illustrious Dana. I believe I cannot express my deep feeling of gratitude better, than by trying to enter into a candid comparison of the existing differences of views as they result on both sides of the Atlantic from differences of personal experience, and differences in nature; further, from those variances that are caused by different systems of classification or nomenclature, and which, as results from your memoir, are all governed by the indisputable fact, that great eustatic movements of the strand-line have taken place.

I intend first to write of tectonic influences on the distribution of seas, second to compare several great eustatic phenomena, and third to discuss the difficulties in finding an explaining hypothesis.

1. *Tectonic movements influencing the distribution of seas.*

First, I must confess myself a heretic in all regarding isostasy. I have in my last volume given the facts [IV, 1909: 608–] which cause me to doubt anything like a deficit in gravity beneath the mountains. Faye has always doubted it and, if I am not wrong, Professor Gilbert seems also to partake of this view. There is not sufficient space here to enter into this question and I only permit myself to doubt likewise whether any sinking can be caused by loading. All these loads seem trifles in comparison to the magnitude of the planet.

The ideas of Dana on mountain-making were the conception of a great genius. Experience tells us now, that caution is necessary in the use of terms like syncline, synclinorium, etc. I formerly used these terms for structures that are produced

* This very valuable contribution came in the form of a letter dated Marz (Márczfalva), Hungary, September 2, 1910, and addressed to the undersigned. The subject matter is of so much importance to geologists that it should have wider circulation than that of a personal letter, and it is here published with the author's consent. It will be seen that as yet geologists cannot explain several of the more fundamental characteristics on The Face of the Earth but that we are approaching a determined synthesis. This desideratum will come all the sooner through the life work of Professor Suess in making accessible the garnered geologic knowledge of all lands, printed in a multitude of languages, in his "Antlitz der Erde," or in the English translation by Sollas and Sollas, "The Face of the Earth."—Charles Schuchert.

by folding, of which both halves or sides form parts of the same tectonic unity. This is not the case with the great "synclinoria" in front of the mountain chains, the "Vortiefen" or "fore-depths" [see *ibid.*, IV; 626].

The great Pacific fore-depths of 7,000 to more than 9,000^m are evidently not caused by folding, as one side is formed by the foreland (mostly covered by the ocean here) while the other is the front of a folded chain. This is clearly visible wherever such a fore-depth enters the continent, as for example in the valley of the Ganges, where one side is the Peninsula (=Gondwana land), and the other the Himalaya, or the valley of Guadalquivir in Spain between the old foreland of the Meseta in the north and the young folded cordillera (Betic) in the south. It is clear that the Pacific Asiatic volcanoes have nothing to do with these depths; they always remain inside the more or less arched chain of mountains. The folds of the cordilleras advance towards the depths and seem to reach them. Sometimes the depths are filled with very thick masses of terrestrial sediments, coming from the new-born cordilleras, sometimes with deep-sea sediments having Radiolaria, as in front of the Carpathians and parts of the Eastern Alps. I regard the thousands of feet of Carboniferous sediments, partly marine and partly continental, which accompany the front of our pre-Permian chains extending from Silesia to southern England as the filling of such a fore-depth. Marcel Bertrand was right in drawing a line from the Bretagne to Newfoundland and in regarding the Appalachian coal fields as the continuation of those of southern England, Belgium, etc. All this is in harmony with the remarkable words of Dana on the existence of a greater trough or deeper channel on either side of the Azoic nucleus and perhaps also gives a hint as to the northern limit of your Poseidon ocean. But this trough is no synclinorium and no anticlinorium exists.*

It will be too great a digression for me to describe here the great Asiatic depths and I prefer to write briefly of the difficulty which arises from the fact, that a transgressing sea enters a fore-depth in one case and an extended river valley in another. Then, too, the contour may be very similar, but the thickness of the deposits is by far greater in the fore-depth. The Cretaceous Flysch with Fucoides and Inoceramus has

* "The region toward the Atlantic border, afterward raised into the Appalachians, was already then, even before the Lower Silurian era closed, the higher part of the land" (319). "We hence learn that in the evolution of the continental germ, after the appearance of the Azoic nucleus, there were two prominent lines of development, one along the Appalachian region, the other along the Rocky Mountain region—one, therefore, parallel with either ocean. Landward, beyond each of these developing areas, there was a great trough or channel of deeper ocean waters, separating either from the Azoic area" (344). Dana, this Journal, vol. xxii, 1856.

filled a great part of the fore-depth of the eastern Alps, Carpathians, and Apennines, and it is very curious that similar beds occur on the external (southern) side of the Alaskan (Aleutides) arch [described fully in "Face of the Earth," IV: 376-378]. Your Coloradoan Sea with the posthumous folding of the Laramide Range and the pressure from the Pacific agrees perfectly with European experience.

Other examples are not so definite. Take the Middle Jurassic. A transgression of this age appears on Franz Josef land and other islands of that part of the Atlantic, attains the northern coast of Russia, forms a broad strip on the west side of the Ural Mountains, attains the Caspian, mixes with Tethys, but lies in transgression beyond the borders of this sea in eastern Bavaria, and at the same time, with very similar fossils, appears in the Argentinian Andes, spreads farther than the southern borders of Tethys beyond Damascus, lies on Gondwana beds in German East Africa, also in transgression on old rocks in Khach (East India), as well as in western Australia, southern New Guinea, etc. This same transgression is met with in different parts of northern Siberia as a wide flat series of beds. It is the Enochkin and Naknek of the Alaskan peninsula and your Sundance transgression (Logan Sea).

In some places the middle Lias has left traces in the regions beyond Tethys, as in Madagascar; *Ammonites amaltheus* of the Lias has been found beneath this transgression in arctic Siberia (I believe on the lower Anabar but have no books here), but with these few exceptions the transgression of about Kelloway age everywhere rests on by far older rocks.

It is the strip along the west or front side of the Urals which connects the Arctic with Tethys, and eminent Russian geologists thought that a syncline was formed in front of the Urals. But curiously enough, transgression also proceeds from Tethys far to the south, and I am inclined to believe that the strip along the west side of the Urals was simply due to the sea entering a river system, let us say of a pre-Jurassic Volga.

I do not know enough about the relations of your Logan Sea to the Oregon Jurassics and of these to the Franciscan Jurassic Radiolaria to speak about them and only desire to point out the necessity of comparison and the difficulties. The evident entrance of fore-depths into the area of the existing continents, as for instance the one in front of the Carpathians and Alps extending through the middle of Europe and depositing Jurassic Radiolaria even in the suburbs of Vienna, always has prevented me from acceding to the opinion, that only "epi-continental seas" had entered the present continents. In Europe north of the Alps mountain-making ended before the upper Carboniferous or upper Permian, and coincides very nearly with what you say about the fixing of the broader relations by the Appalachian Revolution of the Atlantic realm. Only sinking of regions seems to have occurred since that time in northern Europe.

2. Comparison of several great eustatic movements.

It has long been known that the stratigraphic series of the Alps is more complete by far than that of its foreland. Within this foreland the pre-Permian mountains (which I compare to your Appalachians) are to be separated from those regions in which no orogenetic process is known since the beginning of the Cambrian. Such I once named Archeboles, but the name is bad, because pre-Cambrian folds are well known in these same regions. The environs of Saint Petersburg and the rim of the Baltic shield are types of horizontal Cambrian.

This difference between the less extensive marine series of the foreland and the more complete series of the folded chains seems to exist all over the world with few exceptions (southeastern Himalaya where the fore-depth cuts off part of the foreland, Mackenzie district and Argentina where the folds enter the less complete series of the foreland, the Jura Mountains which form a sort of complicated parma with a transitional series). In seeking to compare the marine series of the United States with that of Europe, I believe I ought to divide the immense array of facts offered by your maps into three groups or regions, as defined by Dana in 1859, viz., (1) the so called Azoic nucleus or Laurentia, (2) the Appalachians and (3) the western mountains. To these I add as a fourth area the United States Range of Ellesmere land which is thrust on Laurentia from the north and adds a new example of the completion of the marine series as soon as a folded region is entered.

Of these four regions Laurentia presents the imperfect marine series of an undisturbed nucleus or shield and has much in common with Gondwana land; Appalachia may be regarded as the continuation of the pre-Permian mountains of Eurasia (Altaides); the United States Range seems to be an Asiatic fragment; while the Mesozoic and upper Palæozoic of your western mountains has decided relations to Tethys. In this I believe I am not in contradiction with your results.

Europe cannot boast of a Palæozoic series comparable in completeness with that of the United States. I have read with great interest what you write regarding the interrelation of Atlantic biota such as that of the Paradoxides fauna, but I fear I am not able to say more about the older palæozoics than I have already said in my "Face of the Earth;" perhaps other information will be found in the last volume, which was not at your disposal. I will restrict my remarks to the undisturbed region extending to Texas and the western mountains.

These undisturbed regions (those in which Cambrian is not folded) not only show the clearest marks of the negative periods, but also the slow creeping upon them of the transgressions. The negative marks of the strand-line are found more rarely and with difficulty in the folded regions with their rich marine series.

A great negative phase appears at the limit of Jurassic and Cretaceous (Comanchic). This is the Wealden, extending certainly from Poland across Hanover, southern England, Spain, Portland, to the Potomac beds of Maryland, Texas, and Colorado to Alberta, etc. If no other case were known, this one would be sufficient to prove the wide extension of similar movements. The contrast is given by the Spiti beds of the Himalayas, as described a short time ago. In England the Jurassic ends with oscillations in the Purbeck, then follows the Wealden as the time-equivalent of lower Neocomian (Berriasien) and then the marine Cretaceous series. In Himalaya all is marine and difficulties exist in separating the latest Jurassic (upper Tithonian) from the Berriasien. At this time climatic differences seem to have existed in the seas (Knoxville?).

I do not think that lower Neocomian exists in Texas; the oldest forms from Trinity seem to me to be Gault, according to Kilian's determination, and although it may seem daring on my part, I venture to state that the equivalents of the European Cenomanian (upper Greensand) begin within the Fredericksburg. This is the introduction to the great transgression known to me (your Coloradoan Sea is a part of it). The full series exists with lower Neocomian in the southern Andes as well as in the Alps, but in leaving these one sees the Gault creeping over older rocks in northern France while the Cenomanian transgression spreads from the United States through Europe, covering the Sahara from the Atlantic to the Nile, then passing southern Russia and attaining even the desert near Kashgar. Then there seems to appear a pause or even a small regression during the Turonian, perhaps coinciding with your remarks about Pierre, and after this the maximum of the transgression is attained in the Senonian with outliers in the Arctic (central western Greenland) as well as in the Antarctic (Scott).

Next appears the great and probably rapid negative movement of the strand-line, which forms the limit between the Mesozoic and Cenozoic. North America indeed possesses extremely little lower Eocene. This absence seems to occur all over the world in the undisturbed regions except parts of the Sahara.

I will try to point out but two peculiarities of the upper Cretaceous transgression:

a. The great inundation does not, as far as I know, attain the northernmost coasts and islands of Eurasia. Here, on the contrary, transgressions appear in undisturbed (only faulted) regions, a condition which we are not accustomed to see in these areas. Such are the upper Carboniferous and Triassic marine beds of Bear Island, etc.; the Kelloway, etc., which has been described; then Lias at one locality in northeastern Siberia; the Volga beds of lower Cretaceous age in northern Russia; the coast of Siberia, also spreading to the center of Russia; and finally the circumpolar late Champlain transgression. It seems almost as if in certain Mesozoic phases the transgressions in undisturbed regions were complementary to those in lower latitudes. The upper Cretaceous inundation is traceable to Scotland, attains Scania and Moscow, but is not known farther in the north. Angara land (eastern Siberia) and China have as yet not given a sign of this transgression. You know by far better than I that North America shows the contrary. The upper Cretaceous transgression clearly extends to Yesso and Sakhalin, in northern Alaska along the arctic coasts about Colville River to the delta of the Mackenzie and thence southward into the United States. The undisturbed arctic and subarctic coasts therefore show quite a different marine series in Eurasia and in America.

b. The wide inundation of so many continents and the succeeding probably rather rapid retreat of the marine waters also dissipated the land waters, resulting in the destruction of the large dinosaurs, the inhabitants of swamps, rivers and lowlands, and retaining only those types of Reptilia which exist unto the present day. The freshwater fauna was driven into the upper reaches of the rivers. The Pyrgulifera from Bear River have a very remarkable affinity with the forms from the upper Cretaceous beds of the Gosau of Hungary and similar forms from southern France. The Pyrgulifera living in Tanganyika lake resemble them so much that I am willing to believe that this African freshwater fauna is not a relict of the Cretaceous transgression which seems not to have attained to that part of Africa, but the descendants of the habitants of higher parts of an upper Cretaceous river from the time of the transgression, exactly as Baikal preserves some species of Levantine age.

I will dwell a little longer on the most important question of fluviatile faunæ about which more is said in the last chapter of my book. The development of lungs preceded by gills teaches that life has proceeded from the ocean to fresh water and land. In other cases of animal life no considerable change is visible; examples are the Medusa of Tanganyika, Victoria and the lower Niger. In a like way the marine pelecypods Mysidæ in the upper Volga, now separated by twelve degrees of latitude from the Caspian, are probably older than the separation of the Caspian from the Mediterranean. Another example is the sirenian *Phoca baikalensis*. In Pyrgulifera a Cretaceous freshwater gastropod has been preserved and I regard this as a relict from the head of a Cretaceous river, because the marine Cretaceous trangression and indeed every later marine inundation seems in the center of Africa not to have extended far beyond the southern limit of Sahara. In this way only can we understand that Nile, Niger, Gambia, Senegal, Kongo, Zambesi and lake Tchad (Boulanger's Megapontic sub-region) possess a very uniform fluviatile fauna. Further, the oldest types of fluviatile fishes exist in the oldest continents, Amia and Lepidosteus in Laurentia, Lepidosiren in Brazil, Polypterus and Protopterus in Africa, Ceratodus in Australia.

3. Difficulties in finding a satisfactory hypothesis as to the causes of transgressions.

When I wrote of eustatic movements in 1883 ["Face of the Earth," vol. I] I confessed that I did not understand the transgressions. I thought that variations in rotation might somehow have influence. I also believed and still think that the accumulation of sediment was a *vera causa*, but hardly sufficient. Now, after twenty-seven years I cannot offer you more than a loose heap of doubts regarding the explanation. I have learnt more and know less about it.

Regarding rotation, we must ask: Where was the pole? and has it always been fixed? Many years ago Oswald Heer said that its position was variable, as plants of a warmer climate are known from the Devonian or lower Carboniferous through the whole succeeding stratigraphic series and that signs of refrigeration begin to appear for the first time in the middle Tertiary. Now, the Jurassic ferns from the Antarctic teach a similar lesson and all these plants demand not only a warmer climate but more light than the polar nights afford. Further, the repeated glacial periods in different latitudes seem to hint of great displacements of the poles; several theories have been proposed but none is adequate.

It is quite true, as you remark, that the sinking of part of an ocean's base or part of a continent must increase the rapidity of rotation. The question remains, however, whether the phenomenon is not accompanied by a displacement of the planetary center of gravity.

All measurements of the polar applanation of the globe are executed on the base of the actual strand-line. The result of these measurements therefore, does not represent the applanation of the lithosphere but of the hydrosphere, and the high terraces or strand-lines in high latitudes prove the variability of the hydrosphere's shape. It is very improbable that the quantity of water has greatly increased, and this increase was probably not more than the volume of juvenile waters issued by volcanoes.

The terraces of the north are very distinct, as well as those of a great number of islands in low latitudes of the Pacific; but I cannot with certainty see whether these two sets of phenomena are synchronous and continuous or complementary. I believe in the formation of negative eustatic strand-lines through the sinking of ocean bottoms; therefore I suppose them to be synchronous. Rotation would give complementary lines (better complementary phases, as plus in polar regions and minus at equator), but synchronous negative lines might interrupt them.

What I wrote in 1883 about the considerable attraction of the continents and islands on the adjacent waters was then regarded as fully ascertained by our first authorities. Later on doubts arose and the question seems not yet fully settled.

Nature is parsimonious on occasions in allowing us to follow the actual facts in arctic, antarctic and in tropical regions. What we know is principally the northern temperate zone. In Mesozoic times the American and the Euro-Asiatic-Arctic transgression seem to be different. Of real peri-arctic transgression, that is, actual heaping of water about the north pole, the last inundation (Champlain) offers most proof and still holds as the best evidence for a rotatory hypothesis. On the other hand, the sharpness of all negative lines speaks decidedly against their formation by rotatory phenomena. Therefore I accepted the formation of the elevated strand-lines as due to the making of new depths, and left the cause of transgressions in doubt. Even now I cannot go farther.

I must close. Writing to a fellow geologist from whom I have learnt so much is such a treat to me that I must beg you to forgive the great length of this letter. What I offer you is little more than a number of questions; but questions are the buds on the tree of knowledge.

ART. XIV.—*The Estimation of Silver by Electro-Deposition from an Ammoniacal Solution of the Oxalate;* by F. A. GOOCH and J. P. FEISER.

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

IN a recent paper from this laboratory an account is given of tests upon the efficiency of a silver anode in the fixation of chlorine derived from hydrochloric acid by electrolysis. It was found in these tests that when the silver anode was made by plating platinum gauze with silver in a solution of the double cyanide of silver and potassium the silver deposit invariably included some of the potassium salt. To secure purity of the silver anode an ammoniacal solution of silver oxalate was substituted for the double cyanide solution in the plating process, for the reason that nothing of a non-volatile nature can then be included in the deposit which after ignition consists of pure silver. The present paper describes the adaptation of this process to the quantitative estimation of silver.

The solutions of silver nitrate used in testing this process were carefully standardized by precipitating silver chloride from the hot solution by hydrochloric acid, cooling, digesting over-night, and weighing the silver chloride upon asbestos after heating gently without melting. Depositions were made upon a rotating cathode of platinum—the ordinary crucible,* the double disk of gauze† and a gauze cone set point downward upon the axis of rotation. In the experiments of Table I, measured amounts of the silver nitrate solution (25^{cm^3} or 50^{cm^3}) were drawn from a burette into a small beaker and treated with ammonium oxalate to complete precipitation. The silver oxalate was dissolved in a slight excess of ammonia, and this solution, diluted to 100^{cm^3}, was electrolyzed with a current of 0·25–1·5 amp. and 4–7 volts. The cathode with the deposited silver was dried cautiously over a low flame and thereafter ignited to incipient redness. The details of individual experiments are given in the table.

These results show plainly that the process of depositing silver from the ammoniacal solution of the oxalate, precipitated from the nitrate, is capable of yielding good analytical results. Under the conditions of these experiments the electrolysis should be continued from twenty-five to thirty minutes in order to make sure that the deposition is complete. The

* Gooch and Medway: this Journal, xv, 320 (1903).
† Hildebrand: Jour. Amer. Chem. Soc., xxix, 450 (1907).

TABLE I.

The Electrolysis of Silver Nitrate dissolved in Ammonium Oxalate and Ammonia.

	Ag in $AgNO_3$ taken grm.	Ag found grm.	Error grm.	Current Amp.	Current Approx. N. D.	Current Volt	Time min.	Revolutions per min.
	A crucible used as cathode.							
(1)	0·2687	0·2685	−0·0002 ×	1·5–1	5–3·3	6–7	25	500
(2)	0·2687	0·2687	±0·0000 ×	1·5–1	5–3·3	6–7	30	500
(3)	0·2687	0·2684	−0·0003 ×	1–0·5	3·3–1·7	6–7	30	450
(4)	0·2687	0·2685	−0·0002 ×	1–0·5	3·3–1·7	4–6	30	450
(5)	0·3183	0·3181	−0·0002 ×	1·5–1	5–3·3	4–6	20	450
(6)	0·3183	0·3178	−0·0005 +	1·5–1	5–3·3	4–6	10	450
	Gauze discs used as cathode.							
(7)	0·3183	0·3179	−0·0004 ×	1–0·5	0·5–0·25	4–6	20	400
(8)	0·3183	0·3182	−0·0001 ×	1–0·25	0·5–0·10	6–8	25	400
(9)	0·3183	0·3181	−0·0002 ×	1–0·25	0·5–0·10	5–8	25	400
(10)	0·3183	0·3180	−0·0003 ×	0·75–0·25	0·4–0·10	5–7	40	450
(11)	0·3183	0·3180	−0·0003 ×	1· –0·25	0·5–0·10	4–6	40	450
(12)	0·3183	0·3176	−0·0007 +	0·75–0·25	0·4–0·10	6	20	450
	Gauze cone used as cathode.							
(13)	0·2687	0·2686	−0·0001 ×	1·5 –1	3–2	4–6	25	500
(14)	0·2687	0·2683	−0·0004 ×	1· –25	2–0·5	6–7	30	450
(15)	0·2687	0·2684	−0·0003 ×	1· –5	2–1	4–6	25	450
(16)	0·2687	0·2686	−0·0001 ×	1· –0·25	2–0·5	4–6	25	450
(17)	0·5375	0·5373	−0·0002 ×	1·5 –1	3–2	6–7	25	450
(18)	0·5375	0·5371	−0·0004 ×	1·5 –1	3–2	6–7	25	500

× Deposition complete, as shown by H_2S test.
+ Deposition incomplete, as shown by H_2S test.

deposit is naturally more adherent when the cathode surface is relatively large and the current density low. When the current density is high the deposit is apt to be voluminous, shrinking considerably upon drying, and this phenomenon was especially notable in the case of the deposits upon a comparatively small and smooth surface of the crucible. The best form of apparatus appears to be the gauze cone set point-downward and so placed with relation to an annular platinum band used as the anode that the end of the axis where the centrifugal effect of rotation is least shall not receive much of the deposit. Experiments made with stationary gauze electrodes were not successful nor were those made with a dish cathode and stirring anode.

Other experiments in which the silver was first precipitated as silver chloride and then deposited from the solution in ammonia and ammonium oxalate are given in Table II. In these experiments, in which the solutions were more strongly ammoniacal than those of the experiments of the preceding series, the deposits were dark and spongy, but they became lighter in color and more compact upon drying.

TABLE II.

The Electrolysis of Silver Chloride dissolved in Ammonium Oxalate and Ammonia.

	Ag in $AgNO_3$ taken grm.	Ag found grm.	Error grm.	Current: Amp.	Current: Approx. N. D.	Current: Volt	Time min.	Revolutions per min.
			A crucible used as cathode.					
(1)	0·3191	0·3187	−0·0004	1·5–1	5–33	5–7	20	500
(2)	0·3191	0·3189	−0·0002	1·5–1	5–33	4–6	30	500
			Gauze discs used as cathode.					
(3)	0·3191	0·3185	−0·0006*	1·5–1	0·75–0·5	5–7	15	500
(4)	0·3191	0·3189	−0·0002	1·5–1	0·75–0·5	5–7	25	500
(5)	0·3191	0·3190	−0·0001	1·5–1	0·75–0·5	4–6	35	500

* Time of electrolysis short.

It appears, therefore, that silver may be deposited from an ammoniacal solution of the oxalate, in presence of ammonium nitrate or ammonium chloride, in pure condition and in form suitable for quantitative estimation.

Art. XV—*Notes on the Armored Dinosauria*; by G. R. Wieland.

[Contributions from the Paleontological Laboratory of Yale University.]

With the progress of exploration in many fields it becomes more and more evident that an interesting parallel must exist between the long-persistent Testudinata and the shorter-lived armored Dinosauria, a group which plainly constituted a numerous and varied cosmopolitan race with its dermogene bones always as distinctly ranged in keels as in any turtles. For, as insisted upon several years since,* not only is a primary comparison afforded by the keels, but secondarily as well, the lumbar-hip carapace, present in the Nodosauridæ though not in the Stegosauridæ, finds its analogy in the osteodermal mosaic of *Dermochelys*.

Nevertheless, despite the cumulative evidence for the existence of a race of keeled saurians of world-wide distribution, and despite the frequent occurrence of more or less isolated plates from these keels, only the median dorsal line of *Stegosaurus* and the lumbar-hip carapace of *Polacanthus* (with *Stegopelta* Williston†), are so far known with any degree of satisfying exactness. Indeed it appears that collectors, in both Europe and America, have been so little fortunate in finding the keeled Dinosaurs with their plates more or less naturally aligned *in situ* as to long leave the existence of such a great group obscure, although field work has but recently reached a far point in the collection of integumented skeletons of the unarmored, swift-footed Laramie Hadrosaurs. Nor was it known until three years ago that in that most explored of all vertebrate yielding horizons of North America, the Niobrara chalk, typical armored saurians occur. Then, as described in this Journal,‡ the plates assigned to the new genus *Hierosaurus* (with dermal plates characterized by deep and broad horn shield sulci), were found by the fossil hunter Sternberg.

As it transpired, the interest of these fossils had not been fully recognized by their collector. In consequence, as was later learned on the occasion of a visit by Mr. Sternberg at the writer's home, many much weathered and broken fragments of the type had been left behind. But fortunately, as found so desirable by us both, Mr. Sternberg was able to make the needed reëxamination of the locality before the frosts of another winter had set in, securing and sending every last remaining fragment.

*A new Armored Saurian from the Niobrara; by G. R. Wieland. This Journal, vol. xxvii, March, 1909, p. 250-252.

† A new Armored Dinosaur from the Upper Cretaceous of Wyoming; by S. W. Williston, Science, N. S., vol. xxii, No. 564, October 20, 1905, p. 503-540. [Preliminary note on *Stegopelta landerensis*, from the Fort Benton. An illustrated description is not yet published.] ‡ Loc. cit.

And indeed from this second instalment of the type much more has been learned than might have been anticipated. In it, as enumerated below, nearly every part of the skeleton is represented. In fact, after careful search and reuniting of many separated fragments, it is found that although much of the new material, especially of the limb bones, is too much weathered and broken to permit restoration, there are present far more than twice as many complete elements as were first secured; while taking both collections together, quite one-third of the entire armor is directly indicated, and inferentially, more than half. To the description of this new material we may now turn with the remark that the recovery of such a large part of the armor in intimate association with the skeleton assures us that the Niobrara must in time yield finely conserved armored saurians.

Further Structures of Hierosaurus.

Figures 1–3a.

The additional portions of the skeleton of *Hierosaurus* described herein have the same general surface characters and features of weathering as the plates first collected, and are to be regarded as part of one and the same type. They come from the same locality, and so far as I can determine represent but a single animal, with the exception of the caudal bands shown in the first description (cf. figures 7, 7*a*, loc. cit.).

As forwarded by Mr. Sternberg, this second instalment includes the following skeletal parts:

(*a*). One large flat caudal spine of isosceles triangular form 15 centimeters high with a base 13+ cm. long. Base somewhat crushed but showing clearly outlined surface of attachment about 4 cm. wide. (Cf. fig. 3, 3*a*.)

(*b*). Distal half of a somewhat lower spine than the preceding.

(*c*). Two portions of summits of spines of moderate to large size.

(*d*). A low set spine strictly intermediate in form between the preceding and following (fig. 1*b*).

(*e*). One elliptical and ridged dermal plate 10×15 cm. (fig. 1*c*).

(*f*). A subrhombic dermal plate like *e*, 9×15 cm.

(*g*). Four oblong elliptical elements ranging from 9 to 11 cm. long and from 3 to 5 broad, and having a submedian ridge varying from a shallow sigmoid (fig. 2*e*) to a crescent (fig. 2*f*, *g*), the latter form being doubtless one of the most anterior in which the tendency to form a posteriorly set spine is clearly marked.

(*h*). Three smaller oblong ridged elliptical elements about 8×3 cm. (fig. 2, *a*–*c*).

(*i*). Series of twenty-five incomplete plates like the two preceding groups. Length average 8 to 10 cm.

(*j*). About fifty additional fragments of smaller elongate ridged plates, less than 10 cm. in length. Some must be portions of one and the same plate, the group doubtless representing about twenty-five plates. Average length under 10 cm.

(*k*). Six much crushed dorsal (?) centra 6 cm. long. Nearly platyan or slightly cœloplatyan.

(*l*). Four toe bones 4×2 cm. (may include a caudal vertebra).

(*m*). Fragments of ribs of T-shaped section with the top very heavy, breadth 3 cm.

Fig. 1.

Figure 1.—*Hierosaurus Sternbergii* Wieland. Cranial and dermal elements referred to the original type. × 0·37.

s, *s*, lower outer portion of right squamosal with series of fused epijugals (*s*, *s*) indicating the presence of a Triceratops-like frill of considerable size if correctly identified (comparison is primarily to be made with the "postcranial scutes" of *Stereocephalus tutus* Lambe) ;—

e, inner side of a characteristic cranial element supposed to be the right jugal with the free concave side (at *e*) forming part of the orbital border ;—

b, dermal element, rising into a large posterior spine with the suggestion of a possible bifid condition. (The rugose crescentiform base is shown below) ;—

c, dermal plate traversed throughout by a strong ridge not rising into a spine.

(*n*). A portion of post cranial band—cf. figure 1, *s. s*—as well as larger parts of same rugose surface character, with heavy sulci. All may be supra-cranial plates.

(*o*). A cranial element (jugal)—cf. figure 1*e*.

(*p*). Many fragments of limb bones and other parts of skeleton not determinable but bulking up as great as the parts determinable.

The principal anatomical features readily determinable from this type, as in part illustrated in my previous description (cf. loc. cit. figures 1–7*a*) and by the accompanying figures 1–3*a*, are:—

1. That the length of the animal was about four meters, being perhaps less than half the size of *Stegosaurus*, and distinctly smaller than *Stegopelta*;—whence the length of a spine series measured from near the skull over the lumbar-hip carapace, and including the anterior three-fourths of the tail, would be three meters more or less.

2. The dermal elements present in whole or part now number nearly 70. Hence if all were arbitrarily placed end to end with an allowance of say one-fourth their actual size as abutting space, a length of from 9 to 10 meters on keel lines or the equivalent of three full keel lengths is present. Or counting off space for the lumbar-hip carapace, fully four keels.

3. Since the dermal elements no doubt fairly represent all the keels and yet include no strictly bilateral members, it is not likely that there was a true median keel, whence five to six keels are arbitrarily demonstrated as present.

To make an estimate of the maximum number of keels is however seen to be impracticable. One can only say that there appear to have been at least as many as on the turtles with a neural, two pleural, two supra-marginal, and two marginal keels, or seven in all.

4. Since a few cranial bones are present, but no portion of the lumbar-hip carapace which was no doubt well developed, it is likely that the dermal elements recovered are mainly of the anterior dorsal region.

5. The complex character of the armor is striking, combining as it does a system of free keels which lose their identity in a lumbar-hip carapace and must then reappear in the caudal rings. No less too is the *tout ensemble* one of the most ornate that has ever been demonstrated. For as we see the elements of the keels vary regularly in shape from tubercles through rounded, oblong, elliptical, subrhombic and crescentic forms, with regularly increasing elevations passing from points to ridges both straight and sigmoid, low bifid, and at last huge caudal spines.

The specific isolation of *Hierosaurus Sternbergii* is believed to be clearly established, since the nearest form with which it can be compared is *Stegopelta* of Williston (loc. cit.) from a different horizon however, the Fort Benton. Not as yet clearly illustrated, that genus is described as having mainly rounded dermal elements, whereas those of the present fossil

FIG. 2.

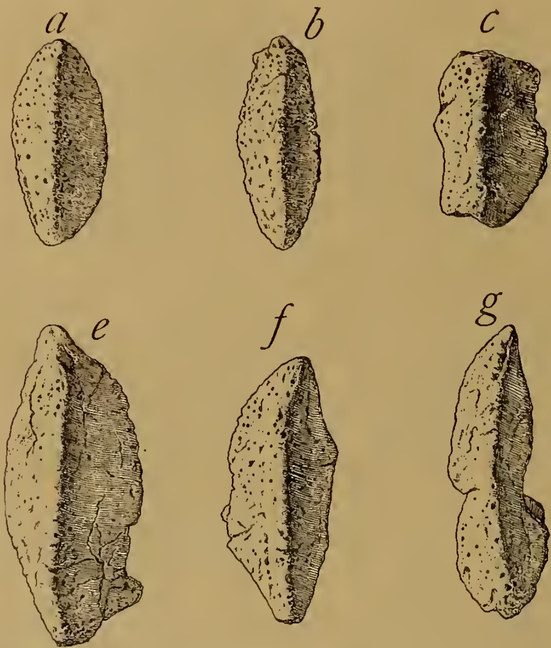


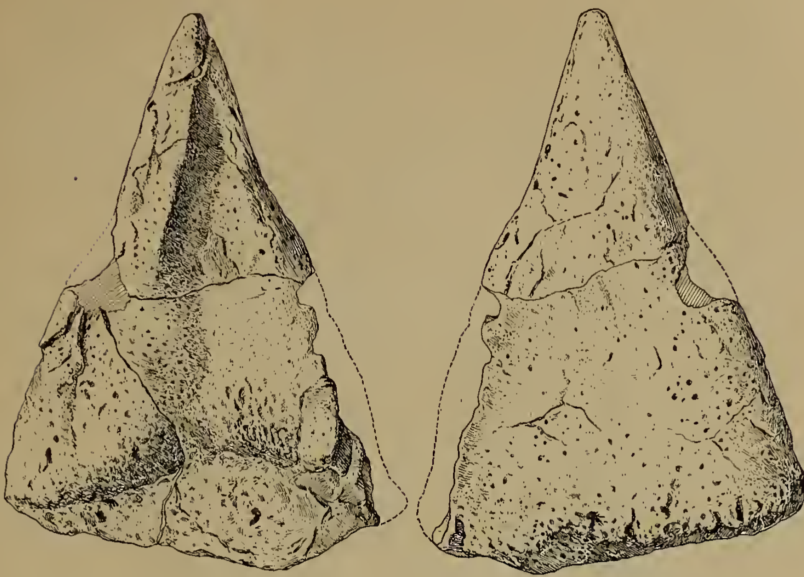
FIGURE 2.—*Hierosaurus Sternbergii* Wieland, × 0·37. Characteristic dermal elements showing variation from the straight keeled forms *a-c*, to the crescent keeled forms, *f*, *g*, and the sigmoid keel *e*. In all these instances (except *c*, incomplete) it can readily be determined by inspection of the specimen which is the anterior end. [That of *e* is below.]

cannot be so described. But in other respects these forms are so near as to make it possible that a fuller knowledge of both will warrant bringing the Niobrara saurian within the genus *Stegopelta*; while the next nearest relation is doubtless the slightly older *Stereocephalus* of Lambe* from the Belly River series of the Red Deer River, Alberta.†

* New Genera and Species from the Belly River Series (Mid-Cretaceous); by Lawrence M. Lambe. Contributions to Canadian Paleontology, vol. iii, Ottawa, 1902, p. 25.

† Since penning these lines I have shown the type material of *Hierosaurus* to Professor Williston, who says he believes the form generically distinct from *Stegopelta*, and calls attention to the fact that in the latter many of the dermal plates bear a large shallow pitting whereas no such markings are present in any of the *Hierosaurus* plates, though so many have been recovered.

Fig. 3. Fig. 3a.



Figures 3, 3a.—*Hierosaurus Sternbergii* Wieland, × $\frac{7}{20}$. Large broad-based caudal spine of the type, 20 centimeters long. Figure 3 shows the slightly fluted intero-superior side, and figure 3a the rather flat extero-inferior surface. The base was broad and heavy, the apex ornately outcurved and sharp.

The family attribution of both genera along with *Polacanthus* Hulke, *Nodosaurus* Marsh, *Palæoscincus* Leidy, *Stereocephalus* Lambe, and *Ankylosaurus* Brown, we think surely lies within the Nodosauridæ of Marsh.

It is thus seen that the type of *Hierosaurus*, though promising but little of its true interest when first noted in fragments weathered, broken and scattered in the Kansas chalk hills, shows students as well as collectors that exhausted fossil-bearing horizons are as yet unknown. As enumerated, the elements recovered indicate that approximately an entire skeleton was present when erosion of the matrix began. Evidently future search in the Niobrara cannot fail to reveal other complete examples, mayhap with their keels fairly in place.

But for the present the evidence available for even tentatively illustrated restorations of mail-clad Dinosaurs remains too baffling. Perhaps if one were in ignorance of both *Polacanthus* and *Stegopelta* it would be possible to produce a plausible generalized restoration of the armor of our Niobrara form, seeing that it has quite the longest series of finely conserved plates of any specimen so far obtained. Indeed Brown,* overlooking *Polacanthus* entirely, has attempted with far less material to restore the keels of his *Ankylosaurus*. But as Williston† has rightly said of this restoration, "It is based on too scanty material to serve as a satisfactory basis for a restoration * * since the form must be included in the same family as *Polacanthus* Hulke." Whence it is pertinent to remark that vertebrate paleontologists have reached the time when it is well to realize that even though what is more a surmise or a guess prove fortunate, its value both present and future must depend on the concrete evidence which lies behind it, as we have learned from severe experience.

We may pass on to a brief notice of some further structures of the mail-coated Dinosauria of much present interest.

Pleural Armor of Stegosaurus.

So far, the startlingly strange, complex, and ornate aspect at once indicated by even lesser portions of the mail-clad Dinosaurs, has naturally led to so called "new families." Not to mention a long series of genera of convenience, we thus have the Scelidosauridæ, Polacanthidæ, Stegosauridæ, Nodosauridæ, Ankylosauridæ, etc., etc.

Now while this nomenclature of expediency may really foreshadow the degree of complexity the mailed saurians will ultimately be found to exhibit, they are none the less to be regarded as a compact and homogeneous series. And in all likelihood this series displayed as much uniformity in the general alignment of its keels as might be observed in a similar array of Cretaceous Testudinate families. From our viewpoint we hence hold it safe to predict that buttressing pleural keels will certainly be found in addition to the two great and firmly set dorsal Stegosaurian keels recovered. On both anatomical grounds and relationship this must be the conclusion; though it is very clear that such pleural keels would be *low*, since the mid-line armor had become the dominant means of defense, or at least region of accelerated growth. Even so there is in the nearly rigid back a most curious parallel to the turtles, and we believe that restorations should take more cognizance of this fact in dealing with the leg flexion than they have so far.

That pleural keels have not been so far recovered, or recognized must be explained away as due to accidents of preservation and collection—even to paucity in field observations or notes. At best the chance to find more or less loose peripheral

* The Ankylosauridæ, a new family of Armored Dinosaurs from the Upper Cretaceous, by Barnum Brown. Bull. Am. Mus. Nat. Hist., vol. xxiv, Feb. 13, 1908, pp. 187–201.

† American Naturalist, vol. xlii, Sept., 1908, p. 629.

elements is always most precarious, as we know from the frequent dissociation of testudinate marginals.

Dinosaur Mail from the Ceratopsia Beds.

Figures 4–7.

There is strong reason to believe that owing to accidents of preservation, the course of erosion from their matrix, and even

Fig. 4.

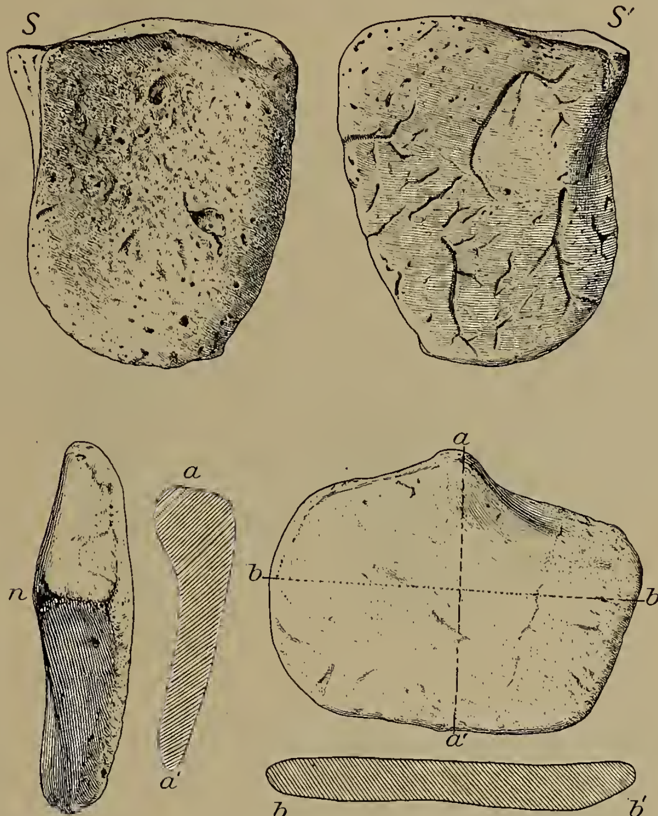


Figure 4.—Oblong dermal plates of Nodosauridæ or Ceratopsidæ from the Ceratops beds of Converse County, Wyoming. ×$\frac{1}{3}$. Forms illustrating extreme displacement of the spinal node. In the upper figure *s* is the inner, and *s*′ the outer view of a plate, the inner left basal angle of which rises as a distinct triangular spinal elevation *ss*′, 3 centimeters high. Which is the major axis, remains uncertain.

In the lower figures, the spinal node is at the middle of the upper edge at the end of the transverse axis *aa*′, although the trifaced feature is as distinct as before. The entire form is shown by the transverse and longitudinal sections *aa*′ and *bb*′ respectively, *n* being the upper inner face of the plate, and its node.

to the fortunes of collection, the bony plates thus far found more or less closely associated with the reptiles of the Ceratops beds do not represent the true abundance and proportion of

Fig. 5.

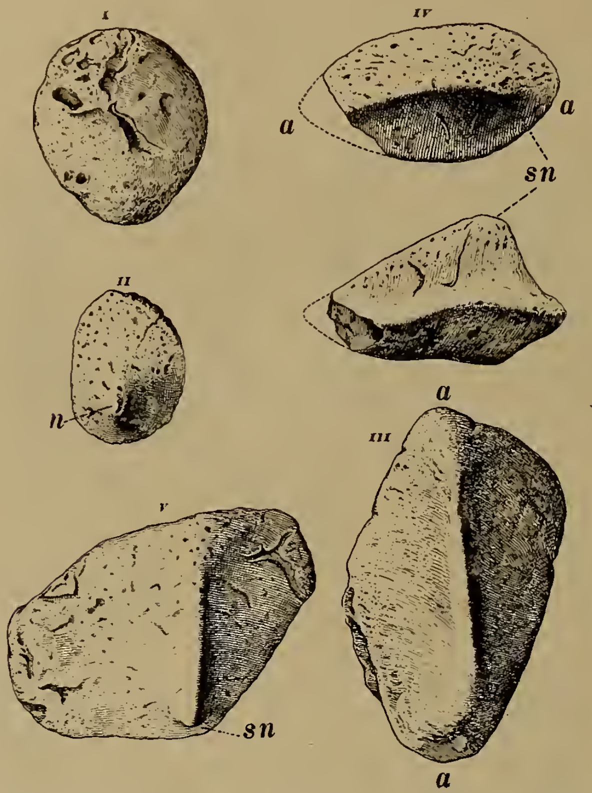


Figure 5.—Rounded, elliptical and subrhombic dermal plates of Nodosauridæ or Ceratopsidæ, further illustrating the great variety of form and the changing development and position of the spinal node. All are from the Ceratops beds of Converse County, Wyoming, and at least in part from the same individual as the plates shown in figure 4.

I–V form a series passing from a rounded flattened tubercle (I) to a form with a low node (II), to a ridged form (III), and then a form with a heavy spinal node *sn* (IV). In V the spinal node *sn* lies near to the posterior border.

All are of heavy and comparatively dense bone, upper surfaces usually showing nutrition canals.

armored saurians in that horizon. Such armor is as a rule found at some distance from the skeletons to which it belongs, and yet it cannot serve as a satisfactory basis for new species. There may, therefore, be far more of it in the various collections than one might suppose from the minor mention it receives in all accounts of Dinosaurian material from the Ceratops beds of the Laramie and Belly River series.

The plain fact is that we have been entirely misled by a seeming paucity of such armor not in accord with the existence in the Laramie of numerous representatives of the armored race, each bearing, as one may readily calculate, anywhere from 200 to 300 dermal elements varying from mere tubercles up to huge staked plates. Indeed it would be of very considerable interest to know the actual number and proportion of these

Fig. 6.

Figure 6.—Subrhomboidal Nodosaurid or Ceratopsid dermal element from the Ceratops beds of Converse County, Wyoming. × $\frac{4}{5}$. (Thickness 1·5 centimeters.)

The upper surface, showing the large nutrition canals radiating from the subcentral and little elevated nodal area. The under surface is distinctly convex and shows the *Nodosaurus textilis* type of striated surface. A frequent and typical form.

elements in the collections, and especially their associations; though it is, we repeat, greatly to be feared that field notes sufficient to reveal the full cumulative value of this evidence may be lacking. The more are we impressed with this idea because of the fact that the discovery of the armored saurians has been late, is only beginning now. Furthermore we can add very tangible evidence to these views, having but recently secured from Mr. Sternberg a collection from the Laramie of some thirty most interesting dermal elements, the chief forms of which are figured herewith. These are supposedly from two individuals and may represent *Ankylosaurus*, or an ally; though it is, as we must insist, by no means proven that some of these forms did not pertain to Ceratopsia, just as Professor Marsh supposed they did. Forms like these were found near Ceratopsians by Hatcher, and Sternberg says he found one of these plates accompanying the *Triceratops* skull he sent to the British Museum two years ago.

As readily seen from inspection of the figures, these elements present far more variety of form than do those of *Hierosaurus*. They also vary all the way from tubercles to plates of large size, and from mere knots of bone to armor with the most ornate ridging. Taking the elements as a whole there is in fact a notably small number with flat upper surfaces, the tendency being to rise first as a point, then as a more or less rounded elevation, and more often into a keel. Finally, there is the backward projection and elevation into a free spine.

Fig. 7.

Figure 7.—Thick strongly rugose Ceratopsid or Nodosaurid dermal element from the Ceratops beds of Converse County, Wyoming.

At *h* a strong horn-shield groove appears, not to be confused with the nutrition canals, and showing further evidence of a high development of horn-shield systems in many of these forms.

The figures 4–7 taken in conjunction with those illustrating *Hierosaurus* give a fair idea of form-range in Dinosaurian dermal armature where passing beyond the stage of minor patternless ossifications such as may have been present in various heavy-skinned Dinosaurs and have been pointed out to me as accompanying *Pelorosaurus*. But they by no means show the range in these types characterized by a dominant linear arrangement of the elements, on which these studies are based. In particular one notes that the spinal node, as we term that point, line or area which tends to project, whether pronounced or not, may occupy any portion of the face. Usually the spine once it becomes pronounced of course rises from the posterior half. But as a ridge the node may even rise to form the edge of a plate as in figure 4.

* * * * * * * *

In all the armored saurians there is the constant variation in general form of the plates and spines suggesting close abutment to suit the different body areas, but yet producing no doubt a rigidity of body in most of the later forms approaching that of testudinates. Indeed these animals in the larger sense started in the direction of testudinate armoring but ran off to bizarre patterns. As a rule, however, the transition from low, flat or erect plates to large spines does not appear so abrupt as in the case of the more or less fluted caudal spines of *Stegosaurus*; but taken all in all, it is evident enough that there was present throughout an entire armored race a most ornate keeled armorial pattern. And while the complexity of this pattern as yet baffles exact restoration, it is now seen to be most likely that forms with their armor in place will soon be discovered, revealing in full the structure and number of the keels, the degree of carapacial and hornshield development, the extent of possible comparison with the armor of the Testudinata, the correlated skeletal structures, and finally following anatomical features, the extent and the nature of the antithetic course of evolution which must be involved in the development of the late Cretaceous carnivorous and mailed and horned Dinosauria.

Indeed so extended has already become the evidence here added to, that a further brief word of interpretation is pertinent. At first sight all development of dermal armature may appear to be mainly a senile feature, due even to inertia—the general life movement of the individual and the race.* But it is also evident that the development of dermal ossicles in series finally resulting in a protective osteodermal armature or carapace is a most profound change coördinated with striking endoskeletal alteration. Used with less success by the Dinosauria, as already much specialized, the accomplishment of this change however appears to have given the Testudinata an exceedingly long lease of life.

It is hence in our view most probable that not so much bathmic courses and tendencies as ordinary exigencies of life and environment were really primary factors in the origin of armored reptilian races. At least ever since the discovery that races of formidable carnivores like *Megalosaurus* and *Lælaps* developed side by side with such strongly armored herbivores as *Scelidosaurus*, *Hylæosaurus* and *Stegosaurus*, it has seemed reasonable to believe that a completer knowledge of Dinosaurian faunæ must finally reveal some of the modes of adjustment to a life of attack and defense in these dominant but comparatively short-lived apposite lines. For if ever the vertebrate paleontologist might hope to detect boundaries between the direct origin of organs to meet obvious necessities, and their appearance with the aging of races as secondarily used senile features, here where all the characters are writ large

* On page 106 of this Journal, Aug., 1902, the parallel modification of cervicals in long separated Testudinate races was cited by the writer as a case of evolutionary inertia. It is a conspicuous one, and is correctly named inertia, whereas the term momentum, now used by some, implies a knowledge of rates of evolution we do not as yet possess. The general term is certainly preferable.

must be the point. Though in the simple relations of attack and defense involved in spines, bony plates, horns and teeth, nothing we can to-day observe in the reptiles or the mammals of the land or sea could have quite prepared us for that veritable apotheosis of force finally involved in the juxtaposition of *Tyrannosaurus* with the Ceratopsia as justly included members of the great group of keel-armored saurians here hypothesized.

Certainly then one can not bring himself to seek an explanation of the evident parallel development of these structurally antithetic series, and their brief culmination in the latest Cretaceous, as a chronological accident, explicable in terms of senility and bathmism, or of mere developmental inertia.

That one or the other of these opposed series could so arise as an aging race during continental and climatic evolution is thinkable. But that both the carnivorous and horned and mail-coated herbivorous Dinosaurian lines so developed their formidable array of structures of attack and defense synchronously, appears improbable. Such equal rates of evolution have never been demonstrated; though in any alternative one is surely led to believe that when once the Dinosaurian lines are known in approximate paleontologic totality, the sequence and cause of complementary development in these groups, whether simple as it now seems, or obscure, may not only be largely understood, but that the facts will aid us notably in gaining very definite conceptions of fundamental biologic factors involved. Indeed it is most evident that any idea that the study of the Dinosauria can be in the least barren must be wholly erroneous, and that contrariwise, this group is destined to yield in *largesse* evolutionary testimony of everyday bearing that can be learned nowhere else.

Art. XVI.—*Original Gneissoid Structure in the Cortlandt Series*; by G. S. Rogers.

In the course of a rather detailed investigation of the Cortlandt Series the attention of the writer was attracted by a peculiar structure occasionally occurring in these rocks, which seems to be undoubtedly of an original gneissoid character. By way of introduction a word of review about the Cortlandt Series itself may not be out of place. The rocks cover an area of about 25 square miles, and are situated just southeast of Peekskill or about 35 miles north of New York City. They constitute a small but rather complete igneous complex, containing examples of all of the main varieties from granite to peridotite. Although hitherto they have been thought of as a wholly basic group of rocks, more careful work reveals the fact that nearly a third of the whole series consists of granite, syenite, and a diorite often acid enough to be called monzonite. Pyroxenites, often chrysolitic, make up somewhat less than a third, while several varieties of norite comprise most of the remaining types. Trachyte, sodalite-syenite, gabbro, and many dike rocks are also represented, and there are moreover several contact developments of very peculiar and abnormal composition. Finally, emery has been mined for the last 30 years, chiefly along the borders of the district.

The Cortlandt Series is rather well known from the work already done on it by two eminent geologists, Professors J. D. Dana and G. H. Williams. Professor Dana* described the rocks in connection with his work on the limestone belts of Westchester County. He directed his attention especially to the origin of the rocks, giving only a brief general description of their petrographic characters. He noticed, however, that on Montrose Point several very different kinds of rock are associated in the most intricate way, generally as successive bands; and cites one case in which norite and pyroxenite are found in alternate layers of constant grain only three or four inches wide. There are also other less pronounced cases; and from these phenomena, as well as from the occasional streaked appearance of the rocks, Dana concludes that they were originally volcanic ashes or tuffs, which, on being subjected to intense local metamorphism, lost most of their bedded structure and became pseudo-massive. In his last paper, however, which is based on the revelations of the new railroad cut

* Geological Relations of the Limestone Belts of Westchester Co., N. Y., this Journal (3), xx, 194. Also, Origin of the Rock of the Cortlandt Series, *idem* (3), xxii, 103; and Note on the Cortlandt and Stony Point Hornblendic and Augitic Rock, *idem* (3), xxviii, 384.

through Stony Point, he abandoned his former explanation and pronounced the rocks truly igneous. In 1886 Professor G. H. Williams* published his first paper on the Series, and in it treats the rocks as unquestionably igneous. He also mentions their occasional streaked appearance, and points out that this is just what would be expected in igneous rocks which had undergone some regional metamorphism.

The present paper is therefore not the first to describe the structure, although it is the first to interpret it as originally igneous. Recognizing the existence of such an original gneissoid structure in other parts of the world, it becomes evident that Professor Dana has described several rather obvious examples of it. The northern part of Montrose Point, where these cases occur, is a complicated mixture of a biotite-augite norite† and an olivine pyroxenite, the latter lying mainly to the south and west. These varieties appear to interpenetrate very intricately, and occasionally a structure such as Professor Dana describes is to be found. The writer noticed in one case a streak, about four feet wide, of the coarse dark pink norite in a cliff of black pyroxenite. This comparatively narrow strip was coarser, if anything, than the pyroxenite, and was coarse moreover to its very edge, having thus none of the characteristics of a dike. Analyses of these two types, given below, show their great chemical differences.

It is in the various norites, however, that the structure is best shown. It may be stated first, as a general rule, that the finer grained a norite is, the simpler it is, i.e., a very fine-grained norite is composed chiefly of feldspar, with considerable hypersthene, while the coarser varieties carry in addition either hornblende or biotite and augite. The fine-grained simple norite is never found in large areas, but always as inclusions in the coarser and therefore more complex varieties. It often occurs in biotite norite, for example, as small, rounded flow-like patches, or again as streaks; or it may be banded with the coarser rock. In this case the chemical difference is not so great, as the accompanying analyses show

A. Biotite augite norite, from Montrose Point. Analysis by M. D. Munn, for J. D. Dana, this Journal (3), xxii, p. 104,

* The principal papers are: Peridotites of the Cortlandt Series, this Journal (3), xxxi, 26; Norites of the Cortlandt Series, *idem* (3), xxxiii, p. 135 and p. 191; and Gabbros and Diorites of the Cortlandt Series, *idem* (3), xxxv, p. 438.

† The names used to denote the different rocks are, it is believed, sufficiently explicit to obviate, for the purposes of this paper, a more detailed petrographic description. The analyses given serve the purpose; Professor Williams, in the papers cited above, gives very minute descriptions should these be desired.

1881. Contains andesine, augite, hypersthene, biotite, apatite and magnetite. Symbol, II. 5.3.4. *Andose.*

B. Augite peridotite (olivine pyroxenite) from Montrose Point. Analysis by W. H. Emerson, for G. H Williams, this Journal (3), xxxi, p. 40, 1886. Contains augite, hypersthene, hornblende, olivine, magnetite and pyrrhotite. Symbol, IV. 2.1.2.

C. Norite, from 1½ miles south of Peekskill. Analysis by G. S. Rogers. Contains orthoclase, andesine, hypersthene, a little biotite, apatite, ilmenite and magnetite. Symbol, II. 5.3.4. *Andose.*

D. Biotite norite, 2 miles east of Montrose Point. Analysis by G. S. Rogers. Contains orthoclase, labradorite, biotite, hypersthene, apatite, ilmenite and magnetite. Symbol, II. 5.4.3. *Hessose.*

	A.	B.	C.	D.
SiO_2	55·34	47·41	51·49	46·10
Al_2O_3	16·37	6·39	20·72	18·66
Fe_2O_3	·77	7·06	1·80	3·00
FeO	7·54	4·80	7·28	9·58
MgO	5·05	15·34	3·82	6·71
CaO	7·51	14·32	6·71	8·26
Na_2O	4·06	·69	3·70	2·57
K_2O	2·03	1·40	2·14	1·59
H_2O+	·58	2·10	·31	·18
H_2O-	----	----	·10	·10
TiO_2	----	----	2·26	2·88
P_2O_5	----	----	·15	·70
MnO	·40	----	·13	----
BaO	----	----	tr.	tr.
S	----	·49	·11	·18
Sum	99·65	100·00	100·72	100·51

Norms.

	A.	B.	C.	D.
or	12·2	8·3	12·2	9·4
ab	34·1	5·2	30·9	21·5
an	20·3	10·6	32·5	34·8
C	----	----	·5	----
di	14·0	47·9	----	5·0
hy	11·4	6·7	13·8	3·0
ol	5·3	8·6	2·9	15·9
mt	1·2	10·2	2·6	4·4
il	----	----	4·2	5·3
ap	----	----	·4	1·2

Now if the simpler norite be not quite so fine-grained it will not be entirely pure; and this is the case in most places. In fig. 1 the mass of the rock is a biotite-augite norite, while the white streak is merely a finer and therefore simpler facies, containing only small amounts of biotite and augite. In one place it shows an included patch of the coarser rock. Fig. 2 shows the same relations on a smaller scale, but in better

Fig. 1.

Fig. 2.

Figs. 1, 2. Original gneissoid structure in the Cortlandt Series.

development, so that the rock might easily be mistaken for a real metamorphic gneiss. A number of other equally good instances might be shown, for the structure is quite common; but these suffice to show its general aspect. It may be added that none of the rocks of this series exhibit any great amount of shearing; and that in all the cases examined which show this flow structure, it is absent, even in thin section. The phenomenon could not, therefore, be due to ordinary regional metamorphism.

The classic locality for this structure is on the Isle of Skye, in Tertiary gabbro, where it was first described as such by Sir Archibald Geikie and Professor Teall.* From their photographs it appears to be little, if any, better developed than in the Cortlandt. The same structure, however, has been described in wonderful perfection by Professor A. G. Högbom* from the Island of Ornö, just south of Stockholm. Here the black and white bands are narrow and numerous, and may be traced for 60–80 meters with the utmost ease. The zone in which this development occurs constitutes the periphery of an igneous (dioritic) complex. It is also found strikingly developed near Montreal; this occurrence will be described by Professor Frank D. Adams in a forthcoming work.

The explanation now accorded this phenomenon is simple and plausible. Eliminating Dana's idea of worked-over volcanic ashes, and Williams' suggestion of the ordinary regional metamorphism of igneous rocks, we are thrown back on some force concomitant in its action with the cooling of the rock. Since the several layers or streaks are always quite different in mineralogical composition, and more or less so in chemical, it is evidently a question of magmatic differentiation. It is inconceivable that the structure be due to the differentiation of a magma *in situ*—after it has reached its present position—since the differentiation is into bands which bear no definite relation to the borders of the magma; and the idea of successive intrusions—first of a light band and then of a dark—is equally inapplicable, since even when there is a sharp line of demarcation separating two bands, the individual grains seem to interlock across the line. The only remaining hypothesis, therefore, is that of the intrusion of a molten mass already heterogeneous. Professors Geikie and Teall ‡ push their conclusions thus far; Mr. Harker § goes a bit further. He appears to favor the view that the structure is due to the approximately simultaneous intrusion of two different magmas, which would give rise to a thorough interpenetration of the two. This would explain why the banded structure, which always shows evidence of flowage, is seldom straight and clear-cut. The assumption would be then that the mass must have

* On the Banded Structure of some Tertiary Gabbro on the Isle of Skye. Quar. Journ. Geol. Soc., Nov. 1894, i, 646.

† Zur Petrographie von Ornö Hufvud, Bull. Geol. Instit. Upsala, x, 150.

‡ Op. cit.

§ Natural History of Igneous Rocks, New York, 1909.

promptly begun to cool and harden while resting quietly, as otherwise the two magmas might combine to form a third and homogeneous one. Mr. Harker's alternative view is that the mass was intruded as a unit, already heterogeneous, the two different magmas having been partly mixed before intrusion. Whichever be the correct theory, it is evident that in the Cortlandt Series the simple norite magma was very small in comparison with the more complex norite magmas, since the former always appears as included bands in the others, while these latter cover extensive areas.

It is interesting to note that here, as in most of the other examples of this structure, there have been distinct changes in our conception of its significance. The old school of American geologists, of which Professor Dana was the last great disciple, were very prone to consider as worked-over sediments what are now called true igneous masses; and he therefore even adduced this structure to prove the sedimentary origin of the rocks. Dr. Williams, on the other hand, was one of the early exponents of the school which has laid great stress on metamorphic action in igneous rocks, and he accordingly passed it over without concern, as being merely an evidence of regional metamorphism. To-day we are passing—or perhaps have passed—through yet another change; Vogt, Högbom, Harker, Adams, Pirsson, Kemp and others are now, in the light of our present greater knowledge, reading into igneous action many attributes, for the manifestation of which an entirely different origin had hitherto been postulated. The formation of this original gneissoid structure is a case in point. Up to the present it has not been recognized in many localities; should it be found to be more common than is now thought, however, it may prove illuminating (as Sir Archibald Geikie suggests) in connection with some of the puzzling structures of the ancient and obscure igneous gneisses.

Columbia University, New York.

Art. XVII.—*Thaumasite from Beaver County, Utah*;* by B. S. Butler and W. T. Schaller.

Introduction.

The interesting mineral thaumasite was first described in 1878 by Baron von Nordenskiöld† from material collected at the copper mines of Åreskuta, Jemtland, Sweden. Since that time it has been noted from other localities in Sweden and in 1896 it was described by S. L. Penfield and J. H. Pratt, from Berger's quarry, West Paterson, New Jersey. The latter locality is the only one where it had been noted outside of Sweden, previous to the one here described.

During the summer of 1909 one of the authors (B. S. Butler) while engaged in a geological survey of the Frisco district, Beaver County, Utah, found a mineral of unusual appearance which on examination in the office proved to be thaumasite. The mineral was found in the Old Hickory mine of the Majestic Copper Company, located in the Rocky Range, Rocky district, Beaver County, Utah, about four miles northwest of the town of Milford on the Salt Lake, Los Angeles and San Pedro Railroad.

Geological Occurrence.

The Rocky Range is built up at the southern end, where the mine is located, of a series of interbedded dolomitic limestones and quartzites of probably Carboniferous age which have been intruded by monzonite. The intrusion of the monzonite has produced typical contact alteration of the limestone, resulting in the formation of magnetite, garnet and pyroxene with some pyrite and chalcopyrite. At the Old Hickory mine the limestone for several feet from the contact has been largely replaced by magnetite, with a small percentage of the contact silicates, and sulphides of iron and copper. As the distance from the contact increases the amount of magnetite decreases and the contact silicates become correspondingly more abundant, and these in turn give place to the carbonates composing the limestone. The zone of magnetite carrying copper values as chalcopyrite and secondary alterations of this mineral (covellite, chalcocite and copper carbonate) has furnished the ore that has been shipped from the mine. In the general vicinity of the mine and especially to the north and northwest, there are veins in the limestone from a fraction of an inch to upwards of a foot in width, composed of a dense white mate-

* Published by permission of the Director of the U. S. Geological Survey.
† Comptes Rendus, vol. lxxxvii, p. 313, 1878.

rial with conchoidal fracture that on analysis proved to be composed largely of magnesium carbonate with some calcium carbonate. These magnesite veins, however, were not observed in the Old Hickory mine.

The Old Hickory mine has been developed to a depth of about 300 feet and four levels have been opened. A vertical shaft extends to the lowest level while the second level, about 100 feet deep at the shaft, is connected with the surface by a tunnel. The first level is about 80 feet below the surface and about 20 feet above the tunnel level. On this level the magnetite body has been opened for a distance along the strike of about 125 feet. To the east of this, from 10 to 25 feet from the magnetite body, a parallel drift has been run in the altered limestone. One hundred feet south of the shaft a crosscut from this drift extends to the east about 25 feet, where it encounters quartzite. Throughout this eastern drift and crosscut are a great number of veins of white material varying from the thickness of paper to upwards of two inches. To the north of the crosscut many of the veins are open with crystals projecting into the openings while others are composed of a dense white substance completely filling the space. The material from these veins proved on examination to be a mixture of quartz and carbonate, the latter probably largely calcite. In the east crosscut just east of the drift and extending across the drift to a crosscut on the opposite side, is a zone of veins having a general northeast-southwest direction, though the individual veins vary in direction and are connected by crossveins making a network. These are composed of thaumasite completely filling the fissures.

The fissuring occurred later than the contact metamorphism of the limestone and the filling of the fissures with thaumasite of course occurred at a still later period. The thaumasite was not found associated with the quartz and carbonates in the same veins and the relative age of the minerals was not determined. At the Paterson, New Jersey, occurrence of thaumasite, the mineral is in trap associated with heulandite, apophyllite, laumontite, pectolite, chabazite, scolecite, and natrolite, the thaumasite crystallizing later than the zeolites. No zeolites were found associated with the thaumasite at the Old Hickory mine, though these were especially looked for. It seems probable, however, that the mineral was found under physical conditions similar to those favorable to the formation of zeolites.

Physical Characters.

In the hand specimen the thaumasite from Beaver County is a nearly pure, white mineral with silky luster due to its fibrous character. It is readily recognized in the field as an unusual mineral by its silky luster and lightness (specific gravity 1·84). Under the microscope it is seen to be composed of minute slender prisms, none of which showed terminal faces. Microscopically it is most readily distinguished by its low index of refraction and rather high double refraction; $\omega=1{\cdot}507$, $\epsilon=1{\cdot}468$, as determined by Lévy and Lacroix. The indices of refraction for the Beaver County mineral were approximately determined by immersion in solutions of known index as $\omega=1{\cdot}500+$, $\epsilon=1{\cdot}464+$. The mineral extinguishes parallel to the elongation of the prisms and is probably hexagonal, as it has been found to be in the previously described occurrences. Crystals suitable for measurement and exact determination of the refractive indices were not found.

Chemical Composition.

A determination of the density of the thaumasite by means of the Joly balance gave the value 1·84. A second determination, using the Thoulet solution and small fragments of the mineral, gave the value 1·85. These figures are slightly lower than those found by Penfield (1·88) on the New Jersey thaumasite.

The analyses of the Utah thaumasite, with the ratios deduced therefrom, are shown below.

Analyses and ratios of thaumasite, Utah.

SiO_2	10·14	·169	1·06	1
SO_3	12·60	·156	·98	1
CO_2	6·98	·159	1·00	1
CaO	26·81	·479	3·00	3
H_2O	42·97	2·387	14·95	15
$(Al,Fe)_2O_3$	·20	·002 }	·05	
MgO	·23	·006 }		
Alk.,P_2O_5	trace			
	99·93			

The ratios agree very closely with the established formula $3CaO.SiO_2.SO_3.CO_2.15H_2O$ and the mineral is very pure, only a trace of some foreign matter, probably a silicate, being present.

A comparison of the analyses of the mineral from Utah, from New Jersey and from Sweden (the average of the three original analyses given by Lindström), strikingly shows the uniform composition of this rare mineral.

Comparison of analyses of thaumasite.

	Jemtland, Sweden.	New Jersey.	Utah.	Theory.
SiO_2	9·70	9·26	10·14	9·64
SO_3	13·02	13·44	12·60	12·86
CO_2	6·86	6·82	6·98	7·08
CaO	27·28	27·13	26·81	27·01
H_2O	42·20	42·77	42·97	43·41
$(Al,Fe)_2O_3$	·16	----	0·20	----
MgO	----	----	0·23	----
Na_2O	·11	0·39	tr.	
K_2O	·08	0·18		----
P_2O_5	---	----	tr.	----
Cl	·12	----	----	----
	99·53	99·99	99·93	100·00

The new locality in Utah makes the third general locality in which this mineral has been found, or the fifth distinct mine, the three localities in Sweden being fairly close together.

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Art. XVIII.—*Nomenclature of the Lower Paleozoic Rocks of New York*; by H. P. Cushing.*

Introduction.—Work on the early Paleozoic rocks of northern New York during the past few years has not only added materially to our knowledge concerning them, but has emphasized the necessity of certain modifications and certain amplifications of the nomenclature. Since these results are scattered through various official publications, it is believed that a summary of them will be a convenience to many.

Though begun by Cushing, the work has been actively participated in by Drs. Ulrich and Ruedemann. We have been so closely associated, and have so freely shared ideas, both in the field and in correspondence, that it is now an utter impossibility to assign to each his appropriate share. The writer therefore appears here merely as the scribe, and not at all as the sole author.

The Saratogan Formations.

Ulrich and Cushing have, in a recent paper, presented the detailed evidence which has led to the belief that the Little Falls dolomite, formerly classed with the Beekmantown, belongs rather in the same group with the Potsdam sandstone. It is not the intention to repeat the discussion here, but merely, for the sake of completeness, to note the matter.† The Saratogan in New York consists of the Potsdam sandstone below and Little Falls dolomite above, with a series of passage beds between named the Theresa formation. The Little Falls dolomite is shown to be the equivalent of the basal division and a half of what was formerly classed as Beekmantown in the Champlain valley. It comprises division A and the lower half of division B. In the Mohawk valley the Potsdam disappears because of overlap and the Little Falls rests on the Precambrian. In the Black river valley both disappear and still younger beds lie on the Precambrian.

The fossiliferous limestone which overlies the Potsdam at Saratoga and which furnished the fauna described by Walcott and determined by him to be upper Cambrian, was named the Greenfield limestone by Clarke and Schuchert.‡ This name was preoccupied, having been applied by Grabau to an Ohio formation of Monroe age. We propose to call it the Hoyt limestone, and we regard it as a local, calcareous phase of the basal portion of the Little Falls dolomite, of which it becomes a member. It is exceedingly local, being confined, so far as

* Published by permission of the State Geologist of New York.
† Bull. 140, N. Y. S. M., pp. 97-140. ‡ Science, Dec. 15, 1899.

surface exposures are concerned, to the immediate vicinity of Saratoga.

The Potsdam and Little Falls are the only two absolutely conformable formations in the entire early Paleozoic section of New York. In all other cases there is an unconformity between formations and frequently between subformations. To draw the line between Cambrian and Ordovician at this horizon is thus to draw it at the one place where there was continuous deposition between two formations. Structurally and faunally the Potsdam and the Little Falls belong to the same system and group. Their normal affiliations are with one another. And there is no diastrophic warrant whatever for putting a systemic boundary between them.

The Beekmantown Group.

In this paper just cited, Ulrich and Cushing separated from the Little Falls dolomite the upper division, heretofore classed with it, which Vanuxem called the "fucoidal beds," and which careful reading of his report shows that he would himself have separated as a distinct formation, had his district alone been in question. The name proposed for this new division is the Tribes Hill limestone. It is much more calcareous and more fossiliferous than the Little Falls, and there is a distinct and widespread break between the two. Ulrich regards the fauna as of earliest Beekmantown age, and on the basis of his determination the line between the Beekmantown and Saratogan is drawn at this break. This formation is the only representative of the Beekmantown which occurs on the south and west sides of the Adirondack shield.

In the Champlain valley Brainard and Seely some years ago divided the Beekmantown into five subdivisions, which they lettered from A to E.* The equivalence of division A and the lower half of B with the Little Falls dolomite, and the impropriety of classing them as Beekmantown at all, having now been shown, there yet remain the upper three and one-half divisions, with a thickness of from 1300 to 1400 feet. The thorough faunal study of this formation, and its proper subdivision and naming, constitute the most important problem which awaits the investigator of the early Paleozoic rocks of New York. It is reasonably certain that the four lithologic divisions of Brainard and Seely will require much readjustment, when the faunas are collected and studied, and it would be folly therefore to give them names as at present constituted.

It is not known whether the Tribes Hill limestone is present in the Champlain valley or not. If it be, it is represented

* Bull. Am. Mus. Nat. Hist., vol. iii, pp. 1–23.

in the dove limestones of division B; but up to the present these have furnished no fossils and precise correlation cannot be made until these are forthcoming. We greatly doubt its presence; we doubt if the Beekmantown of the Champlain valley has a single member in common with that of the Mohawk. And certainly, with the exception of the Tribes Hill, Beekmantown deposition in New York was confined to the Champlain trough and to its prolongation southward; and to a branch trough extending up the St. Lawrence valley. The Mohawk and Black river valleys were unsubmerged. And, during Tribes Hill time on the other hand the Mohawk and lower Black river valleys were submerged, the Champlain valley probably not. This contrasted distribution might seem to support the recent suggestion of Raymond that the Tribes Hill should be classed with the Little Falls dolomite beneath rather than with the Beekmantown.* Raymond's argument is wholly paleontologic, and must be answered by a paleontologist. There was oscillation both preceding and succeeding the Tribes Hill, and the relative importance of the two breaks cannot be determined in New York. To be able to class the Tribes Hill with the Little Falls would much simplify areal mapping in the Watertown region, where the Saratogan has comparatively meager representation. The thinned western edge of the Potsdam is present, followed by some 25 feet of passage beds (Theresa). These are directly overlaid by a similar small thickness of impure limestones with the Tribes Hill fauna. The Tribes Hill beds are so like the calcareous members of the passage beds beneath that Cushing was constrained to map the two together as a single lithologic unit. And yet, according to our results, the boundary between two systems must lie midway in that thin, lithologic unit. But Ulrich is positive in his correlation of the faunas and, in reply to the incongruity of distribution between the Tribes Hill and the remainder of the Beekmantown, points out that the early Devonian was characterized by similar incongruity, the distribution of the Helderberg and Oriskany rocks contrasting sharply with that of the Onondaga and its successors.

The Chazy Group.

There is an unconformity between the Beekmantown and Chazy groups which marks a time of extensive withdrawal of the sea from the New York region. Like their Beekmantown predecessors the Chazy rocks in New York are chiefly restricted to the Champlain trough. They do not however run southward along that trough as the Beekmantown rocks do, but

* This Journal, Nov., 1910.

pinch out before the upper end of Lake Champlain is reached; and are wholly absent at Ticonderoga and all points south of that within the State.

In the Champlain valley the group is separable into three well-marked formations, as Brainard and Seely were the first to show.* These were named by Cushing the Day Point, Crown Point and Valcour limestones.† More recently a formation of supposed Chazy age has been recognized and described in the Watertown region and named by Cushing the Pamelia limestone.‡ It has a length of outcrop of some 70 miles in the State of New York, and probably an even greater extent across the border in Canada. In this district it rests either on Tribes Hill, Theresa or Potsdam, or else on the Precambrian, and is overlain unconformably by the Lowville. It cannot be successfully correlated with any of the Champlain Chazy, either lithologically or faunally, and seems to represent a deposit in a wholly separate basin; and therefore evidence as to its precise position must be obtained from without the State.

In 1896 Winchell and Ulrich revived Safford's name *Stones River* group for the deposits of the interior basin, or basins, representing the Chazy interval; or more strictly speaking, the lower and middle Chazy interval (Day Point and Crown Point) of the Champlain section.§ The Chazy and the Stones River basins of deposit were for the most part separate, with but slight and interrupted opportunity for commingling of faunas. The Pamelia limestone is the New York representative of the Stones River group, but represents only its extreme upper portion.

The southern Pennsylvania section which has recently been described by Stose seems to furnish the evidence desired for closer correlation of the Pamelia.‖ Ulrich studied the faunas and furnished the correlation statements for that folio, and the correlation with the New York formations, as here given, is due to him. The Beekmantown of the Chambersburg region is overlaid by the Stones River formation, with a maximum thickness of 1050′; and this by the Chambersburg limestone, of 750′ maximum thickness. Ulrich regards the Pamelia as the equivalent of the upper part of the upper division of the Stones River of the Chambersburg section. The middle division, which carries *Maclurea magna* and other fossils is regarded as the equivalent of the New York middle Chazy (Crown Point limestone).

* Am. Geol., vol. ii, pp. 323–330.
† Bull. 95, N. Y. S. M., p. 368.
‡ Bull. G. S. A., vol. xix, p. 161; Bull. 145, N. Y. S. M., pp. 68–79.
§ Geol. Surv..Minn., vol. iii, p. xc.
‖ Mercersburg-Chambersburg Quadrangles, Folio 170, U. S. G. S.

On the Mercersburg quadrangle the basal 150–170′ of the Chambersburg limestone carries a fauna which, on the basis of several identical species, among them *Rhynchonella plena*, Ulrich correlates with the upper Chazy (Valcour limestone) of the New York section. This directly overlies the upper Stones River (Pamelia), and just above it the Lowville fauna comes in. Hence it follows that the New York Pamelia is, in age, intermediate between the middle and the upper Chazy of the Champlain Valley, and that there must be a break there between those divisions. Also that the New York Chazy consists of four divisions, Day Point, Crown Point, Pamelia and Valcour limestones. And further, that Chazy deposition was confined to the Champlain trough until Pamelia time; that then the northwest border was overlapped by the sea which withdrew, at the same time, from the Champlain trough; and that, at the close of the Pamelia, the reverse oscillation took place, the sea returning to the Champlain trough and withdrawing on the northwest.

Lowville and Black River Limestones.

In their readjustment of the nomenclature of the New York formations in 1899, Clarke and Schuchert gave the name Lowville limestone to the formation previously called the Birdseye.* Also, following the custom which had gradually grown up in the State, they classed the darker-colored limestones between the Lowville and the Trenton as Black River limestone. This usage of Black River did not at all accord with that of the early New York geologists, but was convenient and had gradually become customary. However, the type sections of neither had received detailed study, and hence they had not been precisely defined.

In their areal mapping in the Watertown region in 1907–08 Cushing and Ruedemann found the typical, thin-bedded, dove limestones of the Lowville to be overlaid by a thickness of 25–30′ of thick-bedded, black, blocky limestone, above which followed the Trenton. An uncomformity was also detected between the black beds and the dove limestones. The black limestones constituted a natural, lithologic unit, and we so mapped them and called them Black River, this being the type region of the formation. Subsequent study of the section in company with Ulrich disclosed another break midway in the black limestones, separating them into a lower portion with much chert, and an upper in which chert was chiefly lacking, and whose chief member is the massive, chertless bed known as the *7 foot tier*. That this upper break was a more con-

* Science, Dec. 15, 1899.

siderable one than that between the black and dove limestones was suggested by the limited distribution of the 7 foot tier as compared with that of the chert beds beneath, the latter accompanying the Lowville all the way up the Black River valley and also across into Ontario, while the 7 foot tier was restricted to the immediate vicinity of Watertown. Ulrich also urged that, in many localities without the State where he had studied the sections, the lower break was bridged by deposit, so that the dove limestone Lowville graded upward into the cherty beds; and that the sharp lithologic difference between the two in the Watertown region was local, rather than the general rule. He conceded that at Watertown the natural method for areal mapping purposes was to class the two black limestones, the chert beds and the 7 foot tier, together as we had done. But he emphasized the fact that this was not the usual rule, that in many districts no separation of the chert beds from the Lowville was possible, and that the name Lowville limestone was capable of vastly more extensive application as a formational name were the chert beds included in the formation at the type locality.

Ruedemann, Ulrich and Cushing had also, during 1907, 1908 and 1909, carefully studied the beds, latterly called Black River, in many localities on all sides of the Adirondack region. These beds are mostly thin, and often of patchy distribution, especially in the Mohawk valley, and we found that they were of quite various age, representing the thin, shoreward edges of embayment deposits, with repeated and quite local oscillations of level. Plainly a considerable time interval was represented, and the term *Black River* was one of very loose application.

In the final reports of the four geologists of the early survey (1842) the name Black River limestone was somewhat variously used by the different men, though the statements of Vanuxem, Mather and Hall in regard to it do not greatly vary. They make it include the interval between the Calciferous and the Trenton. Vanuxem heads his chapter on the group as follows :

"Black River limestone. Synonyms—Birdseye limestone, Mohawk limestone, base of the Trenton limestone, as used in the reports of the Third District. Black marble of Isle la Motte, Seven-foot-tier, and Chazy limestone of Dr. Emmons, *the latter mass connecting the Birdseye with the Calciferous sandrock proper.*"*

The formation was chiefly confined to the Second and Third Districts, and Mather and Hall, in their reports, apparently simply followed Vanuxem.

* Geol. 3d Dist., p. 38.

Emmons did not use the term Black River at all, though the Chazy was practically confined to his district, and the remainder of the formation was as fully shown as in the Third district. It is, however, quite differently shown. He plainly did not sympathize with the term, and probably objected to the inclusion of Chazy in it. The above quotation also indicates that Vanuxem did not feel sure of the propriety of extending the term to cover the Chazy. Emmons used instead the terms Chazy limestone, Birdseye limestone, and Isle la Motte marble, and did not sanction the use of a group term to include the three. Emmons correlates the 7 foot tier at Watertown with the black limestone at Glens Falls, Chazy, and Isle la Motte. But the Glens Falls, Chazy and Isle la Motte occurrences represent the horizon of the chert beds rather than that of the 7 foot tier.

Vanuxem's broad use of the term Black River has been consistently followed by some writers since, and notably so by the Geological Survey of Canada.

In the first volume of the Paleontology (1847) Hall seems to advocate a quite different use of the term, though he nowhere makes an explicit statement to that effect and there is little evidence that he had any detailed acquaintance with the Watertown section. The most specific statement made is at the bottom of p. 41, where he says that *Murchisonia perangulata* "occurs in a siliceous, cherty mass of the *Birdseye limestone* . . . . near the upper termination of the rock at Watertown." Now there is little or no chert in the Lowville proper and it seems that the reference here can only be to the cherty beds just under the 7 foot tier, which Cushing and Ruedemann mapped with it as a single lithologic unit. If Hall regarded the chert beds as Birdseye he must have restricted the use of Black River substantially to the 7 foot tier.

Since the appearance of Hall's report there has been no use of the term Black River in New York in the comprehensive Vanuxem sense. A usage has grown up however which is not so sharply restrictive as that of Hall, namely that of calling everything Black River which lies between the Lowville and the Trenton. As thus used the term had no precision, since it had not been determined just what was included in the Lowville. Our recent work about Watertown, which we extended so as to include study of the type section at Lowville, gave precise definition to the Lowville formation for the first time.* At the same time a very complicated and difficult nomenclatorial problem was presented. If we included the chert beds with the 7 foot tier as Black River, in accord with present New York usage, and excluded them from the Lowville, as the Watertown sections seemed to suggest we should do, diffi-

* Bull. 145, N. Y. S. M., pp. 79-86.

culties arose in the Champlain sections, and Ulrich urged difficulties without the State, which rendered it impossible to give either of the names Lowville and Black River as wide application as they might otherwise secure. If we adopted Hall's restricted use of Black River we practically wiped it out as a New York name, since the 7 foot tier is thin and occurs only about Watertown. It was finally decided, therefore, that it would be best to revert to Vanuxem's usage (except for the inclusion of the Chazy) and to apply the name Black River to the entire rock group between the Trenton and the Chazy, the usage which the Geological Survey of Canada has consistently followed. The Lowville thus becomes the lower division of the Black River group. The black, cherty beds of the Watertown region, between which and the typical Lowville an unconformity exists, we class provisionally as the uppermost member of the Lowville, and name it the Leray formation, from the river exposures in Leray township, Jefferson county. The section there is, however, not complete. At Lowville, for example, is a thickness of 5′6″ of cherty limestone with *Columnaria halli* and *Stromatocerium rugosum* not seen at Watertown. And to the south, at Newport, in the valley of West Canada creek, this Stromatocerium bed is the sole representative of the formation, the remainder having disappeared.

The Champlain valley seems a wholly separate trough of deposit for these beds. There is present a trifling thickness only of Lowville proper, followed by black, massive beds in much greater thickness than elsewhere in New York. The upper portion of these black beds seems to represent the Leray horizon, and the remainder to bridge the interval represented by the break between the Lowville and Leray in the Watertown sections. The Champlain succession seems unbroken, but deposit did not commence there till late in Lowville time.

The upper subdivision of the Black river group in New York (the Lowville being the lower) is nowhere represented by any considerable thickness of deposit, with the possible exception of the extreme east, where the shales of the Levis channel, overthrust to the west, are met with. Otherwise the deposits are thin, scattered, and of quite varying age, indicating repeated oscillations and prevalence of near shore conditions throughout. In the Watertown sections we group with the 7 foot tier the massive bed below, and the thin one above, into a formation of 13′ thickness which we call the Watertown limestone. It occurs only in the immediate vicinity; and otherwise there is no representative of the upper Black River on the western side of the Adirondack region.

Amsterdam limestone.—There is present in the eastern Mohawk sections and the Saratoga region a limestone of Trentonish aspect, which the early geologists were clear-sighted enough to distinguish from the typical Trenton. Conrad called it the Mohawk limestone; but this term was variously used by the different geologists, was hence abandoned in the final reports, and instead the formation was referred to as "base of the Trenton" limestone. The rock is chiefly in the third district, and that most excellent geologist, Vanuxem, discusses it in his chapter on the Black River limestone, with which he classes it notwithstanding the name used.* We propose to call it the Amsterdam limestone. It has of late years been usually referred to as Trenton, both along the Mohawk and at Saratoga, but is older than anything in the type section at Trenton Falls, and is properly referable to the Black River, forming the youngest division of the group in New York. It is also a deposit in a different trough from that of the type Trenton and, during Amsterdam time, the entire western border of the Adirondacks was unsubmerged. The Amsterdam is emphatically a deposit of the eastern and southeastern border only. On the southeast (eastern Mohawk and Saratoga) it rests on the Tribes Hill or Little Falls and is followed by shaly limestones and shales, or simply by shales. In the Champlain valley true Trenton limestone overlies the Amsterdam, though even here only the lower Trenton consists of limestone. In the lower Mohawk region the bulk of the true Trenton consists of shale, with some thin, intercalated limestone bands in the lower portion.

The view here urged in regard to this formation is nothing but the old view of Conrad and Vanuxem, and a new term is proposed for the formation because of the confusion attending the use of the term Mohawk limestone in the Annual Reports, and its ultimate abandonment by the proposers; and also to avoid conflict with Clarke and Schuchert's useful and more comprehensive term Mohawkian.† The type sections are along the Mohawk in the vicinity of Amsterdam.

The shales.—Above the Black River or the Trenton limestones black shales follow, in all the New York sections. In the Champlain region limestone deposit continued through the lower Trenton, but the upper Trenton is represented by shales, with occasional thin limestone bands; in the eastern Mohawk and Saratoga sections the shales follow the Amsterdam, and the entire Trenton consists of shales except for the immediate base which consists of alternating, shale and thin limestone bands; in the western Mohawk sections there is again a

* Geol. 3d Dist., pp. 43-5. † Science, Dec. 15, 1899.

limestone of lower Trenton age followed by shales and thin limestone bands; only in the western border sections (West Canada creek and Black river) did limestone deposition continue through to the end of the Trenton. Much of shaly Trenton has heretofore been called Utica. As the result of recent work Ruedemann has the problem of the age of these shales well in hand, and with most important results.

Paleozoic Submergence of the Adirondack Region.

Some years ago Cushing expressed the view that the entire Adirondack region was submerged during Utica time, basing the opinion on the thickness of the Champlain Paleozoic section (Potsdam-Utica) and the present altitudes of the Precambrian summits of the Adirondacks. The assumption was that the successive seas overlapped ever more extensively on the oldland, without extensive downwarping of the marine troughs. It was further thought that the Utica shale was found on all sides of the region.* Shortly afterwards, and independently, Ruedemann expressed the same view, his argument being that the orientation of the graptolites in the shales indicates currents clear across the region.†

Our recent results cast much doubt on the correctness of these previous views. As the evidence accumulates it points more and more strongly to deposit in downwarping troughs, in which large depth of deposit by no means implies *extensive* overlap on the shores. Usually also deposit on the east side of the region was coincident with sea-withdrawal on the west, and vice versa. Even when submerged at the same time, as in the Trenton, the deposits on the two sides are so different, both lithologically and faunally, as to indicate that the two basins had no very direct connection. Entire submergence of the Adirondack tract during the Utica appears unlikely. It follows that there has been no complete submergence of the area since the earliest Precambrian.

Chart.—In order to present more concisely the nomenclature modifications suggested in this paper, the chart below is hereappended. It makes no pretence of completeness so far as the major division are concerned, giving simply the chief groups into which the rocks present are divided, their subdivisions, and the general sections of the northwest, southwest, south, southeast and northeast borders of the Adirondacks.

* 18th Rep., N. Y. State Geol., pp. 76–7.
† Am. Geol., Feb. 1898, p. 75.

	Watertown region	Trenton Falls	Mohawk valley	Saratoga vicinity	Champlain valley
	Utica shale	Utica shale	Utica shale	Utica shale	Utica shale
Trenton group	Trenton limestone	Trenton limestone	Trenton shale Trenton limestone	Trenton shale	Trenton shale Trenton limestone
				Amsterdam limestone	Amsterdam limestone
Black River group	Watertown limestone Leray limestone Lowville limestone	Leray limestone Lowville limestone	Lowville limestone		Black River limestone
Chazy group	Pamelia limestone				Valcour limestone Crown Point limestone Day Point limestone
Beekmantown group	Tribes Hill limestone		Tribes Hill limestone		Division C, D and E of the Beekmantown Tribes Hill limesto'e (?)
Saratogan	Theresa formation Potsdam sandstone	Little Falls dolomite	Little Falls dolomite	Little Falls dolomite Hoyt limestone Theresa formation Potsdam sandstone	Little Falls dolomite Theresa formation Potsdam sandstone

NOTE.—Parallel lines represent the greater, and dotted lines the lesser unconformities. Unbroken lines represent absence of breaks.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The Determination of Copper as Sulphate.*—Recoura states that he has made a practice of weighing copper as anhydrous sulphate and finds the method extremely simple and accurate, although it does not appear that the method has been previously recommended. When a neutral solution of copper sulphate is evaporated to dryness and the residue is heated in the oven to 180–200° C., it loses the last traces of water with considerable difficulty, and this fact is undoubtedly the reason why the determination of copper in the form of the sulphate has not been used. But Recoura has found that such is not the case when a solution of copper sulphate containing free sulphuric acid is thus evaporated and heated. Even when the amount of sulphuric acid is small, the salt when heated a short time at 180–200° contains neither water nor sulphuric acid and reaches a constant weight. The following results are given where exactly 1 g. of copper sulphate was taken in each case :

Time of heating at 190°	Neutral solution Residue	Acid solution Residue
1 hour	1·0045	1·0005
2 hours	1·0040	1·0001
4 "	1·0022	
48 "	1·0006	

It appears, therefore, that the method is satisfactory, and that it is to be preferable to the method of weighing cuprous sulphide, at least in many cases. Many compounds of copper which contain nothing that is not volatile at 200° may be treated with dilute sulphuric acid in a platinum capsule, and then simply evaporated, heated to 180–200° for two hours and weighed. Other compounds of copper which are not directly soluble in dilute sulphuric acid may be first dissolved in a little concentrated nitric acid, and then treated as before. The sulphide requires roasting in a porcelain crucible over a good burner before dissolving in nitric acid.—*Bulletin,* IV, vii, 832.

H. L. W.

2. *A New Method for Determining Boiling Points and Vapor Pressures.*—Smith and Menzies of Chicago University have devised an important method for making these determinations in a very simple way with the use of very small quantities of substances. The substance is placed in a small glass bulb having a capillary tube which is bent in a semi-circle just above the bulb, so that its straight, open end is directed downward. The bulb tube is then attached to a thermometer, and placed in a heated liquid bath according to the usual manner of making melting-

point determinations. When the boiling point is reached vapor escapes from the capillary tube, and this may rise through the liquid of the bath as bubbles or be absorbed by it according to circumstances of solubility. In determining the boiling point the temperature is raised somewhat above the required temperature, then by cooling the point is found where the bubbles cease to be given off, or the liquid recedes in the capillary tube. For taking vapor pressures the apparatus is modified so that the heating is carried out in a test-tube containing some of the liquid used as a bath, and this in turn is placed in a beaker containing the same liquid. The test tube is closed with a stopper through which passes the thermometer as well as a glass tube connecting with a manometer and also with suction or compression apparatus. With this arrangement boiling points may be taken at various pressures, and of course these give the vapor pressures.

The quantity of substance required for these determinations is only about 0·1 g, and it is important to notice that the boiling points of solids which do not melt, as well as liquids, may be taken in this way. The liquids recommended for use as a bath are, besides water, sulphuric acid of 92·75 per cent, paraffine of M. P. 53°, a two nitrate mixture with KNO_3 and $NaNO_3$ in the proportion 54·55 to 44·5, and a three nitrate mixture with $NaNO_3$: KNO_3 : $LiNO_3$ :: 18·18 : 54·54 : 27·27. A correction for the pressure of the liquid of the bath above the opening of the capillary tube is required, and tables are given showing the specific gravities of the different liquids mentioned above at various temperatures. The authors give very satisfactory results of determinations made by the new method, and it is their opinion that the boiling points thus determined are more accurate than by the old methods, because there can be no difference in the temperature of the liquid, the vapor and the thermometer.—*Jour. Amer. Chem. Soc.*, xxxii, 897. H. L. W.

3. *The Reactions of Nascent Hydrogen in the Dry Condition.*—Vournassos has found that the nascent hydrogen produced by heating dry sodium formate is capable of combining with various simple substances which do not combine with hydrogen directly, but which form hydrogen compounds indirectly. Thus by heating sodium formate with phosphorus, or with sodium phosphites or phosphates, PH_3 is obtained; likewise H_2S is obtained by heating the formate with sulphur, sodium sulphite, or a sulphide of mercury, lead or tin. With arsenic AsH_3 is produced. Antimony gives a little SbH_3. Silicon does not react, but $SiCl_4$ and SiS_2 give a little SiH_4. B_2O_3 heated with metallic sodium and the formate gives a gas which appears to be BH_3. The nitrides give NH_3, the cyanides HCN, and the alkaline carbides C_2H_2.—*Comptes Rendus*, cl, 464. H. L. W.

4. *Synthetic Sapphire.*—Verneuil has obtained artificial sapphires by fusing before the oxyhydrogen blowpipe alumina mixed with 1·5 per cent of magnetic oxide of iron and 0·005 per cent of titanium dioxide. The ovoid masses obtained gave a

beautiful sapphire color, and had the same optical properties as the natural mineral. It is remarkable that the oxides employed should give a blue color.—*Comptes Rendus*, cl, 391. H. L. W.

5. *Influence of Temperature on the Compressibility of Metals.*—E. GRÜNEISEN'S experiments on this subject extended over a range of temperatures of −190° to 166°. He used a Cailletet pump for high temperatures and bombs filled with hydrogen gas for low temperatures. He, therefore, did not go above a pressure of 500 atmospheres. He finds that the compressibility increases with the temperature, or in other words the expansion coefficient diminishes with increasing pressure. Apparently with a linear expansion one must have a linear compressibility.—*Ann. der Physik*, No. 16, 1910, pp. 1239–1274. J. T.

6. *Ionization of the Atmosphere due to Radio-active Matter.*—This subject is of importance in regard to the observed difference between the case of transmission of wireless signals at night and in the daytime. A. S. EVE, McGill University, gives a table which indicates a decreasing ionization with altitude which can be detected at an elevation of 100 meters, and also that at 1000 meters the penetrating rays from the earth are ineffective ionizers.—*Phil. Mag.*, Jan., 1911, pp. 26–39. J. T.

7. *Thomson Effect.*—This has been measured by P. CERMAK in lead, mercury, tin, zinc, cadmium, and aluminium; the effect has been found extremely small, but never constantly nothing. In the transition from the solid to the liquid state the curve representing the Thomson effect is a continuous one; while that representing the change in resistance is a broken one.—*Ann. der Physik*, No. 16, 1910, pp. 1195–1215. J. T.

8. *Velocity Measurement of Röntgen Rays.*—A very voluminous paper on this subject has been published by E. MARX. He discusses various method-causes of error; maxima and minima in the bundle of rays, phase differences and other conditions. Various wave lengths were found, which depend so much upon these conditions that a definite wave length is apparently not reached. The paper concludes with a discussion of Bragg's theory, corpuscular theory of neutrals and doublets, and the bearing of the impulse theory on the existence of an ether.—*Ann. der Physik*, No. 16, 1910, pp. 1305–1391. J. T.

II. GEOLOGY.

1. *Osteology of Pteranodon;* by GEORGE F. EATON, PH.D. Memoirs of the Connecticut Academy of Arts and Sciences, vol. II, pp. 1–38 and pls. i–xxxi, July 1910.—In this volume Dr. Eaton discusses the morphology of the American pterodactyl genus Pteranodon, basing his descriptions upon material in the Peabody Museum of Yale University assembled by Professor Marsh and numbering in all no fewer than 465 individuals. Of this material but seven specimens, including the types of the three species

Pteranodon ingens, *P. longiceps*, and *P. occidentalis*, were sufficiently complete to form the immediate basis for research. No attempt is made to amplify specific descriptions and the author plunges at once into the osteology of the genus, during which certain details of specific distinction are mentioned.

The skull shows a complete obliteration of sutures, and in its extremely narrow proportions and the extension of the great supraoccipital crest and of the toothless jaw is utterly unique among vertebrates. The curious spirally grooved jaw articulation, resembling that of the pelican, though developed to a higher degree, the effect of which is to bow outward the rami of the lower jaws, together with the apparent presence during life of a gular pouch, is suggestive of fish-eating habits. The supraoccipital crest is compared with that of Phalacrocorax, Chelydra, and Chamæleo and its initial development is accounted for by the necessity for increased origin of the powerful temporal muscles. How far these spread over the crest is not known, but it is supposed that a secondary function of the crest must have arisen to account for its extreme development. In this connection a counterpoise for the long jaws and the effect of the crest as a vertical aëroplane cannot be entirely disregarded.

The cervical vertebræ, while apparently massive, are of extreme lightness of construction. As in certain birds the anterior dorsals are fused into a rigid notarium, then, after an interval of three or four free vertebræ, the long synsacrum of nine or ten coössified vertebræ appears, again very bird-like in structure. The tail was evidently very short and of little value in flight.

The shoulder girdle is very massive, the scapulæ articulating with a very distinct facet on either side of the fused dorsal spines of the notarium. There is a powerful sternum, somewhat keeled for the origin of the great muscles of flight.

The limb bones have been well described by earlier authors but note is taken of the various ways in which they may be modified by the crushing to which they have been subjected and which renders specific distinctions based upon these elements of little value. The phalangeal formula of the manus is correctly stated for the first time and shows the ordinary reptilian sequence of bones.

Two admirable restorations are given which are, however, composite, in that elements from more than one species had to be used in their construction. One shows the animal from the side, the other from below with wings broadly expanded as in the plaster replicas preserved in the Yale and U. S. National Museums and in the British Museum of Natural History, all of which were made under Dr. Eaton's supervision.

Dimensions of the various specimens under consideration are given, the most interesting being the alar expanse, conservatively estimated in that the bones were given their natural angulation. They range from *Pteranodon* sp. (Cat. No. 1181) with 3·390^{m}

(=11 ft. 1 in.) to *P. ingens* type (Cat. No. 1175) with 6·803^{m} (=22 ft. 3 in.). Still another individual (Cat. No. 2514), if the proportions of the known bones were carried out, would have the tremendous expanse of 8·163^{m} or 26 feet 9 inches!

The geologic and geographic localities of the seven described specimens are given — all from the Niobrara chalk of Wallace and Trego counties or from the Smoky river in western Kansas.

It is to be regretted that a specific summary was deemed inadvisable, for the author was certainly better fitted than any one else to attempt such revision. Nothing is said as to relationships with other Pterosaurs or of the life conditions other than the following brief suggestion on page 13:

"The occurrence of Pteranodon remains in the chalk deposited in a shallow sea and at a distance of not less than one hundred miles from the probable shore line, also the shape and proportionate size of the jaws, have given rise to the supposition that this pterodactyl lived principally upon small fish taken at the surface in a manner somewhat similar to that adopted by the Skimmer, Rhynchops."

The only suggestion in the way of a cause of extinction is the danger of parturition, owing to the development of crest and wing bones "the immoderate proportions of which, however, were probably due entirely to postnatal growth."

Mr. Eaton has done an excellent piece of descriptive work and the plates, prepared from photographs and pen drawings, are admirable. R. S. L.

2. *The Age of Mammals;* by HENRY FAIRFIELD OSBORN. Pp. i–xvii, 1–635, with 220 text figures. New York, 1910 (The Macmillan Company). Price $4.50 net.—This admirable book in its present form is the outcome of the series of Harris lectures delivered in 1908 before the students of Northwestern University. Many of the facts set forth are of course known to men of science, especially to such as have had the privilege of being Osborn's pupils, but the assembling of the great array of truths to find which one would have to go far afield or delve into various sources, often in foreign tongues, is a work of the utmost value to the student and teacher of mammalian life and likewise to the serious reader. The problems discussed are not those of the evolution and descent of the various phyla, but rather the sources of origin of the various mammalian groups, their wanderings over the face of the globe and the final extinctions of the races which have passed away, together with the competition of the elements of the successive faunas in time and space.

Paleogeography, the climatic changes and the consequent evolution of plant life, which form the fundamental factors influencing animal change, are fully discussed, illustrated by excellent geologic and geographic charts. Of the mammals themselves, the great array of fossil skeletons in the American Museum together with the well-known restorations in the flesh by Charles R. Knight form most ample and admirable illustrations. Especially interesting are the outline sketches of the associated animals of the various faunas.

In the introduction Osborn discusses the North Polar theory of the origin of land mammals near the North Pole, whence they spread southward, ascribing the idea to Haacke in 1886. It is but just to state that an earlier writer, G. H. Scribner, advanced a similar thesis as to the origin of the flora and fauna of the earth in his little monograph entitled "Where did Life Begin?" and published in 1883. Except for this the bibliography is apparently very complete and the appendix also contains a new and copious classification of the mammalian genera, living and extinct.

The volume is an excellent example of bookmaking and the type clear and legible, the principal room for criticism being the half-tones, many of which, notably those of Knight's drawings, do not do justice to the originals. R. S. L.

3. *Tertiary Faunal Horizons in the Wind River Basin, Wyoming, with Descriptions of New Eocene Mammals;* by Walter Granger. Bull. Amer. Mus. Nat. Hist., Vol. xxviii, Art. xxi, 1910, pp. 235–251, with 6 text figs. and 3 pls.—This excellent little bulletin by Mr. Granger summarizes his work of exploration in the Wind River Basin as follows:—

"1. The Wind River Basin is covered throughout the greater part of its area with beds of the Wind River group, pertaining to the Lambdotherium Zone.

"2. Mammalian remains are extremely rare or absent from these beds except in two localities in the northern and north-eastern part of the basin, viz., along Alkali Creek and between Muddy Creek and the Owl Creek Mountains.

"3. Lying along the northern border of the Tertiary deposits in the northeastern corner of the basin, between the foothills and the Lambdotherium beds, apparently older than the latter and with the best exposures along Cottonwood Creek, is a series of 350 feet or more, containing a fauna intermediate between the Lambdotherium Zone and the Coryphodon Zone of the Big Horn Wasatch, the genera being all common to both zones.

"4. Along the southern border of the basin, on the divide between Sweetwater River and Beaver Creek, there is exposed a thickness of 1,100 feet of Tertiary, a remnant of deposits which undoubtedly extended over a large part of the basin at one time. Three distinct faunal levels, as indicated by mammalian fossils, are exhibited, Lower Eocene, Upper Eocene, and Lower Oligocene, the levels being correlated with (1) the ?Coryphodon Zone of the Wasatch, (2) the ? Diplacodon Zone of the Uinta, and (3) the Titanotherium Zone of the White River. An unconformity exists between the Eocene and Oligocene, but no break in sedimentation was detected in the Eocene series.

"5. Between the Coryphodon and Diplacodon levels are several hundred feet of unfossiliferous beds, the lower part of which pertain probably to the Lambdotherium Zone of the White

River group, and the upper part possibly to the Middle Eocene faunal zones of the Bridger Basin." R. S. L.

4. *Geological Survey of New Jersey. Annual Report of the State Geologist*, HENRY B. KÜMMEL, for 1909. Pp. 123. Trenton, 1910.—The latest volume from the New Jersey State Survey contains, in addition to the Administrative Report by the State Geologist, three detailed papers upon "Development of the Passaic Watershed by Small Storage Reservoirs," by C. C. Vermeule; "Records of Wells in New Jersey, 1905–1909," by Henry B. Kümmel and Howard M. Poland; and "Notes on the Mineral Industry," by Henry B. Kümmel. The first of these reports is accompanied by a large folded map.

III. ASTRONOMY.

1. *Transactions of the Astronomical Observatory of Yale University.* Vol. II, Part II, pp. 213–325. Published by the Observatory, 1910.—Part I of this publication ranks among the foremost of contributions to the world's knowledge of stellar distances by reason of the number of star measures recorded, the high character of the work and the important deductions made from it. The present publication is of less importance only because of the smaller number of parallax measures in it. The character of the work is the same.

Part II gives the work of the Observatory on 35 stars, performed by Dr. Chase with the collaboration of Dr. Elkin and Mr. Smith. The stars discussed are grouped in five classes, as follows:

A—6 stars with remarkably large proper motions.

B—6 second magnitude stars not previously tested by reliable methods.

C—7 stars from Part I which showed either exceptionally large parallax or appreciable negative results.

D—Additional stars from Vol. I, of large proper motion, remeasured.

E—Certain stars in the Pleiades which might furnish evidence of the parallax of the group as a whole.

The most elaborate discussion is that of Arcturus, the earlier measures of which, by Elkin, gave a parallax so small as compared with what might be expected from its brightness and proper motion that a remeasurement seemed called for.

The present discussion covers everything that has been done on this star at the Winchester Observatory during twenty-three years, by Elkin, Chase and Smith. The groups of measures by each observer are all reduced independently by three different methods, each based on a different hypothesis as to the weighting of the observations; and the conclusions reached as to the parallax of Arcturus may well be regarded as final. ($\pi = +0.''066 \pm 0.''006$.)

At the end of the volume the results presented in it are collated with those of the previous volume, thereby exhibiting the results of all the work of the Winchester Observatory in parallax from its establishment to the present time.

The conclusions reached as to the relation of parallax to distance and proper motion appear in the following table:

Proper Motion	0.″00 to 0.″34.		0.″41 to 0.″54.		0.″55 to 0.″65.		0.″66 to 0.″96.		1.″01 to 7.″07.	
	″		″		″		″		″	
Mag. 0·0–2·5	+0·031	13 stars	+0·100	2 stars	+0·113	3 stars	———	0 stars	+0·200	2 stars
" 3·0–5·0	+0·026	9 "	+0·024	7 "	+0·114	5 "	+0·091	8 "	+0·162	6 "
" 5·1–7·0	−0·010	7 "	+0·034	14 "	+0·064	16 "	+0·036	20 "	+0·111	8 "
" 7·1–9·0	———	0 "	+0·040	23 "	+0·032	23 "	+0·018	19 "	+0·128	12 "

"While the groups are small there is, with slight exception, manifest a very decided sequence of values both with respect to magnitude and size of proper motion such as one might expect. This is very gratifying in that it shows, in our opinion, as well as does the comparison of different series upon the same stars, that on the whole the work is comparatively free from systematic error." W. B.

2. *Determination of the Solar Parallax from photographs of Eros made with the Crossley Reflector of the Lick Observatory*, under direction of Charles D. Perrine. Pp. 98. Washington, 1910. Published by the Carnegie Institution.—The photographs from which this parallax determination has been made were taken at the opposition of Eros in 1900. Owing to the remoteness of the Lick Observatory from the others engaged in the work, its measurements were arranged so as to admit of independent reduction, and consisted of sets at large hour angles east and west of the meridian, together with meridian observations of the planet for correction of the ephemeris. In the reduction most elaborate precautions have been used to detect all systematic errors, with the result that everything except an insignificant item of this sort has been satisfactorily accounted for.

As a final check 20 of the plates showing the largest discrepancies were remeasured and an independent determination of the parallax made from them, and, almost as a work of supererogation, even a third independent determination from the five most discrepant of the former 20 plates was also carried through.

The fact that neither of these determinations differs appreciably from the full result is taken as a convincing test of the absence of every source of appreciable error from measurements and reductions.

The correction deduced for the assumed parallax of 8·80″ is +·0067″ ±·0025″.

The probable error here given is estimated from the probable errors derived in the following ways:

P. E. 126 equations	±0·0027″
96 equations	18
18 daily means	52
15 daily means (omitting 3 largest values)	34
8 results used in final combination	18

W. B.

3. *Les Déterminations des Longitudes et l'Histoire des Chronomètres;* par JEAN MASCART, Astronomer at the Observatory of Paris, pp. 62. (Extrait des Journal, "L'Horologier").—This is an account of the development that took place from about 1760 to 1780 in methods of determining longitude and time, especially at sea, and more particularly in making marine chronometers and testing them on long voyages. The expedition of the Flora, which was one of several chronometer-testing expeditions undertaken for the first time at this epoch, and the most important of them, is described at length. The transits of Venus which occurred in 1761 and 1769 gave an impetus to progress in these lines, from the demands which they made for accurate chronometers to be taken to the widely separated stations at which the transits were observed. W. B.

4. *Project for the Reform of the Calendar;* by CARLOS A. HESSE, Iquique. Presented to the Fourth (Pan-American) Scientific Congress.—The author would divide the year into 13 months of 28 days each, the last month to be called Trecember, and the odd day Jan. 0, and at leap year, 00. The numerous advantages that would attend such an orderly arrangement are forcibly presented.

The abstract proposition can hardly be contradicted, but the irrational obstacles of tradition and mental inertia are pretty certain to be insurmountable to this, as to other such attempted revisions, for an indefinite period to come.

The revised calendar, which would be perpetual, and which the author would like to see introduced in 1912, would be as follows; and "future generations would learn it by heart from earliest infancy." W. B.

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	1912
1	2	3	4	5	6	7	APRIL
8	9	10	11	12	13	14	JULY
15	16	17	18	19	20	21	OCTOBER
22	23	24	25	26	27	28	TRECEMBER

IV. Miscellaneous Scientific Intelligence.

1. *Report of the Secretary of the Smithsonian Institution for the year ending June 30, 1910.* Pp. 89. Washington, 1910.—The report of Dr. Walcott, recently issued, gives an interesting summary of the work of the Smithsonian Institution in its many lines of activity. Although the Institution is already committed to so much, it is interesting to note that the Secretary is planning to further extend its usefulness. He calls attention to the importance of a national seismological laboratory, observations at which would not only serve to give a large mass of important scientific data, but might also serve to predict occurrences as serious as that at San Francisco in 1906. A number of similar laboratories are now being conducted in different parts of the world, and it is a reproach to this country that it has taken no steps in this direction hitherto. The estimate of initial expense involved is moderate, amounting to some $20,000 for the equipment of the laboratory and the expense of the first year. It is much to be hoped that it will be found practicable to undertake this work at an early date, although it is intimated that it may be necessary to look for a special gift; such gifts have already been made effective in other lines of research.

The total permanent fund of the Institution amounts to nearly one million dollars, and the appropriations for the year covered in this report amounted to $720,500. The Secretary remarks with some detail upon the large and valuable collections made by the Roosevelt expedition, the work of which was comprised between April, 1909, and March, 1910. It is stated that the series of large and small mammals from East Africa is probably more valuable than is to be found in any other museum in the world. The series of birds, reptiles and plants, is also of great importance. Of the special investigations now being carried on or planned for the near future, may be mentioned that of Dr. Walcott on the Cambrian and pre-Cambrian rocks in Western Canada; also the biological survey of the Panama Canal zone to be undertaken in the winter of 1910–1911; and the work of Dr. A. Hrdlička on the antiquity of man in South Africa. These last researches, carried on for two months in the spring of 1910, fail to substantiate a large part of the claims that have been made. The specimens, both human and archeological, agree with those of the American Indian, and, so far as observed, bear only intrusive relations to the Quaternary or Tertiary deposits with which they are associated. It is noted that the new museum building is practically completed in essential respects, and the transfer of collections and laboratories is going on rapidly.

The results of the work of the Astrophysical Observatory are summarized by the Director, C. G. Abbott, as follows: "The work of the year is notable for the determination of the absolute scale of pyrheliometry and for the success of spectrobolometric observations of the solar constant of radiation on Mount Whitney. These agree with simultaneous observations of the same kind on

Mount Wilson. Reducing these and other results to the absolute scale of pyrheliometry, we may fix the average value of the solar constant of radiation at 1·925 calories per square centimeter per minute for the epoch 1905–1909. Making allowance for the higher values which must prevail at sun-spot minimum, the solar constant may be estimated at 1·95 calories as an average value for a sun-spot cycle. No reason has been found for departing from the view heretofore held that short-interval variations of 5 per cent or more from this value occur. The energy distribution in the solar spectrum outside the atmosphere has been determined with the bolometer on Mount Whitney between wave lengths 0·29μ in the ultra violet and 3·0μ in the infra-red. This region appears to contain full 99 per cent of all the solar energy outside the atmosphere. The apparent temperature of the sun as computed by three different methods comes out 6430°, 5840° and 6200° of the absolute scale. Researches on the transmission of moist columns of air for long-wave rays such as the earth emits, have been continued to wave lengths beyond 15μ, and for columns of air 800 feet in length. Secondary pyrheliometers, standardized to the absolute scale, have been sent to Russia, France, and Italy, and also furnished to the United States Weather Bureau and Department of Agriculture."

2. *Library of Congress. Report of the Librarian of Congress and Report of the Superintendent of the Library Buildings and Grounds, for the fiscal year ending June 30, 1910.* Pp. 305, with 7 plates. Washington, 1910.—All of those immediately interested in the important matter of library administration will welcome this annual volume from Mr. Putnam, since the Congressional Library, of which he has charge, rightfully serves as a model to the other large libraries in the country. It is interesting to note that the total appropriations for the Washington Library and associated copyright office for 1911 amount to about half a million. The accessions to the Library, including pamphlets, are about 90,000. Among the various appendixes is to be noted that which enumerates the important series of manuscripts and transcripts which have been received during the year.

3. *Academic and Industrial Efficiency. A Report to the Carnegie Foundation for the Advancement of Teaching;* by MORRIS LLEWELLYN COOKE. Bulletin Number Five. Pp. vii, 134. New York City, 1910.—The investigation detailed in this Bulletin was carried on by Mr. Cooke of the American Society of Mechanical Engineers, under the direction of the Carnegie Foundation. Eight institutions served as the object of investigation, the effort being to obtain an estimate of the cost and output in teaching and in research in the department of Physics. The data have evidently been obtained with all possible fulness and accuracy, and although the results are presented with some frankness of criticism, and although the suggestions made as to the proper place of research in an educational institution of the first rank, will not meet with universal approval, there can be no question of the value of having information of this kind brought together and presented to the interested public.

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MORGANITE.

I beg to advise my numerous patrons that after considerable difficulty have secured a small lot, in the rough state, of this very rare and new gem from Madagascar; this is the first opportunity ever offered collectors to purchase this unique variety of Beryl in this country.

REMARKABLE RUBY GEM CRYSTALS IN MATRIX FROM BURMA.

These I have just secured from a mining engineer, who has returned from a visit to this celebrated locality, and was fortunate in securing the lot; the crystals are of the very finest quality in color and shape and are of the pigeon-blood quality; prices and further particulars on application.

REMARKABLE COLLECTION.

I have received a remarkable collection of crystallized minerals of the finest quality, representing old finds and very rare examples of recent localities which I have just placed on sale.

HERKIMER QUARTZ.

Just secured a good lot of crystallized quartz in Bituminous limestone, the finest I ever saw, and in the same box were a fine lot of quartz on matrix from Amsterdam, N. Y.. It is known that specimens are not obtainable now; as this locality is all built over their value will be appreciated. Prices range from 25 cents to $1.50.

Have received a very remarkable Amethyst from Port Arthur, China, 9 x 10, beautiful color: would make an exceptionally good museum specimen. Must be seen to be appreciated.

A FEW REMARKABLE GOLD SPECIMENS.

One consisting of one inch solid vein of gold, very rich, contains 20¾ ounces; the matrix itself is a rich ore of gold. One side of the specimen is polished; it is 3½ x 2¾ x 2½ inches in size. I am selling this at a sacrifice; former value $500, as announced in the JOURNAL OF SCIENCE, July, 1909; will be disposed of now for $300, the actual value of the gold in the specimen.

IRIDESCENT PYRITES.

A recent trip of a local mineralogist awarded him a small lot of the finest quality of pyrites from South River, N. J. They are of the iridescent quality, the finest from this locality I have ever seen. Do not fail to secure one of these brilliant specimens.

I shall be pleased to send anyone on request, an assortment, prepaid, for selection, and guarantee satisfaction.

A. H. PETEREIT,

81—83 Fulton Street, New York City.

Phone Beekman 1856.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XIX.—*The Transmission of Light through Transparent Inactive Crystal Plates, with Special Reference to Observations in Convergent Polarized Light*; by Fred. Eugene Wright.

Introduction.

The problem of the refraction and reflection of light on inactive, transparent crystal plates has long attracted the attention of physicists and crystallographers, and has proved a fruitful field of investigation from the standpoints both of theory and of applied physical optics. The general problem was first successfully attacked in 1835 by F. Neumann[1] in Germany and by J. MacCullagh[2] in Ireland, Neumann using strictly analytic methods; MacCullagh, on the other hand, inclining rather to geometric methods and attaining thereby greater simplicity in his treatment of the whole. Both Neumann and MacCullagh showed keen mathematical insight and judgment in overcoming the inherent difficulties of this problem; their work, moreover, was remarkably thorough and comprehensive, and has served as the foundation on which all subsequent investigations have been based. Their general conclusions have remained intact and valid to the present day, even though their methods of calculation have been superseded by simpler and more effective methods and their fundamental assumptions have been modified to some extent and expressed in terms more nearly in accord with modern views on the nature of light.

[1] Theoretische Untersuchungen der Gesetze, nach welchen das Licht an der Grenze zweier vollkommen durchsichtiger Medien reflektiert und gebrochen wird. Berliner Akad. Abh. 1835, Math. Abt. p. 1–160; also Poggendorf's Annalen. xlii, 1–37, 1837.

[2] Phil. Mag. (3), viii, 103, 1835; x, 42, 1837; On the Laws of Crystalline Reflexion and Refraction, Trans. Roy. Irish Acad. xviii, p. 31, 1837; Collected Works. 1880.

Besides the papers by Neumann and MacCullagh, the most important contributions to this subject have been made by D. Brewster[1] (1819), A. Seebeck[2] (1831), A. Cauchy[3] (1836), C. G. Stokes[4] (1852), J. Grailich[5] (1855), A. Cornu[6] (1867), G. Kirchhoff[7] (1876), H. A. Lorentz[8] (1877), F. Kohlrausch[9] (1878), R. T. Glazebrook[10] (1882), Th. Liebisch[11] (1885), J. Danker[12] (1885), J. Conroy[13] (1886), C. Spurge[14] (1886), J. Norrenberg[15] (1888), Lord Rayleigh[16] (1888), P. Drude[17] (1889), C. Pulfrich[18] (1890), A. Potier[19] (1891), W. Voigt[20] (1896), C. Viola[21] (1899), A. Osthoff[22] (1905), P. Kaemmerer[23] (1905), F. Pockels[24] (1906).

In all these investigations, interest has centered in the reflected rather than in the refracted waves. The phenomena, however, resulting from the transmission of light through crystal plates are of great importance in practical microscopic diagnosis and merit detailed consideration, from the standpoint both of general theory and of observation. The present investigation was undertaken primarily to determine the influence

[1] Phil. Trans., 1819, p. 145.

[2] Pogg. Ann., xxi, 290, 1831; xxii, 126, 1831; xxxviii, 276, 1836; xl, 462, 1837.

[3] Compt. Rend., ii, 364, 1836.

[4] On the composition and resolution of streams of polarized light, etc., Cambridge Trans. ix, 399; Phil. Mag. (4), ii, 316, 1852.

[5] Wien Sitzungsber. (II), xi, 817, 1853; xii, 230, 1854; xv, 311, 1855; xix, 226, 1856; Denkschr. Math. Nat. Kl. ix, 57, 1855; xi, 41, 1856; Pogg. Ann. xcviii, 205, 1856.

[6] Recherches sur la reflexion cristalline. Thése fac. Scienc. Paris, 1867; Ann. Chim. Phys. (4), xi, 1867.

[7] Über die reflexion u. Brechung des Lichtes an der Grenze krystalliner Mittel., Abh. Berliner Akad., 1876.

[8] Über die Theorie der Reflexion u. Refraction d. Lichtes, Schlömilch's Zeitschr. xxii, 1, 1877.

[9] Wied. Ann., iv, 1, 1878.

[10] On the Refraction of plane polarized Light at the Surface of a uniaxial Crystal. Phil. Trans. clxxiii, 595, 1882.

[11] Über Totalreflexion an doppeltbrechenden Krystalien. Neues Jahrb. i, 245, 1885; ii, 47, 1886; Lehrb. d. Physik. Kryst., 1891.

[12] Neues Jahrbuch, Beil. Bd. iv. 241, 1885.

[13] Proc. Roy. Soc., xl, 173, 1886.

[14] Proc. Roy. Soc., xli, 463, 1886; xlii, 242, 1887.

[15] Über Totalreflexion an doppeltbrechenden Krystallen. Wied. Ann., xxxiv, 843, 1888.

[16] Phil. Mag. (5), xxvi, 241, 1888.

[17] Wied. Ann., xxxvi, 532, 865, 1889; xxxviii, 265, 1889. Physik. d. Aethers, 1894. Lehrbuch d. Optik (2d edition), 1906.

[18] Das Totalreflectometer, 1890.

[19] Sur la principe du Retour des rayons et de la Reflexion cristalline, Journ. de Phys. (2), x, 349, 1891.

[20] Compend. d. theoret. Phys. ii, 622, 1896.

[21] Zeitschr. Kryst., xxxi, 40, 1899; xxxvi, 245, 1902.

[22] Über die Reflexion u. Brechung des Lichtes an Zwillingsebenen volkommen durchsichtiger inaktiver, einachsiger Krystalle. Neues Jahrb., Beil. Bd. xx, 1, 1905.

[23] Über die Reflexion und Brechung des Lichtes an inactiver, durchsichtigen Krystallplatten, Erster Teil. Neues Jahrb., Beil. Bd. xx, 159, 1905.

[24] Lehrbuch d. Kristalloptik, 1906.

of certain factors which underlie the methods for the measurement of the optic axial angles, especially the method of Professor Becke[1] and the writer's modification[2] of the same.[3]

These methods are based on the degree of curvature of the dark hyperbolas or zero isogyres of the interference figure and depend, therefore, on the polarization directions of waves transmitted along different paths. In microscopic work, the influence of the boundary surfaces, not only of the crystal plate, but also of the intervening glass plates, on these waves enters the problem and tends to render it more complicated. In the following pages the general mathematical treatment of the problem of light transmission through transparent inactive crystal plates is given in Part 1 and several important and apparently new relations are deduced which simplify the presentation materially. In Part 2 results of calculation are checked by series of observations with apparatus specially designed for the purpose.

The results of the investigation show that the methods proposed by Professor Becke and by the writer are approximate methods only; both furnish results of about the same order of accuracy, the one advantage of the writer's method being that of slightly greater simplicity. They show, furthermore, that a theoretically correct method is not attainable because of many factors, each of only slight influence, which enter the problem and complicate the relations seriously.

Part 1.[4]—*Theoretical.*

The Boundary Conditions.[5]

Light waves, in passing through a crystal plate, encounter peculiar conditions, both on entering the plate and emerging from it. At the limiting surfaces of the plate, the crystalline material ends abruptly and the system of forces which result from the crystal structure are suddenly cut off from further action. On emerging from the plate the light waves pass from the influence of these forces to that of an entirely different

[1] Tschermak's Mitteil., xxiv, 35, 1905; xxviii, 290, 1909.

[2] This Journal (4), xxiv, 332–338, 1907; Tschermak's Mitteil., xxvii, 293, 1908.

[3] In the course of this investigation the writer has corresponded frequently with Professor Becke and is indebted to him for several suggestions and for his open consideration of the points in question.

[4] In the preparation of this section the following books and papers have been consulted especially: Drude, Lehrbuch d. Optik; also Drude in Winkelmann's Handbuch d. Physik; Liebisch, Lehrbuch d. Kristalloptik; Pockels's Lehrbuch d. Kristalloptik; and P. Kaemmerer, Über die Reflexion u. Brechung des Lichtes an inaktiver, durchsichtigen Kristallplatten, Neues Jahrb., Beil. Bd. xx, 159, 1905.

[5] The subject of boundary conditions is thoroughly treated by P. Drude in Winkelmann's Handbuch der Physik, vi, 1169, 1906; also in Drude's Physik d. Aethers, 511, 1894.

system, but this passage from the one set of conditions to the second, although very rapid, is a continuous process, since, physically speaking, there are no discontinuities in nature. On the one side of the surface the light waves are entirely within the influence of the crystal forces; on the other, within that of the second medium; at the boundary surface, the transition from the one sphere of influence to the second is accomplished. There the two sets of forces meet and the result is a continuous passage of the one set to the second, so far as their influence on external forces is concerned. Whatever theory or hypothesis of light is adopted to explain the phenomena, this continuity must be taken into account. In the electromagnetic theory of light a "boundary[1] surface between two substances of dielectric constants ϵ_1 and ϵ_2 must be considered an inhomogeneous surface in which the dielectric constant passes continuously though very rapidly from the value ϵ_1 to ϵ_2 in the direction of the normal to the surface." The general equations of the electromagnetic theory are valid even in this film:

$$\frac{4\pi}{c}j_{x'} = \frac{\partial w}{\partial y'} - \frac{\partial v}{\partial z'}, \quad \frac{4\pi}{c}j_{y'} = \frac{\partial u}{\partial z'} - \frac{\partial w}{\partial x'}, \quad \frac{4\pi}{c}j_{z'} = \frac{\partial v}{\partial x'} - \frac{\partial u}{\partial y'} \qquad (1)$$

$$\frac{4\pi}{c}s_{x'} = \frac{\partial Y}{\partial z'} - \frac{\partial Z}{\partial y'}, \quad \frac{4\pi}{c}s_{y'} = \frac{\partial Z}{\partial x'} - \frac{\partial X}{\partial z'}, \quad \frac{4\pi}{c}s_{z'} = \frac{\partial X}{\partial y'} - \frac{\partial Y}{\partial x'} \qquad (2)$$

In these equations of Maxwell, u, v, and w are the components after the x', y', z' axes of the magnetic force (the z' axis being normal to the surface and the x' axis in the plane of incidence); X, Y, Z the components of the electric force; $j_{x'}, j_{y'}, j_{z'}$, the components of the electric density in electrostatic units; $s_{x'}$, $s_{y'}$, $s_{z'}$ the components of the magnetic current, and c a constant, expressing the ratio between the electrostatic and electromagnetic units. The components of the electric and magnetic currents, $j_{x'}, j_{y'}, j_{z'}$ and $s_{x'}, s_{y'}, s_{z'}$ are finite quantities. The right hand side of the equations with differential quotients must therefore also be finite, even when the thickness of the film approaches 0, and the components of the electric and magnetic forces parallel with the boundary surface must be continuous on passage through the boundary surface. This condition is realized mathematically by stating that on either side of an infinitely thin film the two forces are equal.

$$(u)_1 = (u)_2\ , \quad (v)_1 = (v)_2\ , \quad (X)_1 = (X)_2\ , \quad (Y)_1 = (Y)_2\ , \qquad (3)$$

These conditions are perfectly general and must always be fulfilled at boundary surfaces.

[1] P. Drude in Winkelmann's Handbuch der Physik, vi, 1169–1170, 1906.

Boundary Conditions Applied to Transparent Inactive Crystal Plates.

A crystal is distinguished electromagnetically from an isotropic body by the variation of its specific inductive capacity with the direction. If ϵ_1, ϵ_2, ϵ_3, be the three principal dielectric constants of a crystal and μ the magnetic permeability, $= 1$, as is practically the case in all known dielectrics, then the general differential equations, referred to any coördinate system, for the electromagnetic field in a crystal, are:

$$\frac{1}{c}\left(\epsilon_{11}\frac{\partial X}{\partial t}+\epsilon_{12}\frac{\partial Y}{\partial t}+\epsilon_{13}\frac{\partial Z}{\partial t}\right)=\frac{\partial w}{\partial y'}-\frac{\partial v}{\partial z'}=\xi$$

$$\frac{1}{c}\left(\epsilon_{21}\frac{\partial X}{\partial t}+\epsilon_{22}\frac{\partial Y}{\partial t}+\epsilon_{23}\frac{\partial Z}{\partial t}\right)=\frac{\partial u}{\partial z'}-\frac{\partial w}{\partial x'}=\eta \qquad (4)$$

$$\frac{1}{c}\left(\epsilon_{31}\frac{\partial X}{\partial t}+\epsilon_{32}\frac{\partial Y}{\partial t}+\epsilon_{33}\frac{\partial Z}{\partial t}\right)=\frac{\partial v}{\partial x'}-\frac{\partial u}{\partial y'}=\zeta$$

$$\frac{1}{c}\frac{\partial u}{\partial t}=\frac{\partial Y}{\partial z'}-\frac{\partial Z}{\partial y'},\quad \frac{1}{c}\frac{\partial v}{\partial t}=\frac{\partial Z}{\partial x'}-\frac{\partial X}{\partial z'},\quad \frac{1}{c}\frac{\partial w}{\partial t}=\frac{\partial X}{\partial y'}-\frac{\partial Y}{\partial x'} \qquad (5)$$

In these equations, $\epsilon_{hk}=\epsilon_{kh}$ [1].

If the magnetic force be taken as light vector, the components X, Y, Z, of the electric force can be eliminated from (4) and (5) by differentiating equations (5) with respect to t:

$$\frac{1}{c}\frac{\partial^2 u}{\partial t^2}=\frac{\partial}{\partial z'}\left(\frac{\partial Y}{\partial t}\right)-\frac{\partial}{\partial y'}\left(\frac{\partial Z}{\partial t}\right);\quad \frac{1}{c}\frac{\partial^2 v}{\partial t^2}=\frac{\partial}{\partial x'}\left(\frac{\partial Z}{\partial t}\right)-\frac{\partial}{\partial z'}\left(\frac{\partial X}{\partial t}\right);$$

$$\frac{1}{c}\frac{\partial^2 w}{\partial t^2}=\frac{\partial}{\partial y'}\left(\frac{\partial X}{\partial t}\right)-\frac{\partial}{\partial x'}\left(\frac{\partial Y}{\partial t}\right). \qquad (6)$$

and substituting the values $\frac{\partial X}{\partial t}$, $\frac{\partial Y}{\partial t}$, $\frac{\partial Z}{\partial t}$ from equations (4) which are linear functions of these quantities. If, for abbreviation, the right hand side of the equations (4) be made equal respectively to ξ, η, ζ, then $\frac{\partial X}{\partial t}$, $\frac{\partial Y}{\partial t}$, $\frac{\partial Z}{\partial t}$ can be expressed as linear functions of ξ, η, ζ, thus:

[1] A simple proof of this relation is given in Drude, Lehrbuch der Optik, 294, 1906.

$$\frac{\partial X}{\partial t} = \frac{1}{c}(a_{11}\xi + a_{12}\eta + a_{13}\zeta)$$
$$\frac{\partial Y}{\partial t} = \frac{1}{c}(a_{21}\xi + a_{22}\eta + a_{23}\zeta) \qquad (7)$$
$$\frac{\partial Z}{\partial t} = \frac{1}{c}(a_{31}\xi + a_{32}\eta + a_{33}\zeta)$$

in which the so-called polarization constants $a_{11} \ldots, a_{21} \ldots, a_{31} \ldots$, are simple determinate functions of $\epsilon_{11} \ldots, \epsilon_{21} \ldots, \epsilon_{31} \ldots$, and c^2 and for which the relations $a_{hk} = a_{kh}$ hold true just as $\epsilon_{hk} = \epsilon_{kh}$. These equations indicate that a function of the second degree is possible whose partial differential quotients with respect to ξ, η, ζ, are equal, respectively, to $\frac{\partial X}{\partial t}, \frac{\partial Y}{\partial t}, \frac{\partial Z}{\partial t}$. This function is

$$2cG = a_{11}\xi^2 + a_{22}\eta^2 + a_{33}\zeta^2 + 2a_{23}\eta\zeta + 2a_{31}\zeta\xi + 2a_{12}\xi\eta = \text{constant.} \qquad (8)$$

From energy considerations it is evident that this equation (8) must represent an ellipsoid; and if, in it, the constant be $2cG=1$, the equation is then that of a triaxial ellipsoid referred to a coördinate system of any position. This ellipsoid is the "index ellipsoid" of MacCullagh, or "ellipsoid of elasticity" of Kirchhoff, or the "indicatrix" of Fletcher. The coördinate axes can be brought to coincide with the principal ellipsoidal axes by use of the usual transformation equations:

$$\begin{aligned} a^2p^2_1 + b^2p^2_2 + c^2p^2_3 &= a_{11} \\ a^2q^2_1 + b^2q^2_2 + c^2q^2_3 &= a_{22} \\ a^2r^2_1 + b^2r^2_2 + c^2r^2_3 &= a_{33} \\ a^2q_1r_1 + b^2q_2r_2 + c^2q_3r_3 &= a_{23} \\ a^2r_1p_1 + b^2r_2p_2 + c^2r_3p_3 &= a_{31} \\ a^2p_1q_1 + b^2p_2q_2 + c^2p_3q_3 &= a_{12} \end{aligned} \qquad (9)$$

in which p_1, p_2, p_3, q_1, q_2, q_3, and r_1, r_2, r_3, are the direction cosines between the new coördinate axes x, y, z, and the x', y', z' of the old system respectively. Referred to the principal ellipsoidal axes equation (9) becomes $a^2\xi^2 + b^2\eta^2 + c^2\zeta^2 = 1$, in which a, b, c, are the principal light velocities of the crystal. The symmetry axes of this index ellipsoid are the reciprocals of a, b, c, or directly the principal refractive indices of the crystal. In geometric problems of reflection and refraction, the index ellipsoid and the index surface derived from it are specially useful.

On substituting the values of $\frac{\partial X}{\partial t}, \frac{\partial Y}{\partial t}, \frac{\partial Z}{\partial t}$ of equation (7) in (6) we obtain a system of partial differential equations:

$$\begin{aligned}
\frac{\partial^2 u}{\partial t^2} &= \frac{\partial}{\partial z'}(a_{21}\xi + a_{22}\eta + a_{23}\zeta) - \frac{\partial}{\partial y'}(a_{31}\xi + a_{32}\eta + a_{33}\zeta) \\
\frac{\partial^2 v}{\partial t^2} &= \frac{\partial}{\partial x'}(a_{13}\xi + a_{23}\eta + a_{33}\zeta) - \frac{\partial}{\partial z'}(a_{11}\xi + a_{12}\eta + a_{13}\zeta) \quad (10) \\
\frac{\partial^2 w}{\partial t^2} &= \frac{\partial}{\partial y'}(a_{11}\xi + a_{12}\eta + a_{13}\zeta) - \frac{\partial}{\partial x'}(a_{12}\xi + a_{22}\eta + a_{23}\zeta)
\end{aligned}$$

which are free from the components of the electric force and of the electric current.

Equations (4) and (5) are of general validity and obtain therefore, even at the boundary surface of a crystal plate. It is apparent from the last equation of (5) that, as $(X)_1 = (X)_2$, $(Y)_1 = (Y)_2$ at the boundary, $\left(\frac{\partial w}{\partial t}\right)_1 = \left(\frac{\partial w}{\partial t}\right)_2$ or $(w)_1 = (w)_2$ for periodic vibrations. The boundary conditions for a crystal plate may therefore be written:

$$(u)_1 = (u)_2,\ (v)_1 = (v)_2,\ (w)_1 = (w)_2,\ \left(\frac{\partial X}{\partial t}\right)_1 = \left(\frac{\partial X}{\partial t}\right)_2$$
$$\left(\frac{\partial Y}{\partial t}\right)_1 = \left(\frac{\partial Y}{\partial t}\right)_2 \quad (11)$$

of which only four are independent. The last equation of the set may accordingly be discarded. The fourth equation $\left(\frac{\partial X}{\partial t}\right)_1 = \left(\frac{\partial X}{\partial t}\right)_2$ can be expanded by means of (7) and (4) and becomes for the general case of two adjoining crystal plates:

$$a_{11}\left(\frac{\partial w}{\partial y'} - \frac{\partial v}{\partial z'}\right) + a_{12}\left(\frac{\partial u}{\partial z'} - \frac{\partial w}{\partial x'}\right) + a_{13}\left(\frac{\partial v}{\partial x'} - \frac{\partial u}{\partial y'}\right) =$$
$$a'_{11}\left(\frac{\partial w'}{\partial y'} - \frac{\partial v'}{\partial z'}\right) + a'_{12}\left(\frac{\partial u'}{\partial z'} - \frac{\partial w'}{\partial x'}\right) + a'_{13}\left(\frac{\partial v'}{\partial x'} - \frac{\partial u'}{\partial y'}\right). \quad (12)$$

These boundary equations, together with equation (8), are of general validity for transparent, inactive plates, and form the basis on which all detailed work rests.

The partial differential equations (10) representing the movement of the magnetic vector are satisfied by the components u, v, w of the vibration of a plane polarized, advancing wave of constant amplitude. This vibration is defined by the usual equations of the general form:

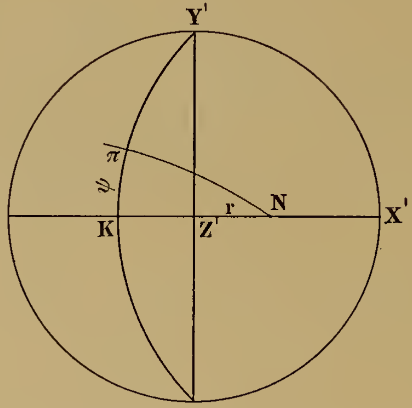
$$u = Al \cos \frac{2\pi}{T}\left(t - \frac{\lambda x' + \mu y' + \nu z'}{q}\right)$$

$$v = Am \cos \frac{2\pi}{T}\left(t - \frac{\lambda x' + \mu y' + \nu z'}{q}\right) \qquad (13)$$

$$w = An \cos \frac{2\pi}{T}\left(t - \frac{\lambda x' + \mu y' + \nu z'}{q}\right)$$

in which A is the amplitude of the vibration or magnetic force; l, m, n, the direction cosines of the line of vibration π, which in this case is that of the magnetic light vector and also the polarization direction; T, the period of vibration; λ, μ, ν the direction cosines of the normal N of the wave propagated with the velocity q. To simplify these equations, let the boundary surface of the plate be the x', y' plane, fig. 1; the

FIG. 1.



plane of incidence, the x' z' plane; the angle between the normal of the advancing wave N, and the z' axis, r, the positive direction of z' being on the crystal side of the boundary surface; let also the polarization azimuth ψ be the angle between the plane of incidence (the $x'z'$ plane) and the plane of polarization (the angle Kπ, fig. 1) counting from the z' axis in the direction of the $+y'$ axis and passing beyond this axis if necessary. In this case,

$$\lambda = \sin r, \qquad \mu = 0, \qquad \nu = \cos r$$

$$l = -\cos r \cos \psi, \qquad m = \sin \psi, \qquad n = \sin r \cos \psi.$$

and the equations (13) reduce to

$$
\begin{aligned}
u &= -\,A \cos\psi \cos r \cos \frac{2\pi}{T}\left(t - \frac{x' \sin r + z' \cos r}{q}\right) \\
v &= \qquad A \sin\psi \cos \frac{2\pi}{T}\left(t - \frac{x' \sin r + z' \cos r}{q}\right) \qquad (14) \\
w &= \quad A \cos\psi \sin r \cos \frac{2\pi}{T}\left(t - \frac{x' \sin r + z' \cos r}{q}\right)
\end{aligned}
$$

For $z' = 0$ it is evident from the boundary conditions, $(u)_1 = (u)_2$, $(v)_1 = (v)_2$ of equations (11) and (14), that for all possible reflected or refracted waves at the limiting surface, T, the period of vibration (color) remains constant $(T_1 = T_2)$; also $\frac{\sin r_1}{q_1} = \frac{\sin r_2}{q_2}$, which is the sine law of wave normals; while $\mu = 0$ signifies that all wave normals lie in the plane of incidence.

By means of equations (14), the general differential equations (10) can be solved and the fundamental formulas obtained for the refraction, reflection, and polarization of light waves in crystals. Thus from equations (4) and (14)

$$
\begin{aligned}
\xi &= \frac{\partial w}{\partial y'} - \frac{\partial v}{\partial z'} = -\,K \sin\psi \cos r \\
\eta &= \frac{\partial u}{\partial z'} - \frac{\partial w}{\partial x'} = -\,K \cos\psi \\
\zeta &= \frac{\partial v}{\partial x'} - \frac{\partial u}{\partial y'} = K \sin\psi \sin r.
\end{aligned}
$$

Wherein

$$
K = A \cdot \frac{2\pi}{T . q} \cdot \sin \frac{2\pi}{T}\left(t - \frac{x' \sin r + z' \cos r}{q}\right)
$$

From these expressions, we find:

$$
\frac{\partial}{\partial z'}(a_{21}\xi + a_{22}\eta + a_{23}\zeta) = \frac{C}{q^2} \cos r\,(-a_{21} \sin\psi \cos r - a_{22} \cos\psi + a_{23} \sin\psi \sin r)
$$

$$
\frac{\partial}{\partial x'}(a_{13}\xi + a_{23}\eta + a_{33}\zeta) = \frac{C}{q^2} \sin r\,(-\,a_{13} \sin\psi \cos r - a_{23} \cos\psi + a_{33} \sin\psi \sin r)
$$

$$
\frac{\partial}{\partial z'}(a_{11}\xi + a_{12}\eta + a_{13}\zeta) = \frac{C}{q^2} \cos r\,(-\,a_{11} \sin\psi \cos r - a_{12} \cos\psi + a_{13} \sin\psi \sin r)
$$

$$\frac{\partial}{\partial x'}(a_{12}\xi + a_{22}\eta + a_{23}\zeta) =$$

$$\frac{C}{q^2}\sin r\,(-a_{21}\sin\psi\cos r - a_{22}\cos\psi + a_{23}\sin\psi\sin r)$$

Wherein

$$C = -A\,\frac{4\pi^2}{T^2}\cos\frac{2\pi}{T}\left(t - \frac{x'\sin r + z'\cos r}{q}\right);$$

similarly from (14)

$$\frac{\partial^2 u}{\partial t^2} = -C\cos\psi\cos r$$

$$\frac{\partial^2 v}{\partial t^2} = C\sin\psi$$

$$\frac{\partial^2 w}{\partial t^2} = C\cos\psi\sin r$$

Substituting the values from these last two sets of equations in (10), we obtain the two equations

$$-\cos\psi = \frac{1}{q^2}(-a_{12}\sin\psi\cos r - a_{22}\cos\psi + a_{23}\sin\psi\sin r) \quad \text{and}$$

$$\sin\psi = \frac{\sin r}{q^2}(-a_{13}\sin\psi\cos r - a_{23}\cos\psi + a_{33}\sin\psi\sin r) -$$
$$\frac{\cos r}{q^2}(-a_{11}\sin\psi\cos r - a_{12}\cos\psi + a_{13}\sin\psi\sin r)$$

which, on rearrangement, become

$$(a) \qquad \cos\psi\,(q^2 - a_{22}) = \sin\psi\,(a_{12}\cos r - a_{23}\sin r) \qquad (15)$$

$$(b) \quad \cos\psi\,(a_{12}\cos r - a_{23}\sin r) =$$
$$\sin\psi\,(q^2 - a_{33}\sin^2 r - a_{11}\cos^2 r + 2a_{13}\sin r\cos r)$$

By division of 15 (*a*) by 15 (*b*) an expression results which is free from ψ;

$$(q^2 - a_{22})(q^2 - a_{11}\cos^2 r - a_{33}\sin^2 r + 2a_{13}\sin r\cos r) = (a_{12}\cos r - a_{23}\sin r)^2 \qquad (16)$$

and which reduces to[1]

$$[a_{11} - 2a_{13}tg\,r + (a_{33} - k^2)tg^2 r][a_{22} + (a_{22} - k^2)tg^2 r] = (a_{12} - a_{23}tg\,r)^2(1 + tg^2 r) \qquad (16a)$$

if k be substituted for the constant value $\frac{q}{\sin r}$ which, by reason of the sine law of refraction, is equal, for all possible waves, to $\frac{q_0}{\sin i}$ where q_0 is the velocity of light in the isotropic medium enveloping the crystal and i the angle of incidence. By means of this standard formula, which can be derived in different

[1] G. Kirchhoff, Über die Reflexion und Brechung an der Grenze Krist. Medien, Berliner Akad. Abh., 1876.—Th. Liebisch, Neues Jahrbuch, II, 191, 1885.

ways, the angle of refraction or reflection of any light waves in the crystal can be calculated.

From 15 (a), the following equation is readily derived:

$$tg\ \psi = \frac{q^2 - a_{22}}{a_{12} \cos r - a_{23} \sin r}$$

which may be written

$$tg\ \psi = \frac{(k^2 - a_{22}) tg^2 r - a_{22}}{(a_{12} - a_{23} tg\ r)\sqrt{1 + tg^2 r}}; \qquad (17)$$

wherein $k = \frac{q_0}{\sin i}$ as in (16). From (17) the azimuth of the plane of polarization can be determined, provided r be known.

Equation (16) is biquadratic and indicates that in a crystal there are four possible waves, of equal significance,—two reflected and two refracted waves,—which must be taken into account in the general boundary conditions for the crystal. The general equations (11), (12) and (14) for the magnetic light vector on passage through the boundary between two inactive, transparent crystal plates may therefore be written:[1]

$$\sum_1^4 A_k \cos r_k \cos \psi_k = \sum_1^4 A'_k \cos r'_k \cos \psi'_k \quad (\text{from } (u)_1 = (u)_2)$$

$$\sum_1^4 A_k \sin \psi_k = \sum_1^4 A'_k \sin \psi'_k \quad (\text{from } (v)_1 = (v)_2) \quad (18)$$

$$\sum_1^4 A_k \sin r_k \cos \psi_k = \sum_1^4 A'_k \sin r'_k \cos \psi'_k \quad (\text{from } (w)_1 = (w)_2)$$

$$\sum_1^4 \frac{A_k \sin r_k}{q^2_k} (\sin \psi_k (a_{11} \cos r_k - a_{13} \sin r_k) + a_{12} \cos \psi_k) =$$

$$\sum_1^4 \frac{A'_k \sin r'_k}{q'^2_k} (\sin \psi'_k (a'_{11} \cos r'_k - a'_{13} \sin r'_k) + a'_{12} \cos \psi'_k)$$

$$\left(\text{from} \left(\frac{\partial X}{\partial t}\right)_1 = \left(\frac{\partial X}{\partial t}\right)_2\right)$$

In the last equation of this set both sides of the equation have been multiplied by the equality $\frac{\sin r_k}{q_k} = \frac{\sin r'_k}{q'_k}$

In the first three equations, the factors of the amplitudes, $A_1 \ldots A_4$, are the direction cosines, l, m, n, of the line of vibration π with the axes x', y', z'; if the factors of the amplitudes in the fourth equation be indicated by p, the equations can be written in the abbreviated form,[2]

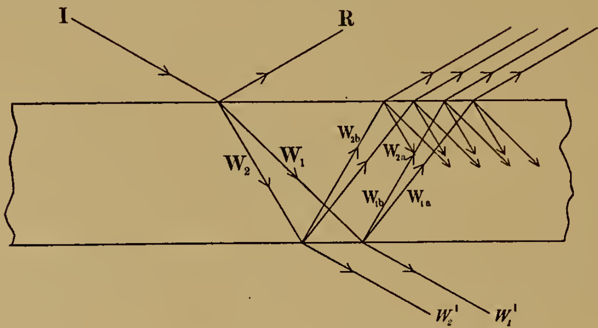
[1] G. Kirchhoff, Ges. Abhandlungen. 367–370, 1882.

[2] A. Potier, Journ. Phys. (2), x, 350, 1891. P. Kaemmerer, N. J., Beil. Bd. xx, 174, 1905.

$$
\left.\begin{aligned}
\sum_1^4 A_k l_k &= \sum_1^4 A'_k l'_k \\
\sum_1^4 A_k m_k &= \sum_1^4 A'_k m'_k \\
\sum_1^4 A_k n_k &= \sum_1^4 A'_k n'_k \\
\sum_1^4 A_k p_k &= \sum_1^4 A'_k p'_k
\end{aligned}\right\} \qquad (18a)
$$

In case the crystal plate is surrounded by an isotropic medium, these general equations become simpler; the index ellipsoid for the isotropic medium is a sphere and its coefficients are $a'_{11} = a'_{22} = a'_{33} = q_0^2$ and $a'_{23} = a'_{31} = a'_{12} = 0$. For the passage of light from the isotropic medium to the crystal plate, there are, in general, one incident wave (I), one reflected wave (R) and two refracted waves, W_1, W_2 (fig. 2); the boundary equations are, then,

Fig. 2.



$$
\begin{aligned}
&D_1 \cos\delta_1 \cos r_1 + D_2 \cos\delta_2 \cos r_2 = (E\cos\epsilon - R\cos\rho)\cos i \\
&D_1 \sin\delta_1 \qquad\quad + D_2 \sin\delta_2 \qquad\quad = E\sin\epsilon + R\sin\rho \\
&D_1 \cos\delta_1 \sin r_1 + D_2 \cos\delta_2 \sin r_2 = (E\cos\epsilon + R\cos\rho)\sin i \\
&D_1 \frac{\sin r_1}{d_1^2}[\sin\delta_1 (a_{11}\cos r_1 - a_{13}\sin r_1) + a_{12}\cos\delta_1] + \\
&D_2 \frac{\sin r_2}{d_2^2}[\sin\delta_2 (a_{11}\cos r_2 - a_{13}\sin r_2) + a_{12}\cos\delta_2] = \qquad (19) \\
&\qquad\qquad\qquad (E\sin\epsilon - R\sin\rho)\sin i \cos i
\end{aligned}
$$

wherein, for the incident wave (I), the reflected wave (R), the faster refracted wave W_1 and the slower refracted wave W_2, respectively, E, R, D_1, D_2, are the amplitudes; ϵ, ρ, δ_1, δ_2, the polarization azimuths; q_0, q_0, d_1, d_2, the normal velocities of the wave; i, $\pi - i$, r_1, r_2, the angles of the wave normals with

z'. In these equations i, E, ϵ, q_0 of the incident wave are known; also by calculation (equations (16) and (17)), r_1, r_2 and δ_1, δ_2 of the refracted waves; and i, q_0 of the reflected wave; unknowns are R, ρ of the reflected wave and D_1, D_2 of the refracted waves W_1, W_2.

In abbreviated form, corresponding to (18a), these equations may be written:[1]

$$\begin{aligned} D_1 l_1 + D_2 l_2 &= (E \cos \epsilon - R \cos \rho) \cos i \\ D_1 m_1 + D_2 m_2 &= E \sin \epsilon + R \cos \rho \\ D_1 n_1 + D_2 n_2 &= (E \cos \epsilon + R \cos \rho) \sin i \\ D_1 p_1 + D_2 p_2 &= (E \sin \epsilon - R \sin \rho) \sin i \cos i \qquad (19a) \end{aligned}$$

At the second boundary surface where the two refracted waves emerge from the crystal plate into the isotropic medium, two sets of boundary equations obtain, one for each refracted wave, W_1 and W_2. At this surface, there are for each incident wave, W_1 and W_2, two reflected waves and one refracted wave as indicated in fig. 2.

For the refracted wave W_1 the boundry conditions reduce to

$$D_1 \cos \delta_1 \cos r_1 + R'_1 \cos \rho'_1 \cos r'_1 + R''_1 \cos \rho''_1 \cos r''_1 = D'_1 \cos \delta'_1 \cos i.$$

$$D_1 \sin \delta_1 + R'_1 \sin \rho'_1 + R''_1 \sin \rho''_1 = D'_1 \sin \delta'_1.$$

$$D_1 \cos \delta'_1 \sin r_1 + R'_1 \cos \rho'_1 \sin r'_1 + R''_1 \cos \rho''_1 \sin r''_1 = D'_1 \cos \delta'_1 \sin i. \qquad (20)$$

$$D_1 \frac{\sin r_1}{q_1^2}\left[\sin \delta_1 (a_{11} \cos r_1 - a_{13} \sin r_1) + a_{12} \cos \delta_1\right] +$$
$$\frac{R'_1 \sin r'_1}{q'^2_1}\left[\sin \rho'_1 (a_{11} \cos r'_1 - a_{13} \sin r'_1) + a_{12} \cos \rho'_1\right) +$$
$$\frac{R''_1 \sin r''_1}{q''^2_1}\left[\sin \rho''_1 (a_{11} \cos r''_1 - a_{13} \sin r''_1) + a_{12} \cos r''_1\right) = D'_1 \sin \delta'_1 \cos i \sin i.$$

wherein, for the incident wave W_1 the faster reflected wave W_{1a}, the slower reflected wave W_{1b}, and the refracted wave W'_1, respectively, D_1, R', R'', D', are the amplitudes; δ_1, ρ'_1, ρ'', δ'_1 the polarization azimuths; r_1, r'_1, r''_1, i the inclination of the wave normals with z'; and q_1, q'_1, q''_1, q_0, the wave normal velocities.

Similarly, for the slower refracted wave W_2 the boundary equations are

$$D_2 \cos \delta_2 \cos r_2 + R'_2 \cos \rho'_2 \cos r'_2 + R''_2 \cos \rho''_2 \cos r''_3 = D'_2 \cos \delta'_2 \cos i$$

$$D_2 \sin \delta_2 + R'_2 \sin \rho'_2 + R''_2 \sin \rho''_2 = D'_2 \sin \delta'_2$$

[1] P. Kaemmerer, Neues Jahrb., Beil. Bd. xx, 176, 1905.

$$D_2 \cos\delta_2 \sin r_2 + R'_2 \cos\rho'_2 \sin r'_2 + R''_2 \cos\rho_2 \sin r''_2 = \qquad (21)$$
$$\cos\rho_2 \sin r''_2 = \qquad D'_2 \cos\delta'_2 \sin i$$

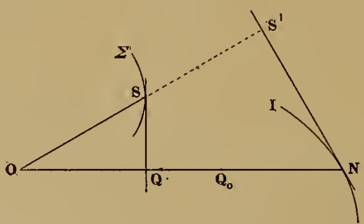
$$D_2 \frac{\sin r_2}{q^2_2}\left(\sin\delta_2\,(a_{11}\cos r_2 - a_{13}\sin r_2) + a_{12}\cos\delta_2\right) +$$
$$R'_2 \frac{\sin r'_2}{q'^2_2}\left[\sin\rho'_2\,(a_{11}\cos r'_2 - a_{13}\sin r'_2) + a_{12}\cos\rho'_2\right] +$$
$$R''_2 \frac{\sin r''_2}{q''^2_2}\left[\sin\rho''_2(a_{11}\cos r''_2 - a_{13}\sin r''_2) + a_{12}\cos\rho''_2\right] =$$
$$D'_2 \sin\delta'_2 \cos i \sin i.$$

These equations (19), (20), (21), agree with the fundamental equations of Neuman, MacCullagh and Kirchhoff derived from the mechanical theory of light. They are, however, exceedingly complicated, and in their solution certain auxiliary geometric and analytic relations are used which simplify and facilitate the practical calculations considerably. The most important of these aids are the index surface introduced by MacCullagh ([1]), Potier's ([2]) generalization of the Neumann-MacCullagh relation, and the conception of the uniradial azimuth as given by MacCullagh([3]) and Neumann.([4])

The Neuman-Mac Cullagh-Potier relation.

The index surface, whose radii vectors are proportional to the reciprocal wave normal velocities or directly to the refractive indices for the direction of propagation, is best adapted to

Fig. 3.



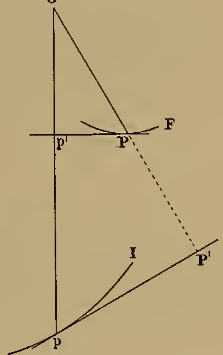
present graphically the relations between refracted and reflected waves. It is derived from the index ellipsoid in the same manner that the ray surface is derived from Fresnel's ellipsoid. The index surface (I) of a crystal is the reciprocal of its ray surface (Σ), just as the index ellipsoid (I) is the reciprocal

[1] J. MacCullagh, Trans. Roy. Irish Acad., xvii, 252, 1833.
[2] Jour. Phys. (2), x, 349, 1891.
[3] Trans. Roy. Irish Acad.. xviii, 31, 1837.
[4] Berliner Akad. Abh., Math. Abt. 144, 1835; Pogg. Ann., xlii, 9, 1837.

of Fresnel's ellipsoid (F). Each point S of the ray surface (Σ) defines a ray direction; the normal OQ to the tangent plane SQ through S of the ray surface is then the radius vector of the normal to the wave producing the ray, S. (Fig. 3.) The extension of this wave normal vector to its reciprocal length ON determines a point N on the index surface. The two points N and S are said to be corresponding points, and the plane NOS is normal to the polarization direction.

Similarly, a point p of the index ellipsoid (I) is the corresponding point P of Fresnel's ellipsoid (F), (fig. 4), if its radius vector coincides in direction with the normal op' to the tangent plane Pp' through P and is equal in length to the reciprocal of the normal $Op'=q$. The radius vector, OP represents a ray of velocity s (fig. 4) while the radius vector $Op = \frac{1}{q}$ is the reciprocal of the corresponding wave normal velocity q. The normal to the plane Pop is then the polarization direction. By obtaining the coördinates of such corresponding points on the two ellipsoids (F) and (I), Potier discovered a simple relation between the expressions l, m, n, p, of equations (18a) which has proved of great value in the solution of problems of reflection and refraction.

Fig. 4.



For the sake of simplicity, let the equation of Fresnel's ellipsoid and the index ellipsoid be referred to the principal axes; Fresnel's ellipsoid is then represented by

$$2F=\frac{x^2}{a^2}+\frac{y^2}{b^2}+\frac{z^2}{c^2}=1; \text{ the index ellipsoid by} \qquad (22)$$

$$2I=a^2\,x^2+b^2\,y^2+c^2\,z^2=1 \qquad (23)$$

If the coördinates of a point P on Fresnel's ellipsoid be $x°_1$, $y°_1$, $z°_1$, then the equation of the tangent planes through P is:

$$(x-x°_1)\left(\frac{\partial F}{\partial x}\right)_{x°_1} + (y-y°_1)\left(\frac{\partial F}{\partial y}\right)_{y°_1} + (z-z°_1)\left(\frac{\partial F}{\partial x}\right)_{z°_1}=0$$

The equations of the normal to this plane are

$$\frac{x}{\left(\frac{\partial F}{\partial x}\right)_{x°_1}} = \frac{y}{\left(\frac{\partial F}{\partial y}\right)_{y°_1}} = \frac{z}{\left(\frac{\partial F}{\partial z}\right)_{z°_1}} \qquad (24)$$

By definition, the point p is common both to the normal and the index surface and its coördinates, x_1, y_1, z_1, are readily found by means of (22), (23), and (24), to be:

$$x_1 = \left(\frac{\partial F}{\partial x}\right)_{x^\circ_1}, \quad y_1 = \left(\frac{\partial F}{\partial y}\right)_{y^\circ_1}, \quad z_1 = \left(\frac{\partial F}{\partial z}\right)_{z^\circ_1} \tag{25}$$

Similarly it can be shown that

$$x^\circ_1 = \left(\frac{\partial I}{\partial x}\right)_{x_1}, \quad y^\circ_1 = \left(\frac{\partial I}{\partial y}\right)_{y_1}, \quad z^\circ_1 = \left(\frac{\partial I}{\partial z}\right)_{z_1} \tag{25a}$$

This reciprocal relation of polar quadrics obtains for all positions of the coördinate system, as can be readily proved by adopting general coördinates in the above equations.[1]

In case two pairs of corresponding points be taken, p_1 P_1 and p_2 P_2, then, in general coördinates,

$$x'^\circ_1 = \left(\frac{\partial I}{\partial x'}\right)_{x'_1}, \quad y'^\circ_1 = \left(\frac{\partial I}{\partial y'}\right)_{y'_1}, \quad z'^\circ_1 = \left(\frac{\partial I}{\partial z'}\right)_{z'_1}$$

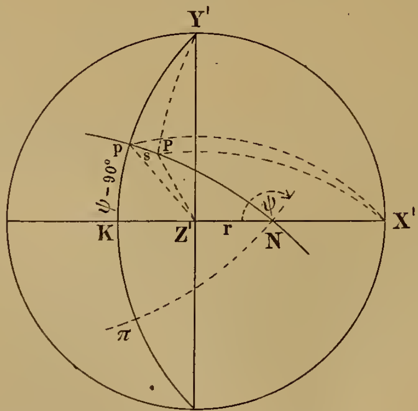
$$x'^\circ_2 = \left(\frac{\partial I}{\partial x'}\right)_{x'_2}, \quad y'^\circ_2 = \left(\frac{\partial I}{\partial y'}\right)_{y'_2}, \quad z'^\circ_2 = \left(\frac{\partial I}{\partial z'}\right)_{z'_2}$$

The general form of $2I \equiv a_{11}x'^2 + a_{22}y'^2 + a_{33}z'^2 + 2a_{23}y'z' + 2a_{31}z'x' + 2a_{12}x'y' = 1$ is that of a homogeneous equation of the second degree, from which it follows that

$$x'_1\left(\frac{\partial I}{\partial x'}\right)_2 + y'_1\left(\frac{\partial I}{\partial y'}\right)_2 + z'_1\left(\frac{\partial I}{\partial z'}\right)_2 = a_{11}x'_1x'_2 + a_{22}y'_1y'_2 + a_{33}z'_1z'_2 +$$
$$a_{23}(y'_1z'_2 + y'_2z'_1) + a_{31}(z_1x'_2 + z'_2x'_1) + a_{12}(x'_1y'_2 + x'_2y'_1)$$
$$= x'_2\left(\frac{\partial I}{\partial x'}\right)_1 + y'_2\left(\frac{\partial I}{\partial y'}\right)_1 + z'_2\left(\frac{\delta I}{\delta z'}\right)_1 \text{ or}$$

$$x'_1x'^\circ_2 + y'_1y'^\circ_2 + z'_1z'^\circ_2 = x'_2x'^\circ_1 + y'_2y'^\circ_1 + z'_2z'^\circ_1. \tag{26}$$

Fig. 5.



[1] MacCullagh, Geometrical Propositions applied to the wave theory of light, Trans. Roy. Irish Acad., xvi, pt. 2, 67; also xvii (1833); Coll. Works, p. 20-22, 1880.

To apply this relation, discovered by Potier, between two pairs of corresponding points on the two ellipsoids (F) and (I), it is necessary to obtain the coördinates of the points. In the stereographic projection (fig. 5), let p and P be the projections of the two corresponding points p and P, Ky' the wave front, $x'z'$ the plane of incidence, N the wave normal, r the angle of inclination of N with z', ψ the azimuth of the plane of polarization, and s the angle pOP (O being the center of the sphere).

The coördinates of p are then:

$$\begin{aligned} x'_1 &= Op \cos px' = -\frac{1}{q_1} \sin \psi_1 \cos r_1 \\ y'_1 &= Op \cos py' = -\frac{1}{q_1} \cos \psi_1 \\ z'_1 &= Op \cos pz' = \frac{1}{q_1} \sin \psi_1 \sin r_1 \end{aligned} \tag{27}$$

and the coördinates of P are

$$\begin{aligned} x'^0_1 &= \text{OP} \cos \text{P}x' = \text{OP} (\sin s_1 \sin r_1 - \cos s_1 \cos r_1 \sin \psi_1) \\ y'^0_1 &= \text{OP} \cos \text{P}y' = -\text{OP} \cos s_1 \cos \psi_1 \\ z'^0_1 &= \text{OP} \cos \text{P}z' = \text{OP}(\sin s_1 \cos r_1 + \cos s_1 \sin r_1 \sin \psi_1) \end{aligned} \tag{28}$$

But from fig. 4, $\text{OP} = \frac{Op'}{\cos \text{P}Op'} = \frac{q_1}{\cos s_1}$ and equations (28) can be written:

$$\begin{aligned} x'^0_1 &= q_1(tg\, s_1 \sin r_1 - \cos r_1 \sin \psi_1) \\ y'^0_1 &= -q_1 \cos \psi_1 \\ z'^0_1 &= q_1(tg\, s_1 \cos r_1 + \sin r_1 \sin \psi_1) \end{aligned} \tag{28a}$$

In fig. 5, P is situated between N and p; in case P lies beyond p, $tg\ s_1$ in (28a) changes sign and becomes negative. If the sign $\pm$ be placed before $tg\ s_1$, therefore, all possible relations are taken into account; for each particular case, the proper sign must be determined.

On substituting these coördinate values (27) (28a) in the Potier relation (26) for two sets of corresponding points p_1, P_1, p_2, P_2 of the waves W_1,W_2 whose normals lie in the plane of incidence $x'z'$, we obtain,

$$\frac{q_2}{q_1}\Big[\sin \psi_1 \cos r_1 \sin \psi_2 \cos r_2 - \sin \psi_1 \cos r_1\, tg\, s_2 \sin r_2 + \cos \psi_1 \cos \psi_2 + \sin \psi_1 \sin r_1\, tg\, s_2 \cos r_2 + \sin \psi_1 \sin r_1 \sin \psi_2 \sin r_2\Big]$$

$$= \frac{q_1}{q_2}\Big[\sin \psi_2 \cos r_2 \sin \psi_1 \cos r_1 - \sin \psi_2 \cos r_2\, tg\, s_1 \sin r_1 + \cos \psi_2 \cos \psi_1 + \sin \psi_2 \sin r_2\, tg\, s_1 \cos r_1 + \sin \psi_2 \sin r_2 \sin \psi_1 \sin r_1\Big]$$

This equation may be rearranged to read

$$\begin{aligned} &(q^2_1 - q^2_2)[\sin \psi_1 \sin \psi_2 \cos (r_1 - r_2) + \cos \psi_1 \cos \psi_2] - \\ &\quad (q^2_1\, tg\, s_1 \sin \psi_2 + q^2_2\, tg\, s_2 \sin \psi_1) \sin (r_1 - r_2) = 0 \end{aligned} \tag{29}$$

This general relation of MacCullagh-Neumann-Potier exists between any two of the four possible waves, W_1, W_2, W_a, W_b, within a crystal plate for each of which the sine law

$$q_1 = \frac{q_0 \sin r_1}{\sin i}, \quad q_2 = \frac{q_0 \sin r_2}{\sin i} \quad \text{or} \quad q_k = \frac{q_0 \sin r_k}{\sin i}$$

is valid. These values introduced into (29) give after division by $\sin (r_1 - r_2)$ the equation

$$\begin{aligned} \sin (r_1 + r_2)[\sin \psi_1 \sin \psi_2 \cos (r_1 - r_2) + \cos \psi_1 \cos \psi_2] - \\ \sin^2 r_1 \, tg\, s_1 \sin \psi_2 - \sin^2 r_2 \, tg\, s_2 \sin \psi_1 = 0 \end{aligned} \tag{29a}$$

Six different equations of this general form are possible, as six combinations of two can be obtained from the four different waves.

Equation (29a) can be simplified by substituting for $tg\ s_1$ an expression containing q_1, r_1, ψ_1, and three constants, a_{11}, a_{13}, a_{33}, of the index ellipsoid. In fig. 4, the coördinates of P are

$\left(\frac{\partial I}{\partial x}\right)_1$, $\left(\frac{\partial I}{\partial y}\right)_1$, $\left(\frac{\partial I}{\partial z}\right)_1$ (equation (25a)) and the length

$$OP = \sqrt{\left(\frac{\partial I}{\partial x}\right)_1^2 + \left(\frac{\partial I}{\partial y}\right)_1^2 + \left(\frac{\partial I}{\partial z}\right)_1^2}\ .$$

Accordingly

$$\cos POp' = \cos s_1 = \frac{Op'}{OP} = \frac{q_1}{\sqrt{\left(\frac{\partial I}{\partial x}\right)_1^2 + \left(\frac{\partial I}{\partial y}\right)_1^2 + \left(\frac{\partial I}{\partial z}\right)_1^2}} \tag{30}$$

The direction cosines of the radius vector OP are proportional to the coördinates of P and therefore from (29) and (29a)

$$\frac{\cos Px'}{\cos Py'} = \frac{x^0_1}{y^0_1} = \frac{\left(\frac{\partial I}{\partial x}\right)_1}{\left(\frac{\partial I}{\partial y}\right)_1} = \frac{tg\ s_1 \sin r_1 - \cos r_1 \sin \psi_1}{-\cos \psi_1}$$

from which

$$\left(\frac{\partial I}{\partial y}\right)_1 = \left(\frac{\partial I}{\partial x}\right)_1 \frac{-\cos \psi_1}{tg\ s_1 \sin r_1 - \cos r_1 \sin \psi_1}$$

Similarly (31)

$$\left(\frac{\partial I}{\partial z}\right)_1 = \left(\frac{\partial I}{\partial x}\right)_1 \frac{tg\ s_1 \cos r_1 + \sin r_1 \sin \psi_1}{tg\ s_1 \sin r_1 - \cos r\ \sin \psi_1}$$

On substituting these values from (31) in (30) we find

$$\cos s_1 = \frac{1}{\sqrt{1 + tg^2 s_1}} = \frac{q_1}{\left(\frac{\partial I}{\partial x}\right)_1 \frac{\sqrt{1 + tg^2 s_1}}{tg\ s_1 \sin r_1 - \cos r_1 \sin \psi_1}}$$

$$\text{or} \qquad tg\ s_1 \sin r_1 = \frac{1}{q_1}\left(\frac{\partial I}{\partial x}\right)_1 + \cos r_1 \sin \psi_1$$

$$\text{But} \qquad \left(\frac{\partial I}{\partial x}\right)_1 = a_{11}\, x'_1 + a_{12}\, y'_1 + a_{13}\, z'_1$$

which from (27)

$$= \frac{1}{q_1}\left(-a_{11} \cos r_1 \sin \psi_1 - a_{12} \cos \psi_1 + a_{13} \sin r_1 \sin \psi_1 \right)$$

Accordingly[1]

$$tg\ s_1 = \frac{(q^2_1 - a_{11})\cos r_1 \sin \psi_1 - a_{12} \cos \psi_1 + a_{13} \sin r_1 \sin \psi_1}{q^2_1 \sin r_1} \ (^2) \qquad (32)$$

On eliminating $tg\ s$ from (29*a*) by means of (32) we find

$$\sin (r_1 + r_2)[\sin \psi_1 \sin \psi_2 \cos (r_1 - r_2) + \cos \psi_1 \cos \psi_2] +$$

$$\frac{\sin r_1 \sin \psi_2}{q^2_1}[a_{11} - q^2_1) \cos r_1 \sin \psi_1 - a_{13} \sin r_1 \sin \psi_1 + a_{12} \cos \psi_1] +$$

$$\frac{\sin r_2 \sin \psi_1}{q^2_2}\ (a_{11} - q_2)^2 \cos r_2 \sin \psi_2 - a_{13} \sin r_2 \sin \psi_2 + a_{12} \cos \psi_2] = 0$$

which on rearrangement becomes

[1] This expression was first derived by P. Kaemmerer (Neues Jahrb., Beil. Bd. xx, 206, 1905), though by a method different from the above.

[2] From the equations (30) and (31) the following relations can also be derived:

$$-\cos \psi_1 = \frac{1}{q_1}\left(\frac{\delta I}{\delta y}\right)_1 = \frac{1}{q^2_1}\left(-a_{12} \cos r_1 \sin \psi_1 - a_{22} \cos \psi_1 + a_{13} \sin r_1 \sin \psi_1 \right)$$

$$\text{or} \qquad tg\ \psi_1 = \frac{q^2_1 - a_{22}}{a_{12} \cos r_1 - a_{23} \sin r_1} \qquad (32a)$$

an equation identical with (17).

$$\text{Also} \qquad \cos s_1 = \frac{q_1}{\left(\frac{\delta I}{\delta z}\right)_1 \frac{\sqrt{1 + tg^2\, s_1}}{tg\ s_1 \cos r_1 + \sin r_1 \sin \psi_1}}$$

$$\text{or} \qquad tg\ s_1 = \frac{-a_{13} \cos r_1 \sin \psi_1 - a_{23} \cos \psi_1 + (a_{33} - q^2_1) \sin r_1 \sin \psi_1}{q^2_1 \cos r_1} \qquad (32b)$$

an expression for $tg\ s$, which is apparently novel. On equating (32) and (32*b*) we find

$$tg\ \psi_1 = \frac{a_{12} \cos r_1 - a_{23} \sin r_1}{q^2_1 - a_{11} \cos^2 r_1 - a_{33} \sin^2 r_1 + 2a_{13} \sin r_1 \cos r_1} \qquad 2c)$$

From (32a) and (32c), we have

$$(q^2_1 - a_{22})(q^2_1 - a_{11} \cos^2 r_1 - a_{33} \sin^2 r_1 + 2\, a_{13} \sin r_1 \cos r_1) = (a_{12} \cos r_1 - a_{23} \sin r_1)^2$$

an expression free from ψ and identical with (16).

$$\cos r_1 \cos\psi_1 \sin r_2 \cos\psi_2 + \cos r_2 \cos\psi_2 \sin r_1 \cos\psi_1 + \frac{\sin r_1 \sin\psi_2}{q^2_1}[\sin\psi_1(a_{11}\cos r_1 - a_{13}\sin r_1) + a_{12}\cos\psi_1] + \frac{\sin r_2 \sin\psi_1}{q^2_2}[\sin\psi_2(a_{11}\cos r_2 - a_{13}\sin r_2) + a_{12}\cos\psi_2] = 0 \quad (33)$$

an equation, which, like 18*a*, can be written in the abbreviated form

$$l_1 n_2 + l_2 n_1 + p_1 m_2 + p_2 m_1 = 0 \quad (33a)$$

This equation is the general Potier relation[1] and is applicable to any two of the four possible waves within the crystal.

Uniradial azimuths.

At the boundary surface of a crystal plate with an enveloping isotropic medium, an incident plane polarized, monochromatic light wave furnishes, in general, one reflected wave in the isotropic medium and two refracted waves, W_1, W_2, within the crystal. The directions and azimuths of the two refracted waves are definitely fixed by equations (16) and (17) and a rotation of the plane of polarization of the incident wave can produce a change in the amplitudes only of the two refracted waves. For a certain value of the azimuth, the amplitude of either W_1 or W_2 becomes zero, and but one refracted wave is transmitted. Such azimuths, ϵ_u, of the plane of polarization of the incident wave, for which only one refracted wave results, are called uniradial azimuths, and were first investigated by MacCullagh[2] and Neumann.[3] For $D_2 = 0$ in equation (19) we find

$$\begin{aligned} &(a)\ (E\cos\epsilon_1 - R\cos\rho)\cos i = D_1\cos\delta_1\cos r_1 \\ &(b)\ E\sin\epsilon_1 + R\sin\rho = D_1\sin\delta_1 \\ &(c)\ (E\cos\epsilon_1 + R\cos\rho)\sin i = D_1\cos\delta_1\sin r_1 \qquad (34) \\ &(d)\ (E\sin\epsilon_1 - R\sin\rho)\sin i\cos i = \\ &\qquad \frac{D_1\sin r_1}{a^2_1}[\sin\delta_1(a_{11}\cos r_1 - a_{13}\sin r_1) + a_{12}\cos\delta_1] \end{aligned}$$

The last equation of this set can be readily reduced by means of (32) to the form

$$(d')\ (E\sin\epsilon_1 - R\sin\rho)\sin i\cos i = D_1\sin^2 r_1(\cot r_1\sin\delta_1 - tg\, s_1)$$

By multiplying the first of these equations with sin i, the third with cos i and adding; also the second with cos i sin i, and adding to the fourth, we obtain

[1] Potier, Jour. de Phys. (2), x, 352, 1891.
[2] Trans. Roy. Irish Acad., xviii, 31, 1837. Collected Works, p. 110, 1880.
[3] Berliner Akad. Abh., Math. Abt. 144, 1835; Pogg. Ann., xlii, 9, 1837.

$$(a)\ \text{E} \cos \epsilon_1 (2 \cos i \sin i) = \text{D}_1 \cos \delta_1 \sin (i+r_1)$$
$$(b)\ \text{E} \sin \epsilon_1 (2 \cos i \sin i) = \text{D}_1 (\sin \delta_1 \sin i \cos i + \sin^2 r_1 (\cot r_1 \sin \delta_1 - tg\ s_1)$$

On division of (b) by (a)

$$tg\ \epsilon_1 = \frac{\sin \delta_1 (\sin i \cos i + \sin r_1 \cos r_1) - \sin^2 r_1\ tg\ s_1}{\cos \delta_1 \sin (i+r_1)}$$

or
$$tg\ \epsilon_1 = tg\ \delta_1 \cos (i - r_1) - \frac{\sin^2 r_1\ tg\ s_1}{\cos \delta_1 \sin (i+r_1)} \qquad (35a)$$

Similarly,
$$tg\ \epsilon_2 = tg\ \delta_2 \cos (i - r_2) - \frac{\sin^2 r_2\ tg\ s_2}{\cos \delta_2 \sin (i+r_2)} \qquad (35b)$$

By means of these formulas the uniradial azimuths for the refracted waves W_1 and W_2 can be calculated. At the second boundary surface of the crystal plate, the refracted wave W_1 produces two reflected waves W_{1a}, W_{1b} and one emergent wave W'_1. (fig. 2). To calculate the azimuth of the plane of polarization of this emergent wave, the relations of Potier are important. The general boundary conditions for this surface and wave W_1 are defined by equations (20), which, after the manner of (18a) can be written in the abbreviated form:

$$\begin{aligned} D_1 l_1 + R'_1 l'_1 + R''_1 l''_1 &= D'_1 \cos \delta'_1 \cos i \\ D_1 m_1 + R'_1 m'_1 + R''_1 m''_1 &= D'_1 \sin \delta'_1 \\ D_1 n_1 + R'_1 n'_1 + R''_1 n''_1 &= D'_1 \cos \delta'_1 \sin i \\ D_1 p_1 + R'_1 p'_1 + R''_1 p''_1 &= D'_1 \sin \delta'_1 \sin i \cos i \end{aligned} \qquad (20a)$$

On multiplying the first of these equations by n_2, the second by p_2, the third by l_2, the fourth by m_2, and adding, we find

$$\begin{aligned} &D_1 (n_2 l_1 + m_1 p_2 + l_2 n_1 + m_2 p_1) + R'_1 (n_2 l'_1 + p_2 m'_1 + l_2 n'_1 + m_2 p'_1) + \\ &\qquad R''_1 (l''_1 n_2 + m_1 p''_2 + l_2 m''_1 + m_2 p''_1) = \\ &D'_1 (n_2 \cos \delta'_1 \cos i + p_2 \sin \delta'_1 + l_2 \cos \delta'_1 \sin i + m_2 \sin \delta'_1 \sin i \cos i) \end{aligned}$$

In this equation the coefficients of D, R′, R″, are = 0 by virtue of the Potier relation (33a), and as the amplitude D′ is not in general zero, the equation reduces to

$$tg\ \delta'_1 = -\frac{n_2 \cos i + l_2 \sin i}{p_2 + m_2 \sin i \cos i}$$

On replacing n_2, l_2, p_2, m_2 in this expression by their respective values from (19), we obtain

$$tg\ \delta'_1 = -\frac{\cos \delta_2 \sin r_2 \cos i + \cos \delta_2 \cos r_2 \sin i}{\frac{\sin r_2}{d^2_2}[\sin \delta_2 (a_{11} \cos r_2 - a_{13} \sin r_2) + a_{12} \cos \delta_2] + \sin \delta_2 \sin i \cos i} \qquad (36)$$

This expression can be simplified, as was (34), by the introduction of $tg\ s_2$:

$$tg\ \delta'_1 = -\frac{\cos\delta_2 \sin(i+r_2)}{\sin^2 r_2(\cot r_2 \sin\delta_2 - tg\ s_2) + \sin\delta_2 \sin i \cos i}$$

or
$$tg\ \delta'_1 = -\frac{\cos\delta_2 \sin(i+r_2)}{\sin\delta_2 \sin(i+r_2)\cos(i-r_2) - \sin^2 r_2\, tg\ s_2} \qquad (36a)$$

On comparing this relation with (35*b*), it is evident that

$$tg\ \delta'_1 = -\frac{1}{tg\ \epsilon_2}$$

$$\delta'_1 = \epsilon_2 \pm 90^\circ \qquad (37)$$

also
$$\delta'_2 = \epsilon_1 \pm 90^\circ$$

This apparently new and important relation greatly simplifies the labor of calculating the azimuths of the planes of polarization of waves transmitted through a crystal plate. In form it is similar to the relation deduced by Potier,[1] that in case a wave W_1 within a crystal plate emerges into an isotropic medium, the emergent wave is polarized at right angles to that wave which, entering the crystal plate in the opposite direction, produces the so-called "Hilfswelle W"[2] of W′. The above relation states that the azimuth of the plane of polarization of the emergent wave W'_1 from W_1 is at right angles to the uniradial azimuth ϵ_2 of the wave W_2. To calculate the azimuths of the emergent waves W'_1, W'_2, it is only necessary, therefore, to calculate the uniradial azimuths ϵ_1, ϵ_2 of the incident waves which produce the refracted waves W_1 and W_2.

Uniaxial Crystals.

In the preceding pages the formulas for the transmission of light through crystal plates have been developed for the most general case, that of biaxial crystals. When applied to uniaxial plates, these formulas become somewhat simpler, and deserve brief consideration as they will be used in the observational part of this paper. The equation of the index surface for uniaxial crystals referred to general coördinates is

$$[o^2(x'^2+y'^2+z'^2)-1][a_{11}x'^2+a_{22}y'^2+a_{33}z'^2+2a_{23}y'z'+ 2a_{31}z'x'+2a_{12}x'y'-1]=0.$$

If, as usual, the plane of incidence be the x' z' plane, ($y'=0$), and the z' axis the normal to the plate, the positive direction of z' being within the crystal plate, this equation can be written

[1] Journ. de Phys. (2), x, 354, 1891.
[2] F. E. Neumann, Berliner Akad. Abh., Math. Abt., 1835.

$$[o^2(x'^2+z'^2)-1][a_{11}x'^2+a_{33}z'^2+2a_{31}z'x'-1]=0. \qquad (38)$$

In this formula x' and z' can, by virtue of the sine law, be readily expressed in polar coördinates; if i be the angle of incidence and r the angle of refraction and n_0 the refractive index of the isotropic medium, then $x' = n_0 \sin i$, and $z' = \dfrac{n_0 \sin i}{tg\, r}$. With these values (38) reduces to

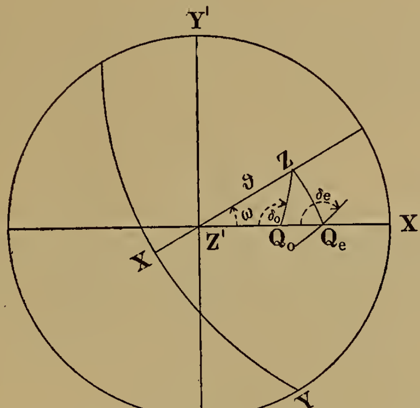
$$[o^2 n_0^2 \sin^2 i\,(1+tg^2 r)-tg^2 r][(a_{11}n_0^2 \sin^2 i-1)tg^2 r+ 2a_{31}n_0^2 \sin^2 i\; tg\, r+a_{33}n_0^2 \sin^2 i]=0. \qquad (38a)$$

From the first half of this equation (38*a*)

$$\sin r_0 = n_0\, o \sin i.$$

To evaluate the coefficients of $tg\, r$ in the second half of the equation (38*a*), let the plane $x'\ y'$ in fig. 6 be the boundary

Fig. 6.



surface of the crystal plate; $x'\ z'$, the plane of incidence, the positive direction of z' being on the crystal side of the boundary surface; x, y, z, the principal ellipsoidal axes of the crystal; θ the polar angle zz', and ω, the azimuth of the principal plane $z\,z'$; let also the angles of inclination of the wave normals, Q_o, Q_e, with the z' axis be $Q_o z'=r_o$, $Q_e z'=r_e$; with the z axis, be $Q_o z=\phi_o$, $Q_e z=\phi_e$. In this case the direction cosines of x', y', z' with x, y, z, are respectively

$p_1 = -\cos\theta\cos\omega$	$p_2 = \sin\omega$	$p_3 = \sin\theta\cos\omega$
$q_1 = -\cos\theta\sin\omega$	$q_2 = -\cos\omega$	$q_3 = \sin\theta\sin\omega$
$r_1 = \sin\theta$	$r_2 = 0$	$r_3 = \cos\theta$

also, in equations (9) $a^2 = e^2$, $b^2 = e^2$, $c^2 = o^2$.

Substituting these values in equation (9), we obtain the usual equations

$$\begin{aligned} a_{11} &= e^2 + (o^2 - e^2) \sin^2\theta \cos^2\omega \\ a_{22} &= e^2 + (o^2 - e^2) \sin^2\theta \sin^2\omega \\ a_{33} &= e^2 \sin^2\theta + o^2 \cos^2\theta \\ a_{23} &= (o^2 - e^2) \cos\theta \sin\theta \sin\omega \\ a_{31} &= (o^2 - e^2) \cos\theta \sin\theta \cos\omega \\ a_{12} &= (o^2 - e^2) \sin^2\theta \cos\omega \sin\omega \end{aligned} \tag{39}$$

and the coefficients of $tg\ r$ in the second half of (38a) become

$$\begin{aligned} a_{11} n_0^2 \sin^2 i - 1 &= n_0^2 \sin^2 i \,[e^2 + (o^2 - e^2) \sin^2\theta \cos^2\omega] - 1 \\ 2a_{31} n_0^2 \sin^2 i &= 2n_0^2 \sin^2 i \,(o^2 - e^2) \cos\theta \sin\theta \cos\omega \\ a_{33} n_0^2 \sin^2 i &= n_0^2 \sin^2 i \,(e^2 \sin^2\theta + o^2 \cos^2\theta). \end{aligned} \tag{40}$$

From equations (38a) and 40), r_e for the extraordinary wave can be calculated. If $n_0=1$, as is practically the case when the crystal plate is surrounded by air, equation (38a) can be written in the following form, which is logarithmically convenient:

$$\sin r_o = o \sin i\,; \tag{41}$$

$$tg\ r_e = \frac{B\cos\omega \pm \sqrt{B^2\cos^2\omega + C\left(\frac{1}{\sin^2 i} + A\cos^2\omega - e^2\right)}}{e^2 - A\cos^2\omega - \frac{1}{\sin^2 i}}$$

wherein

$$\begin{aligned} A &= (e^2 - o^2) \sin^2\theta \\ B &= (e^2 - o^2) \sin\theta \cos\theta \\ C &= e^2 \sin^2\theta + o^2 \cos^2\theta\,. \end{aligned}$$

To find the azimuths δ_o, δ_e of the planes of polarization of the refracted waves W_o, W_e, fig. 6 is again useful. In the spherical triangle $Q_o\, z\, z'$, the relation obtains

$$\cot\delta_o = \frac{\sin r_o \cot\theta - \cos r_o \cos\omega}{\sin\omega} \tag{42a}$$

while in the spherical triangle $Q_e\, z\, z'$

$$tg\ \delta_e = \frac{\cos r_e \cos\omega - \sin r_e \cot\theta}{\sin\omega}\,. \tag{42b}$$

The uniradial azimuths ϵ_o and ϵ_e are calculated from equations (35a). For the ordinary wave the wave normal and ray direction coincide and the angle $s_o=0$.

Accordingly

$$tg\ \epsilon_o = tg\ \delta_o \cos(i - r_o). \tag{43}$$

In the analogous expression for $tg\ \epsilon_e$,

$$tg\ \epsilon_e = tg\ \delta_e \cos(i - r_e) - \frac{\sin^2 r_e\, tg\ s_e}{\cos\delta_e \sin(i + r_e)} \tag{44}$$

$tg\ s_e$ occurs but can be expressed in terms of known angles.[1]

[1] MacCullagh, Coll. Works, 1880. Trans. Roy. Irish Acad., xvii, 1833. Pockels, F., Lehrbuch der Kristalloptik, 194–195, 1906.

In uniaxial crystals the usual formula for $tg\ s_e$ is

$$tg\ s_e = \frac{e^2 - o^2}{q_e^2} \cos\phi_e \sin\phi_e \qquad (a)$$

where ϕ_e is the angle $Q_e z$ of fig. 6. From the spherical triangle $Q_e\ z\ z'$, fig. 6,

$$\cot\phi_e = \frac{\cos r_e \sin\delta_e - \cot\omega \cos\delta_e}{\sin r_e}; \qquad (b)$$

also
$$\cot\phi_e = -\frac{\cos\delta_e}{\sin\omega}(\cot\theta \cos r_e + \cos\omega \sin r_e). \qquad (b')$$

Furthermore, in the principal section through Q_e and z

$$q_e^2 = o^2 \cos^2\phi_e + e^2 \sin^2\phi_e$$

from which expression, we find (c)

$$\frac{e^2 - o^2}{q_e^2} \sin^2\phi_e = 1 - \frac{o^2}{q_e^2} = 1 - \frac{\sin^2 r_o}{\sin^2 r_e} = \frac{\sin(r_e - r_o)\sin(r_e + r_o)}{\sin^2 r_e}.$$

By means of the three equations (*a*), (*b*), (*c*), equation (44) becomes

$$tg\ \epsilon_e = tg\ \delta_e \cos(i - r_e) + \frac{\sin(r_e - r_o)\sin(r_e + r_o)(\cot\omega - \cos r_e\, tg\ \delta_e)}{\sin(i + r_e)\sin r_e} \qquad (44a)$$

or from equations (*a*), (*b'*), (*c*)

$$tg\ \epsilon_e = tg\ \delta_e \cos(i - r_e) + \frac{\sin(r_e - r_o)\sin(r_e + r_o)(\cot\theta \cos r_e + \cos\omega \sin r_e)}{\sin(i + r_e)\sin\omega} \qquad (44b)$$

Having thus found ϵ_o and ϵ_e, the azimuths δ'_o and δ'_e are readily obtained by the use of equations (37).

$$\delta'_o = \epsilon_e \pm 90^\circ \qquad \delta'_e = \epsilon_o \pm 90^\circ \qquad (45)$$

Isotropic Plates.

In the case of isotropic plates, the index ellipsoid reduces to a sphere and the constants of the equation become

$$a_{11} = a_{22} = a_{33} = q^2$$

$$a_{23} = a_{31} = a_{12} = 0$$

Equations (16), (35*a*), (36*a*), then reduce (if the surrounding medium be air $q_0 = 1$)

$$(a) \qquad \sin r = q \sin i = \frac{\sin i}{n}$$

$$(b) \qquad tg\ \epsilon_1 = tg\ \delta_1 \cos(i - r)$$

$$(c) \qquad tg\ \delta'_1 = \frac{-\cot\delta_2}{\cos(i - r)} \qquad (46)$$

In these last two equations, (b) and (c), the azimuth δ_1 may assume any value, since the structure of isotropic substances does not prescribe definite planes of polarization for transmitted waves, as do anisotropic substances; but if δ_1 be once given, δ_2 is then $= \delta_1 \pm 90°$
and the last equation, (c), may be written

$$tg\ \delta'_1 = \frac{tg\ \delta_1}{\cos(i-r)} = \frac{tg\ \epsilon_1}{\cos(i-r)^2} \qquad (46c')$$

From this formula, the angle δ' can be calculated, provided ϵ_1, i and r be given. The difference $(\epsilon_1 - \delta'_1)$ is then the amount of rotation which the plane of polarization of incident, monochromatic light suffers on transmission through the isotropic plate.

In case the light wave passes through several plates, cemented together as in a thin section mount where n_1 is the refractive index of the object glass, n_2 that of the Canada balsam, and n_3 that of the cover slip, an incident wave i becomes r_1 in the object glass, where $\sin r_1 = \frac{\sin i}{n_1}$; similarly, r_2 and r_3 are the angles of refraction in n_2 and n_3 and can be calculated by the general sine formula above. From formula (46b) and (46c) it is evident that the total rotation of the plane of polarization of a transmitted wave under these conditions is

$$\cot \delta' = \cot \epsilon \cos(i-r_1) \cos(r_1-r_2) \cos(r_2-r_3) \cos(i-r_3)$$

Summary.—In the foregoing pages the formulas have been developed which are especially useful in a consideration of the phenomena observed on mounted crystal plates in convergent polarized light. In this discussion, the effects of the plates on reflected light waves have not been treated in detail, nor has a study been made of the relative amplitudes of the reflected and refracted waves; attention has been directed rather to the effects of transparent, inactive plates on the planes of polarization of transmitted light. In the calculation of these effects, four steps are necessary; (1) if the angle of incidence i of the entering light wave be given, the angles of refraction r_1, r_2 of the two transmitted waves are found by means of formula (16) in the case of biaxial plates, or by (41) for uniaxial plates, or by (46a) for the single transmitted wave in isotropic plates. (2) The azimuths of the planes of polarization of the two refracted waves are then found by use of equations (17) for biaxial plates, or (42) for uniaxial plates. In the case of isotropic plates the plane of polarization of transmitted waves may have any azimuth, so far as such azimuths are dependent on the structure of the material. (3) Having given the angle of refraction and the azimuth of the plane of polarization of a transmitted wave, the azimuth of the plane of polarization of the incident wave which produced it is obtained by use of equations (35) for biaxial plates, (43) or (44) for uniaxial plates, and (46*b*) for isotropic plates. (4) To find the azimuth of the plane of polarization of the emergent wave, provided that of the incident wave which produced the refracted wave be known, equation (37) is useful. This last equation, which is apparently new, states that the azimuth of the plane of polarization of an emergent wave δ'_1, resulting from the refracted wave W_1, is 90° from the uniradial azimuth of the incident wave ϵ_2 which produced the refracted wave W_2.

A detailed discussion of the above formulas is deemed unnecessary in this summary, as they are in large measure standard and the effects of the different factors will appear more clearly in the discussion of the data of observation.

In the development of these formulas, no account has been taken of the effects of surface films on the rotation of the planes of polarization of transmitted waves. These films have been shown by P. Drude[1] and others to be occasionally of great influence, especially on plates which have been highly polished, while on freshly cleaved plates they are practically absent. The observations listed in the following pages were made largely on cleavage plates, which, however, were usually exposed for a month or more before the observations were finished and may have accordingly suffered some deterioration.

Part 2.

Observations.

Apparatus.—All observations recorded below were made in sodium light, the crystal plate being mounted on a universal stage on the new model petrographic microscope recently described by the writer.[2] To insure accuracy, the microscope was carefully adjusted and its adjustment tested at intervals in the course of the measurements. The nicol prisms were of the square end Glan-Thompson type and were crossed by pointing the microscope, from which all lenses had been removed, directly toward the sun whose rays are parallel and so intense that a rotation of less than 1′ of arc from the position of exact crossing of the nicols is readily discerned. By means of the iris diaphragms the sun's rays were sent through the microscope centrally so that no rotatory effect of the nicol surfaces on the planes of polarization of the transmitted waves was possible. The ordinary type of nicol prism with oblique

[1] Wied. Ann., xxxvi, 532, 865, 1888; xxxviii, 265, 1889; xliii, 146, 1891.
[2] This Journal (4), xxix, 407–414, 1910.

ends was first used, but was soon discarded because of the effect of its oblique surfaces on the plane of polarization of the transmitted waves. For exact work in extinction angles, the ordinary type of nicol prism is much inferior to the Glan-Thompson type with square ends. Having thus crossed the nicols accurately, the crosshairs of the ocular were adjusted by using the ocular and Bertrand lens as a microscope and focusing on a mounted anhydrite cleavage plate through which parallel sun's rays were passed centrally. Here again the sun's rays are so intense that the position of total extinction of the anhydrite plate can readily be fixed within 1′ of arc. By means of the anhydrite plate which extinguishes parallel with its cleavage edges, the principal sections of the nicols and the ocular crosshairs were brought to coincidence. The universal stage was then attached to the microscope stage and its horizontal axis of rotation brought to coincidence with the horizontal crosshair of the ocular, by use of the lines engraved on the glass disk of the universal stage. This glass disk, together with its supporting ring, was then removed and in its place a second ring of precisely the same dimensions substituted, on which a strip of thin glass plate was cemented, and to which in turn one corner of the crystal plate was cemented, the glass plate serving merely as a support for the crystal plate whose major part was left free and exposed on both sides to air. The surface of the crystal plate was then brought to approximate parallelism with the horizontal circle of the universal stage; it was adjusted to exact parallelism by viewing, through a mounted telescope, the image of a distant light source as reflected from the surface of the crystal plate. The horizontal circle H_2 of the universal stage[1] was then rotated and the crystal plate tilted and turned by means of the horizontal circle H_3 and the vertical circle V_2 until the reflected image remained stationary on rotation of H_2. The circles on the universal stage could be read to 5′ by means of the vernier, while on the microscope stage the vernier intervals were 3′. In neither case, however, were the lines on the circles and verniers sufficiently fine to insure greater accuracy in reading than the 3′ or 5′ intervals on the vernier. In actual work each position of total extinction was determined 10 times and the average taken. On sharp extinctions it was found that the different settings were usually within 10′ of the average.

In the earliest preparations measured, the positions of total extinction were determined by use of the bi-quartz wedge plate,[2] but the fact that, in making the observations with this plate, it was necessary to use the objective and ocular, the glass surfaces of which in turn influence the plane of polar-

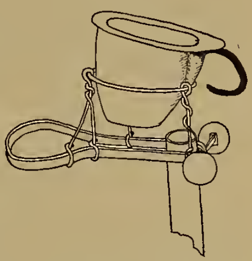
[1] See page 186 below.

[2] This Journal (4), xxvi, 391, 1908.

ization of transmitted waves, was sufficient reason to discard it. In the final arrangement adopted, no glass surfaces intervened between the nicols and the crystal plate. An enlarged image of the plate was obtained by means of a weakly magnifying microscope consisting of the Bertrand lens and ocular, above the upper nicol.

Intense sodium light flame.—To increase the intensity of the sodium light flame, and with it the accuracy of the observations, an arrangement was adopted which in practice has proved entirely satisfactory. A 25^{cc} platinum crucible was filled with a mixture of sodium chloride and sodium carbonate and heated over a Bunsen burner, a special mounting of thick platinum wire having been made for the crucible as indicated in the diagram. A wick of fine platinum wires carried the molten salts from the base of the crucible out into a strong and constant blast lamp flame, the high temperature of which produced an intense sodium flame which lasted for days, until the salts in the crucible were exhausted. An oxy-hydrogen blast was also tried, and although it gave a much more intense flame, its regulation proved troublesome and there was danger that the platinum wick might melt down unless the flame was constantly regulated. The fumes from the salts were carried off under a hood. The microscope was placed in a horizontal position and pointed directly at the flame without intervening reflector.

Fig. 7.



Results.

Isotropic Plates.—Plane polarized light waves, in passing obliquely through a mounted crystal plate, encounter not only the boundary surfaces of the crystal plate, but also those of the object glass, the cover slip and the Canada balsam in which the plate is mounted. Each surface exerts a certain rotatory influence on the plane of polarization of the transmitted light wave. In order to obtain an idea of the effect of the glass plates and Canada balsam alone on the rotation of the plane of polarization of a transmitted light wave, a blank glass slide was prepared consisting of an object glass ($n_{Na} = 1·511$) and a cover glass ($n_{Na} = 1·520$) cemented together with Canada balsam ($n_{Na} = 1·537$). This slide was mounted on the universal stage[1] whose different circles may be designated as follows[2]:

[1] This effect has been considered in some detail by G. Cesàro in the Bull. de l'Acad. roy. de Belgique, Classe d. Sciences, No. 7, Juillet, 1906.
[2] See this Journal (4), xxiv, 343, 1907.

H_1 = circle on stage of microscope supporting universal stage.
H_2 = outer horizontal circle of universal stage.
H_3 = inner and smaller horizontal circle of universal stage.
V_1 = large vertical circle of universal stage.
V_2 = small vertical leaf circles on modified form of universal stage.

The source of light used in this instance was a Nernst light, at the focus of a large condensing lens. The Abbe condensor lens system was removed from the microscope, so that the entering light waves were as nearly parallel as possible. For the exact location of the position of total extinction the bi-quartz wedge plate was used. The upper nicol remained fixed while the lower nicol was rotated to determine the amount of rotation of the plane of polarization.

The results of the observations are included in Table I, in which the probable error of the average angles H is less than 10′. These measurements may be summarized by stating that

TABLE I.

i	ω	δ'	Calculated	δ'-ω	Readings									
22°30′	22°30′	22°50′	22°53′	0°20′	22°50′	50′	51′	48′	51′	51′	52′	51′	52′	52′
"	45 00	45 37	45 33	0 37	45 38	35	37	35	36	38	38	39	39	39
"	67 30	68 00	67 53	0 30	68 00	58	01	01	00	02	00	00	01	01
45 00	22 30	24 19	24 25	1 49	24 19	16	21	17	17	20	20	20	21	21
"	45 00	47 35	47 37	2 35	47 32	33	36	32	36	37	37	36	38	34
"	67 30	69 24	69 18	1 54	69 19	20	25	28	25	21	28	25	25	25

for low angles of inclination of the glass plate, originally plane polarized light is, after transmission, still practically plane polarized, although its plane of polarization has been rotated slightly, the amount of rotation increasing with the angle of inclination. On each boundary surface a certain part of the incident light is reflected and a certain part refracted. For an isotropic body, as an object glass, there is a definite angle (Brewster's angle) for which all reflected light is plane polarized, while the refracted waves are partially polarized. In fact, for every angle of incidence reflected natural light is partially polarized in the plane of incidence. The refracted light must, therefore, also be partially polarized normal to the plane of incidence, as no light disappears. In this manner the polarizing effect of a set of plates may be explained. If the incident light be plane polarized, its plane of polarization is rotated on refraction and the amount of rotation can be calculated from Fresnel's reflection and refraction formulas (46), These formulas have been tested by numerous observers.

especially Jamin,[1] and found to be valid except for light waves incident at Brewster's angle, in which case the light is not perfectly plane polarized, but shows elliptic polarization. In convergent polarized light, therefore, all waves except those near the center of the field and along the principal sections of the nicols suffer from the rotating effect of the glass surfaces of the crystal mount on the planes of polarization. This effect increases in amount as the margin of the field is approached, where total extinction under crossed nicols is noticeably imperfect in the diagonal positions. The glass surfaces of the lenses, both of the condenser and the objective, moreover, exert also a rotatory influence on transmitted plane polarized waves, and for this reason, in convergent polarized light, the field appears to be divided by a dark cross into four less dark quadrants even when no crystal plate intervenes. The amount of rotation and consequent intensity of illumination is greatest for waves contained in planes at 45° from the principal nicol sections. The amount of rotation varies also with the refractive indices of the isotropic substances examined and the enveloping media as indicated by equation (47). It is, however, obviously impossible in practical work to take into account the rotatory effects of all glass surfaces intervening between the two nicols, and all methods based on the exact measurement of extinction angles of obliquely transmitted waves must suffer from this defect and can only give approximate results. This applies both to methods involving convergent polarized light and to the universal stage methods. The error produced from this cause alone is not great (in unfavorable instances, 2° to 4°), but it precludes results of a high degree of accuracy. In the universal stage methods the use of the small hemisphere as recommended by Fedorow materially decreases the rotatory effect both of the glass mount and of the crystal plate, and tends toward greater accuracy as well as increasing the angle of view of the field. The greater the difference in refractive index between the two media, the greater the amount of rotation as indicated by equation (46). The glass sphere not only tends to offer more nearly horizontal surfaces to the entering light wave than the inclined glass mount, but at the same time renders the boundary surface of the glass mount practically inert in its action ; the glass mount in turn decreases materially the amount of rotation which the surfaces of the crystal plate exert when unmounted. These facts justify the application of Fresnel's rule for finding the directions of total extinction in a tilted crystal plate to the universal stage methods, as a close approximation to the truth,

[1] Ann. Chim. Phys. (3), xxix, 263, 1850 ; xxxi, 165, 1850.

the error incurred thereby being of a comparatively low order of magnitude and usually not over 1°.

Uniaxial Crystals.

Of the uniaxial crystals, calcite and nephelite were chosen for measurement; apatite plates were also tried, but they proved to be inhomogeneous and, therefore, unsuitable for accurate work.

Calcite.

On cleavage plates of calcite several different sets of observations were made: (1) The uniradial azimuths of monochromatic light waves emerging from bare cleavage surfaces were determined for different positions of the crystal plate. (2) For these same positions of the plate the points of minimum illumination (maximum extinction) under crossed nicols were ascertained. (3) The same cleavage plate was then mounted in Canada balsam ($n_{Na} = 1{\cdot}537$) between object glass ($n_{Na} = 1{\cdot}511$) and cover slip ($n_{Na} = 1{\cdot}520$), and the positions of minimum illumination were determined between crossed nicols, both with and without the use of the bi-quartz wedge plate. (4) These observational data were compared with the values obtained by calculation from the formulas (41), (42), (43), (44), (37) of the preceding section for the same positions of the crystal plate. (5) Although not strictly comparable with the other angles, the azimuths of the radius OD (fig. 12) for both the ordinary and extraordinary waves were determined graphically.

In Table II, the results of these observations and calculations are assembled; in this table, i = angle of incidence, or, more correctly, the angle of tilting of the crystal plate; r = angle of refraction (horizontal line No. 1 of the table);[1] ω = azimuth of the section $z\,z'$ with the plane of incidence (head line of table); δ = azimuth of plane of polarization either of extraordinary wave (E) or of ordinary wave (O) (horizontal line No. 2); ϵ_u = uniradial azimuth of entering wave (horizontal line No. 3); δ' = azimuth of emergent wave corresponding to refractive wave δ (horizontal line No. 4).

Uniradial azimuths of emergent waves.—On the horizontal line No. 5 the observed azimuths of the emergent waves O and E are listed. The observations were made in strong sodium light and each azimuth was determined ten times. In the table each angle listed is the average of 40 readings, 10 for the position of the plate $+i$, $+\omega$, (5 of each set of 10 readings being made on turning the stage clockwise, and 5, counter-

[1] In these calculations, the values $\omega = 1{\cdot}6585$, $\varepsilon = 1{\cdot}4864$, and $\theta = 44°\ 37'$ were adopted.

TABLE II.

i	No.	ω	22°30′		45°00′		67°30′		90°00′		112°30′		135°00′		157°30′	
			e	*o*	*e*	*o*	*e*	*o*	*e*	*o*	*e*	*o*	*e*	*o*	*e*	*o*
45°00′	1	*r*	25°43′	25°14′	26°06′	25°14′	26°37′	25°14′	27°10′	25°14′	27°37′	25°14′	27°55′	25°14′	28°05′	25°14′
	2	δ	45 44	$\overline{43}$ 29	14 58	$\overline{73}$ 39	$\bar{6}$ 54	84 41	$\overline{24}$ 50	66 38	$\overline{41}$ 12	49 53	$\overline{57}$ 15	33 25	$\overline{73}$ 30	16 48
	3	ε_u	44 47	$\overline{41}$ 45	15 21	$\overline{72}$ 41	$\bar{5}$ 14	84 21	$\overline{22}$ 33	65 20	$\overline{38}$ 57	48 10	$\overline{55}$ 30	31 50	$\overline{72}$ 33	15 52
	4	δ′	48 15	$\overline{45}$ 13	17 19	$\overline{74}$ 39	$\bar{5}$ 39	84 46	$\overline{24}$ 40	67 27	$\overline{41}$ 50	51 13	$\overline{58}$ 10	34 30	$\overline{74}$ 08	17 27
	5	δ′	47 46*	$\overline{45}$ 17*	15 48*	$\overline{76}$ 21*	$\bar{6}$ 01*	84 27*	$\overline{25}$ 01	66 58	$\overline{42}$ 07	50 41	$\overline{58}$ 28	34 24	$\overline{74}$ 14	17 26
	6	δ′	47 39*	$\overline{43}$ 19*	17 45*	$\overline{74}$ 39*	$\bar{5}$ 46*	84 02*	$\overline{24}$ 31	67 10	$\overline{41}$ 51	50 53	$\overline{58}$ 31	34 25	$\overline{74}$ 21	17 08
	7	E	47 40	$\overline{43}$ 05	17 46	$\overline{72}$ 48	$\bar{4}$ 24	85 44	$\overline{22}$ 51	65 19	$\overline{40}$ 10	50 00	$\overline{56}$ 32	33 40	$\overline{73}$ 04	16 52
	8	E	47 28	$\overline{43}$ 31	16 27	$\overline{74}$ 44	$\bar{5}$ 52	83 46	$\overline{24}$ 09	66 44	$\overline{39}$ 56	50 15	$\overline{57}$ 21	35 00	$\overline{73}$ 31	17 54
	9	E	47 50	$\overline{44}$ 14	15 24	$\overline{74}$ 23	- -	-----	-----	-----	-----	-----	$\overline{56}$ 18	33 40	$\overline{73}$ 51	17 03
	10	G	42 24	$\overline{46}$ 42	13 24	$\overline{75}$ 00	$\bar{5}$ 48	85 30	$\overline{22}$ 18	68 36	$\overline{37}$ 48	52 48	$\overline{54}$ 12	36 30	$\overline{71}$ 06	18 48
22°30′	1	*r*	13°48′	13°20′	13°54′	13°20′	14°02′	13°20′	14°11′	13°20′	14°19′	13°20′	14°26′	13°20′	14°30′	13°20′
	2	δ	59 43	$\overline{29}$ 55	32 04	$\overline{57}$ 17	7 44	$\overline{81}$ 28	$\overline{13}$ 57	76 50	$\overline{33}$ 56	56 44	$\overline{52}$ 58	37 29	$\overline{71}$ 34	18 40
	3	ε_u	59 43	$\overline{29}$ 36	32 12	$\overline{56}$ 57	8 16	$\overline{81}$ 21	$\overline{13}$ 12	76 40	$\overline{33}$ 09	56 24	$\overline{52}$ 20	37 08	$\overline{71}$ 13	18 27
	4	δ′	60 24	$\overline{30}$ 17	33 03	57 48	8 39	$\overline{81}$ 44	$\overline{13}$ 20	76 48	$\overline{33}$ 36	56 51	$\overline{52}$ 52	37 40	$\overline{71}$ 33	18 47
	5	δ′	60 25*	$\overline{31}$ 14*	- - - -	- - - - -	8 16*	$\overline{82}$ 04*	$\overline{13}$ 32	76 27	$\overline{33}$ 45	56 36	$\overline{52}$ 52	37 30	$\overline{71}$ 41	18 46
	6	δ′	59 07*	$\overline{31}$ 06*	31 32*	$\overline{57}$ 11*	8 31*	$\overline{82}$ 08*	$\overline{13}$ 29	76 39	$\overline{33}$ 20	56 43	$\overline{52}$ 45	37 34	$\overline{71}$ 06	18 54
	7	E	60 24	$\overline{29}$ 46	33 34	$\overline{56}$ 46	8 58	$\overline{80}$ 56	$\overline{12}$ 46	77 50	$\overline{32}$ 50	57 01	$\overline{52}$ 23	37 46	$\overline{72}$ 16	18 50
	8	E	60 33	$\overline{30}$ 14	32 59	$\overline{57}$ 33	6 56	$\overline{81}$ 53	$\overline{13}$ 11	76 39	$\overline{32}$ 59	57 04	$\overline{52}$ 22	37 51	$\overline{71}$ 00	18 50
	9	E	60 50	$\overline{30}$ 40	33 23	$\overline{57}$ 58	- - - -	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -	$\overline{52}$ 29	37 56	$\overline{70}$ 48	18 47
	10	G	58 54	$\overline{30}$ 15	31 36	$\overline{57}$ 48	7 18	$\overline{81}$ 30	$\overline{13}$ 36	76 54	$\overline{33}$ 00	57 54	$\overline{51}$ 54	38 06	$\overline{70}$ 24	19 36

clockwise); 10 for the position $+i, +\omega$; 10 for the position $+i, 180° -\omega$; 10 for the position $+i, 180°+\omega$. In averaging the readings, all these positions should, with the exception of the sign, furnish identical results. This was found to be the case for all positions of the plate for which good positions of darkness were attainable. Occasionally, however, differences of 20′ or even 30′ between the positions were obtained, even on good plates. The observations were made on bare cleavage plates, 1 to 3^{mm} thick, on which the two refracted waves from a single incident wave were appreciably separated after transmission. A large area of the front surface of each plate was blackened by means of a dull lacquer and rendered opaque (shaded part of fig. 8*a*). When viewed through the plate after

Fig. 8*a*.

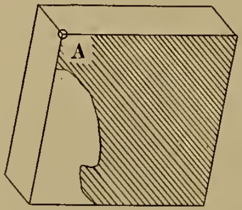
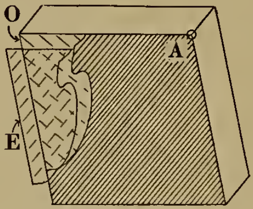


Fig. 8*b*.



rotation through 180° about the horizontal axis, the exposed area of fig. 8*a* appeared as in 8*b*. Two images were observed, one from the ordinary wave O and the second from the extraordinary, E. These two images overlapped to a large extent, but along the margins of the bright part of the plate the image of the extraordinary wave E extended on the left beyond that of the ordinary wave, while on the right and at the top a narrow strip, due entirely to the ordinary wave O, appeared as indicated in fig. 8*b*. The azimuth of the plane of polarization of one of these emergent waves, E or O, was then ascertained by rotating the microscopic stage H_1 until the margin in question disappeared completely. It was found that within the limits of error each edge became completely dark (1) when the azimuth of the plane of polarization of the entering waves was such that the amplitude of its refracted wave was zero (uniradial azimuth of second entering wave); and (2) when the plane of polarization of the emergent wave coincided precisely with the extinguishing plane of the analyzer. These two positions were, within the limits of error, precisely 90° apart, thus proving experimentally the relation (37) deduced from theory; in other words, the uniradial azimuth of an entering wave W_1 is 90° from that of the second emergent wave, W'_2. The doubly shaded portion of fig. 8*b* is the area over which the two images overlap. The positions of extinction of these two images do not coincide exactly and there is, therefore, no position of total extinction for this area. In a thin or weakly birefracting plate, the margins indicated in fig. 8*b* become very narrow and all observations are practically confined to this area of overlap. In the microscopic examination of thin sections this is always the case; it is evident, therefore, that in tilted, thin crystal plates there is no position of total extinction, strictly speaking, but a region of minimum illumination which may extend over several degrees. The emergent light is not strictly plane polarized but shows elliptical polarization and cannot, therefore, be totally extinguished by the upper nicol in any position.

Still another feature deserves mention. In the actual determination of the uniradial azimuths outlined above, it was often noted that for certain positions of the plate, even the margins of fig. 8*b* did not extinguish properly because of repeated internal reflexions. A wave, I (fig. 2), entering at the uniradial azimuth produces a single refracted wave, W_1; from this wave, in turn, one emergent wave, W'_1 and two reflected waves, W_{1a}, W_{1b} are formed. Each of these reflected waves produces one refracted wave R_{1a} and two reflected waves W'_{1a}, W''_{1a}; of these W'_{1a} is parallel with the first refracted wave W_1, while W''_{1a} is parallel with the second possible refracted wave W_2, which would result from the initial wave I if the azimuth of its plane of polarization were not uniradial. The first wave W'_{1a} produces an emergent wave (not indicated in fig. 2), the azimuth of whose plane of polarization is parallel with that of W'_1; from the second wave W''_{1a} a second emergent wave is produced, whose line of propagation is parallel with that of the first, but whose plane of polarization coincides with that of W'_2 and not with that of W'_1. In this case the effect produced is precisely that of an overlap of the two images; there is no position of total extinction but only a region of minimum illumination occasionally covering several degrees. Accurate measurements under such conditions are impossible.

If thin plates be used for the observations, as in thin section work, this effect must always be present, and consequently there are under these conditions no points of total extinction for obliquely transmitted light waves, but only regions of minimum illumination which may extend over several degrees and on which only approximate measurements can then be made. In the thick plates employed in the present experiments, a portion of the exposed area was usually free from the effects of total reflexion and on these portions the positions of extinction were determined. And even there an abrupt shift of the faint margin due to a weak, repeatedly reflected wave, was often observed near the positions of total extinction of one of the waves. If the plate be placed in the position of total extinction for one of the edges in the image under crossed nicols, the edge produced by the second wave, and with it the entire plate, can then be extinguished by rotating either the analyzer, in case the second wave enters at uniradial azimuth, or the polarizer, in case the line of vibration of the emergent first wave is contained in the extinguishing plane of the analyzer. This method of first determining the position of extinction for the one wave and then rotating the polarizer was adopted in many of the above measurements, as the edge produced by the second wave generally extinguished imperfectly because of internal reflexions. Usually, however, internal reflexion did not extend across the entire plate; the area free from it was then observed to became completely dark for a certain position of the polarizer. In this case the nicols were not crossed but included an angle which differed from 90° by exactly the angle of rotation which the entering, plane-polarized waves suffered on transmission through the two boundary surfaces of the crystal plate. The waves entered at their uniradial azimuth and emerged vibrating in the extinguishing plane of the analyzer, and were therefore totally reflected in the nicol. From lines 3 and 4, Table II, it is evident that the total amount of rotation $(\epsilon_u - \delta')$ of the plane of polarization is the same for both the ordinary and the extraordinary wave.

In case the crystal plate is tilted so that the optic axis makes only a small angle with the line of propagation of the refracted waves, it is not possible to obtain satisfactory total extinction. The entering waves, although approximately parallel, are never precisely so, and for a slight difference in direction of propagation, a considerable variation in the azimuth of the planes of polarization of the transmitted waves results. This effect is most pronounced near the optic axis[1] but it is still perceptible on refracted waves, making angles of 20° or even 25° with the optic axis. In the table these positions of imperfect extinction are indicated by an asterisk. On line No. 6 of the table a series of readings on a second cleavage plate is recorded, each angle listed being the average of 20 readings, 10 for the position $+i, +\omega$, and 10 for the position $+i, -\omega$.

In the measurement of these uniradial azimuths, the observer was unfortunately unable, because of other duties, to finish each series of readings as rapidly as could be desired, a month or more often intervening before a series, once begun, was finally completed. This gave opportunity for the effects of surface films to enter the problem, which, as noted by Drude, may seriously affect the accuracy of the values obtained. It is

[1] Compare W. Voigt, Wied. Ann. d. Phys. u. Chemie (4), xviii, 676, 1905.

probable that the recorded differences between calculated and observed values are in part due to the effects of such surface films.

Previous measurements.—F. E. Neumann[1] measured the uniradial azimuths of light waves, entering a calcite cleavage plate at different angles, and found that his results of observation agreed closely with those of calculation. His observations were made in white light and through a prism which separated the two images E and O so that each could be studied alone. Although Neumann's measurements were repeated 40 times and should therefore be very accurate, the use of white light, and also of intervening glass surfaces, introduced sources of probable error which might, under certain conditions, prove serious.

Later, in 1852, R. T. Glazebrook[2] undertook a more elaborate series of determinations of the uniradial azimuths of transmitted waves. His apparatus and method for determining the positions of total extinction were more accurate and refined than those of Neumann, but the agreement between his observed values and those of calculation was only approximate, and less satisfactory than Neumann's values. Glazebrook's measurements, however, were made for the most part on polished plates on which surface films may have been especially active and may have modified the results accordingly. As Drude has shown, an exceedingly thin surface is sufficient to produce marked elliptic polarization in the reflected waves.

Extinction positions of an unmounted plate.—(Line No. 7, Table II.) A series of readings in sodium light was taken to determine, if possible, the positions of maximum extinction of the central part (E and O overlapping) of a calcite cleavage plate. The angles listed are the average of two sets of 10 readings each; the first for $+\omega$, the second for $-\omega$. It was found that the individual settings often varied a degree or more; their average, moreover, was not midway between δ'_o and $\delta_e +$ 90° or vice versa. In short, accurate determinations under such conditions are not possible, and the different positions of extinction were rarely found to be precisely 90° apart.

Extinction positions of mounted plate.—On lines No. 8 and No. 9, Table II, the results of the determinations of the extinction position of a mounted cleavage plate of calcite are listed, in which the measurements were made in Nernst light, (1) with the aid of the bi-quartz wedge (line No. 8) and (2) without it (line No. 9), each angle being the average of 10 settings. In the strong Nernst light, the individual settings agreed more closely, but their averages agree neither with the uniradial azimuths. observed or calculated, nor with the other

[1] Pogg. Ann., xlii, 11–12, 1837. [2] Proc. Roy. Soc., clxxiii, 617, 1882.

observations, differences of a degree or more being not uncommon. The rotatory effects of the glass mounts and lenses are included in these results, and indicate that in actual microscopic work with tilted slides or with interference figures, the observed azimuths of the planes of polarization of any given transmitted wave may differ several degrees from the actual azimuth of the refracted wave within the crystal. This, however, is the azimuth sought for in such observations. The measurements prove that for such tilted thin plates there is no position of total extinction, but rather a region of minimum illumination. Methods based on such phenomena can therefore furnish only approximate results.

On the horizontal line 10 of Table II, the values obtained by graphical construction of the azimuths of the plane z' D (fig. 12) for different positions of the plate are listed. These will be considered in a later section.

Nephelite.

In nephelite the birefringence is weak and the two refracted waves, resulting from a single plane polarized incident wave, follow approximately the same direction of propagation. A satisfactory determination of the uniradial azimuths on thin plates of nephelite is, in consequence, not possible, and has not been attempted. The positions of maximum extinction of the plate tilted at different angles were, however, determined and are listed in Table III. For these measurements a polished plate of nephelite, so cut that the optic axis included an angle of 27° 18′ with the normal to the plate, was mounted (n_{Na} of object glass 1·511, of cover slip, 1·520) in Canada balsam ($n_{Na} = 1·537$) and readings made in strong sodium light. On the horizontal lines, 1 to 4, of Table III, the calculated values of r, δ, ϵ and δ' are listed; on line 5 the positions of extinction are recorded, as determined by direct observations on rotating the plate until the maximum darkness was attained. Each angle given is the average of 20 readings, 10 for $+i$, $+\omega$, and 10 for $+i$, $-\omega$. The individual settings agreed only fairly well, and even for the average values a high order of accuracy cannot be claimed. For these measurements the ordinary microscope lens system was used with the exception of the condensor, which had been removed. On line No. 6, Table III, the results of settings made with the aid of the bi-quartz wedge plate and strong sodium light are recorded, each angle listed being the average of 10 readings, 5 for the position $+ i$, $+ \omega$, and 5 for the position $+ i$, $- \omega$. Since in the case of tilted plates the emergent light is not strictly plane polarized and there is consequently no position of total extinction, the positions of minimum illumination as determined by simple rotation under

TABLE III.

		ω	22°30′		45°00′		67°03′		90°00′		112°30′		135°00′		157°30′	
i	No.		*e*	*o*	*e*	*o*	*e*	*o*	*e*	*o*	*e*	*o*	*e*	*o*	*e*	*o*
45°00′	1	r^1	27°04′	27°18′	27°08′	27°18′	27°14′	27°18′	27°20′	27°18′	27°25′	27°18′	27°30′	27°18′	27°32′	27°18′
"	2	δ	$\bar{8}$ 44	79 58	$\bar{1}9$ 47	69 47	$\bar{3}0$ 36	59 18	$\bar{4}1$ 39	48 22	$\bar{5}3$ 08	36 56	$\bar{6}5$ 05	24 59	$\bar{7}7$ 25	12 37
"	3	ε	$\bar{9}$ 29	79 29	$\bar{1}9$ 18	68 52	$\bar{2}9$ 29	58 04	$\bar{4}0$ 15	46 59	$\bar{5}1$ 44	35 37	$\bar{6}3$ 58	23 56	$\bar{7}6$ 47	12 02
"	4	δ′	$\bar{1}0$ 31	80 31	$\bar{2}1$ 08	70 42	$\bar{3}1$ 56	60 31	$\bar{4}3$ 01	49 45	$\bar{5}4$ 23	38 16	$\bar{6}6$ 04	26 02	$\bar{7}7$ 58	13 13
"	5	E	-----	-----	-----	-----	$\bar{2}4$ 03	65 24	$\bar{3}6$ 35	54 00	$\bar{4}9$ 49	40 29	$\bar{6}3$ 08	27 12	$\bar{7}6$ 36	13 51
"	6	E	-----	-----	-----	-----	$\bar{2}3$ 16	64 36	$\bar{3}6$ 36	52 28	$\bar{4}9$ 14	40 05	63 17	26 37	$\bar{7}6$ 19	13 18
"	7	G	$\bar{1}1$ 05	77 55	$\bar{2}1$ 30	66 30	$\bar{3}2$ 25	60 00	$\bar{4}2$ 50	50 00	$\bar{5}4$ 00	38 40	$\bar{6}6$ 00	26 00	$\bar{7}7$ 45	11 30
22°30′	1	*r*	14°19′	14°22′	14°20′	14°22′	14°21′	14°22′	14°22′	14°22′	14°24′	14°22′	14°26′	14°22′	14°27′	14°22′
"	2	δ	47 24	$\bar{4}2$ 45	I6 12	$\bar{7}3$ 54	$\bar{6}$ 45	83 12	$\bar{2}5$ 42	64 19	$\bar{4}2$ 42	47 20	$\bar{5}8$ 48	31 14	$\bar{7}4$ 29	15 33
"	3	ε	47 00	$\bar{4}2$ 28	15 58	$\bar{7}3$ 45	$\bar{6}$ 43	83 08	$\bar{2}5$ 28	64 05	$\bar{4}2$ 23	47 03	$\bar{5}8$ 31	30 59	$\bar{7}4$ 19	15 24
"	4	δ′	47 32	$\bar{4}3$ 00	16 15	$\bar{7}4$ 02	$\bar{6}$ 52	83 17	$\bar{2}5$ 55	64 32	$\bar{4}2$ 57	47 37	$\bar{5}9$ 01	31 29	$\bar{7}4$ 36	15 41
"	5	E	----	-----	-----	-----	$\bar{2}$ 15	87 41	$\bar{2}2$ 06	68 00	$\bar{3}9$ 45	50 28	$\bar{5}7$ 36	33 18	$\bar{7}4$ 05	16 57
"	6	E	-----	----	23 40	$\bar{6}8$ 29	$\bar{3}$ 29	87 29	$\bar{2}1$ 55	67 53	$\bar{3}9$ 47	49 54	$\bar{5}6$ 26	31 28	$\bar{7}3$ 21	15 52
"	7	G	48 00	$\bar{4}2$ 30	16 00	$\bar{7}4$ 15	$\bar{7}$ 20	82 50	$\bar{2}6$ 00	64 10	$\bar{4}0$ 00	50 30	$\bar{5}8$ 45	31 50	$\bar{7}4$ 00	16 10

[1] In calculating the values r_1 δ_1 ε_1 δ' of this table the values $\omega=1{\cdot}5416$, $\varepsilon=1{\cdot}5376$, and $\theta=27°\ 18'$ were used.

crossed nicols may not coincide precisely with the positions for which the two sides of the inserted bi-quartz wedge plate appear equally lighted: the angles listed in lines 5 and 6, Table III, bear out this inference. In column 7, the positions of the direction D (fig. 12, p. 200) determined graphically, are listed and will be discussed in a later section. From the above observations it is evident that parallel, plane-polarized light waves transmitted obliquely through a crystal plate do not emerge as strictly plane polarized waves. There is, consequently, no position of total extinction, but a region of minimum illumination which may extend over several degrees and which, of course, precludes accurate determinations.

The two positions of approximate extinction, determined by observation, may differ by a degree or more from 90°. The unequal rotation of the planes of polarization by the glass surfaces of the mount is an important factor in this connection.

For positions of the plate in which the direction of ths transmitted light waves made a relatively acute angle with the optic axis, the lack of parallelism of the transmitted waves was keenly felt, and a position of even approximate extinction was not attainable. In such instances the determination was not attempted.

Biaxial Minerals.

Of the biaxial minerals, muscovite and aragonite were selected for measurement, but only a short set of readings was made on each, the object being primarily to determine the positions of maximum extinction as well as possible with the bi-quartz wedge plate. The observations were made in sodium light and with the aid of the usual microscope lens system, except that the condensor had been removed,

Muscovite.—A fresh, bare, cleavage flake was used, and 12 readings were recorded for each position of the crystal plate. The effects of elliptic polarization were not especially noticeable except for the position i = 22° 30′, ω = 22° 30′. Notwithstanding this, the measured positions of extinction are not in general 90° apart, but differ from 90° by several degrees in some positions, as shown in Table IV.

TABLE IV.

i	ω	a	b	Diff.
45°00′	60°00′	10°48	̄78°54′	89°42′
"	45 00	14 14	̄73 32	87 46
"	22 30	15 44	̄71 40	87 24
22 30	45 00	32 41	̄56 31	89 12
"	22 30	54 46	̄34 08[1]	88 54

[1] Elliptic polarization pronounced.

Aragonite.—The polished plate used was nearly normal to the acute bisectrix. The observations were made in sodium light with the aid of the bi-quartz wedge plate, and the usual microscope lens system without condensor. The bare plate was mounted as usual on the universal stage and the positions of extinction for each position of the plate determined 12 times. The individual readings thus obtained agreed fairly

TABLE V.

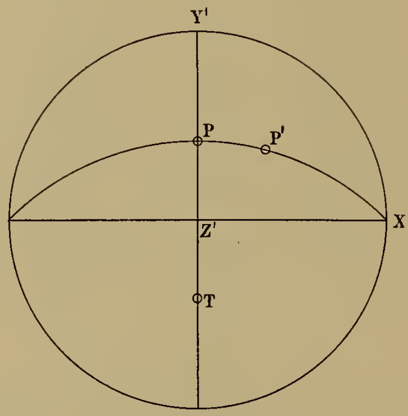
i	*ω*	*a*	*b*	Diff.
50°00′	90°00′	87°36′	$\bar{3}$°18′	90°54′
"	0 00	93 19	1 01	92 18
35 00	90 00	86 59	$\bar{5}$ 07	92 06
"	75 00	84 34	$\bar{7}$ 26	92 00
"	60 00	83 03	$\bar{9}$ 18	92 21
"	45 00	82 16	$\bar{7}$ 16	89 32
"	30 00	81 15	$\bar{7}$ 57	89 12
"	15 00	87 36	$\bar{2}$ 24	90 00
"	0 00	94 57	$\bar{0}$ 07	95 04
30 00	"	86 53	$\bar{0}$ 14	87 07
$\overline{25}$ 00	"	95 38	1 30	94 08
$\overline{40}$ 00	"	87 07	0 07	87 00
19 30	"	Optic axis A.		
$\overline{12}$ 00	"	Optic axis B.		

well, the upper and lower limits of each set of 12 readings being usually about 30′ apart, but a high degree of accuracy cannot be claimed for the angles listed in Table V, the probable error being possibly 15′. The different positions of extinction thus observed are not precisely 90° apart, and often differ from it by several degrees, again emphasizing the difficulty of an accurate determination of the plane of polarization of a light wave transmitted obliquely through a crystal plate.

To find the direction of vibration for a dark point H on an interference figure.

An interference figure is obtained by passing a cone of convergent polarized light waves through a crystal plate and observing the interference phenomena as they appear in the rear focal plane of an objective of short focus when examined through an analyzer. In the course of their passage through the microscope, the light waves emerging from the lower nicol (polarizer) may be considered practically parallel, plane polarized waves. On transmission through the condensor lens system, their directions of propagation are changed and they emerge from it in a sharply convergent cone; but their line of vibration has remained in the same plane except for the slight rotatory effects of the surfaces of the condensor lenses, which, for the moment, may be disregarded. That this is the case, is tacitly assumed in all microscopic work since the rotatory effects produced by the condensor and objective lens systems alone, on the plane of polarization of transmitted light waves, are practically negligible and the field appears approximately dark under crossed nicols. Thus, in fig. 9, if the direction Z′ be the axis of the optical system of the microscope, Y′Z′ the

Fig. 9.



plane of vibration of the entering waves, and P the direction of propagation of one of these waves after refraction, its direction of vibration will then be along T, at right angles to P and in the original plane of vibration. This same direction of vibration, OT, obtains for any other point, P′, in the polar plane to T. A wave propagated along P′, but still vibrating along OT in the original plane of vibration, will be destroyed by the total reflexion in the analyzer, just as is the wave OP. Since the entire field may be covered with waves similar to OP′, whose directions of vibration are contained in the plane of vibration Y′Z′, all the waves of the converging cone from the condensor and objective systems are extinguished by the analyzer and the field appears dark between crossed nicols, provided no birefracting crystal plate intervenes. The effect of the lens system of the microscope is, therefore, to change the directions of propagation of transmitted light waves, but not seriously to affect the plane in which their vibrations take place.[1] Conversely,

[1] That there is some effect on the planes of polarization of transmitted light waves is at once evident, even without accurate measurements, from the lack of uniformity in illumination of the field when viewed under crossed nicols in convergent polarized light. A dark cross divides the field into quadrants which are perceptibly lighter than the bars of the cross. This cross is visible in every microscope and is not always due to faulty construction of the objectives nor to strains in the glass.

if $Z'Y'$ (fig. 10) be the extinguishing plane of the analyzer, and H any dark point in the field of the interference figure, the direction of vibration for this light wave H must be contained in the plane $Z'Y'$ and also in the polar plane to H'; it is accordingly the direction D. If its direction of vibration be not in

Fig. 10.

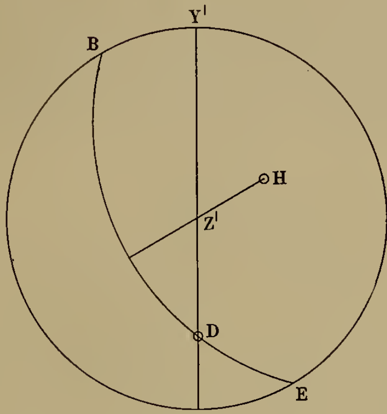
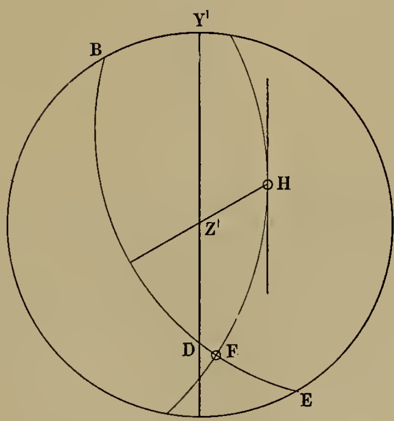


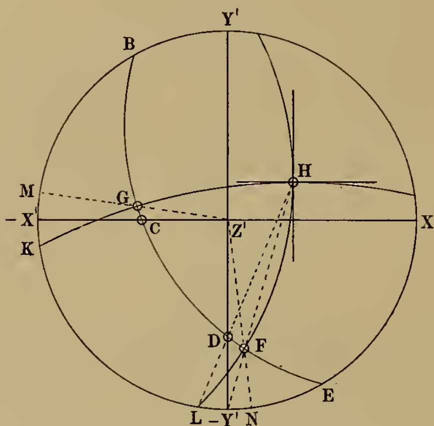
Fig. 11.



the plane $Y'Z'$, it will not be totally extinguished in the upper nicol and the point H will not appear completely dark. Briefly stated, for any dark point H of the interference figure, the direction of vibration is the intersection OD of the extinguishing plane $X'Z'$ of the upper nicol and the polar plane of H. This is the rule of construction given by the writer for finding the plane of vibration of any dark point in the interference figure. As noted above, the rotatory effects of the surfaces, both of the crystal plate itself and of the glass mounts and lenses, are disregarded in this construction. These effects are small but still noticeable, and the method in consequence is only an approximate method.

Professor Becke[1] has described another method for finding the direction of vibration for a dark point P of the interference figure. His method consists in drawing, in stereographic projection, the great circle which is tangent to a line through H parallel with the plane of vibration Y′ Z′ (fig. 11). The intersection F of this great circle with the polar circle of H is then the desired direction. The point can also be found, as Profes-

FIG. 12.[3]



sor Becke has shown recently,[2] by noting that it is at the intersection of the straight line H F $\overline{Y}'$ (fig. 12) and the polar circle to H. This direction of vibration F is not, however, contained in the plane Y′Z′ (fig. 12), the extinguishing plane of the upper nicol, in which case the point H cannot be perfectly dark, if the above reasoning be correct. If the extinguishing plane of the nicol were Z′ X′ instead of Y′ Z′, the point C would be the direction of vibration for a dark point H, while G would be

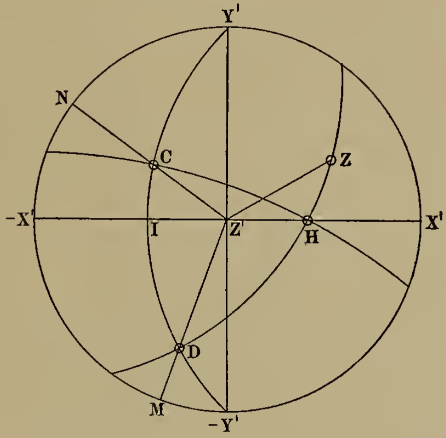
[1] Tschermak's Min. Petr. Mitteil., xxiv, 39–40, 1905.

[2] Tschermak's Min. Petr. Mitteil., xxviii, 293, 1907.

[3] It may be of interest to note that in this figure the line HY′ cuts the great circle HL at F, as Professor Becke has shown; also that the line HD intersects the horizontal circle at L; that the angles LM, X′Y′, KN, are right angles; and that the angle CD is equal to KL, the angle between the lines of projection of the lines OF and OG on the horizontal plane. In fig. 13, the angle $\overline{X}'$M is equal to the angle DI, and also to the angle ZHX′ or 180 $-\delta$ of the spherical triangle ZHZ′.

the equivalent point determined by the method of Professor Becke. According to the writer's method of construction, the directions of vibration of any dark point of the interference figure, as viewed through the upper nicol, must lie in the extinguishing plane of the upper nicol. The directions found by Professor Becke's method are not in general contained in this plane, and appear, therefore, to be incorrectly located. Objection has been made by Professor Becke to the writer's method because the lines D and C (fig. 12) are not 90° apart while the points F and G are precisely so. In answer to this it may be stated that in any direction within a crystal plate, as H in the uniaxial crystal plate of fig. 13, Z being the optic axis,

Fig. 13.



two waves are possible whose directions of vibration D and C (fig. 13) are strictly normal to each other and to the line of propagation H. In the interference figure, however, these directions are not observed along the line of propagation H but as they appear in projection; and in the plane of this projection the lines of vibration are not 90° apart. To assume, therefore, that the planes of polarization of the two possible waves as observed in the interference figure are tangent to the two lines parallel with Y Z through H in stereographic projection, obviously introduces an error. If the point appears dark in the interference figure, its direction of vibration must be contained in the extinguishing plane of the analyzer, and it is with such points alone that the present problem has to do. Along the line of propagation OH (fig. 12), a second direction of vibration is possible at right angles to OD and normal to OH; this direction OC is in general not contained in the plane

$X'Z'$ at right angles to $Y'Z'$; but with this direction the present problem is not concerned, its object being solely to find the direction of vibration of an observed dark point in their interference figure, the extinguishing plane of the upper nicol being given.

In the last paragraph, one factor which has profound influence on the phenomena actually observed, has been purposely held in abeyance, and must now be considered in detail. Let P be a direction on the axial bar in an interference figure along which plane polarized light waves enter at uniradial azimuth. At the upper and lower surfaces of the crystal plate the plane of polarization of these waves suffers a slight rotation and as a result the emergent waves no longer vibrate in their original plane and are consequently not totally extinguished by the upper nicol. The point P is not completely dark. Similarly, let H be a point, adjacent to P on the axial bar of the interference figure, for which one of the emergent waves vibrates in the extinguishing plane of the upper nicol. If this wave alone were considered, the point H would appear completely dark, but along H a second wave is possible whose plane of vibration after emergence neither coincides nor is at right angles with the first; it is not completely extinguished by the upper nicol and accordingly illuminates H slightly. The two adjacent points P and H appear, therefore, only approximately dark, and the narrow fringe between them is of about the same degree of darkness. There is, in short, no point of absolute extinction on the bar. The width of the bar increases as the margin of the field is approached (fig. 15). As the positions of extinction of the two possible waves emerging in one given direction in air do not coincide precisely, and are not exactly 90° apart, there is evidently a range of weak illumination between the positions of uniradial total extinction. For each of the two possible waves, however, the positions of extinction are precisely 90° apart, and if the crossed nicols be rotated through 90°, there will be only a slight change, due to surface film effects, in the position of the axial bars in the interference figure from an unmounted plate. On mounted crystal plates the rotary effects of the surfaces of the glass mount enter the problem and there a rotation of the crossed nicols through 90° often produces a small though perceptible shift in the position of the axial bars, as is evident from the series of measurements on interference figures, represented by (figs. 14*a*, *b*, 17*a*, *b*.)

Observations in convergent polarized light.—The measurements were made in strong sodium light on clear mounted and unmounted cleavage flakes of muscovite and anhydrite. The petrographic microscope was first accurately adjusted, a cap nicol being used whose vernier divisions read directly to 3′,

FIG. 14*a*.

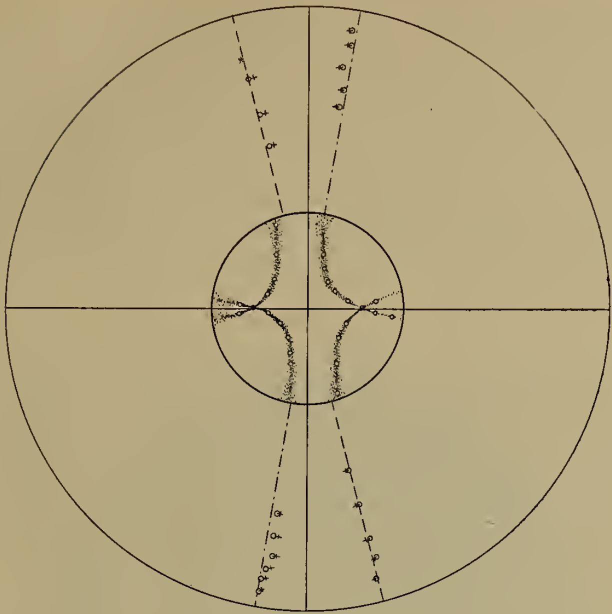
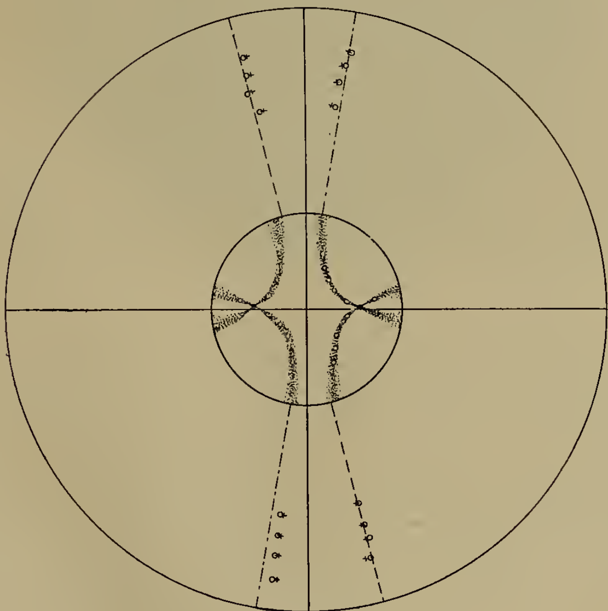
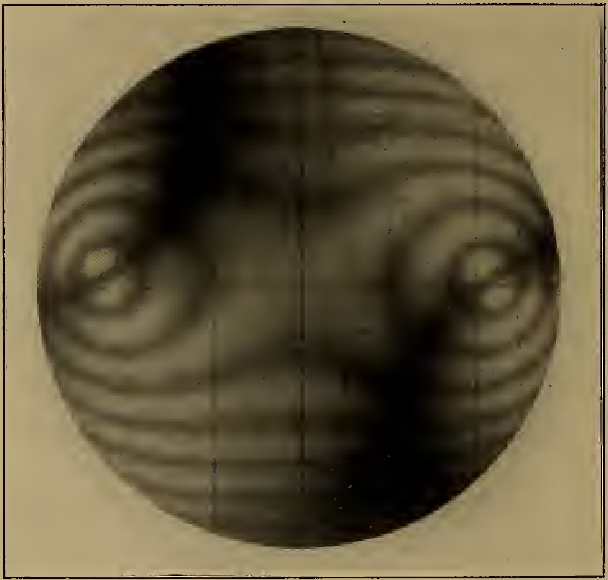


FIG. 14*b*.



which was also the interval of the vernier of the lower nicol; with this arrangement both nicols were situated outside the optical system, and during each set of observations neither the optical system nor the crystal plate were touched. Experience showed that if the upper nicol remained in the tube, as is ordinarily the case, and then rotated, a shift of the optical center resulted, and although almost negligible, was still distinctly noticeable. The cross grating ocular[1] served to locate accurately the different points in the field. The axial bars of the interference figure were plotted directly on cross section paper as they appeared for different angles of rotation of the crossed

Fig. 15.



nicols. The interference figures were sharp and the dark, axial bars clearly defined, although not perfectly dark, and readings could be made to one half of one division (about 1° in angular coördinates) of the coördinate scale of the ocular.

Muscovite.—Several fresh cleavage flakes of this mineral were observed in convergent polarized light and the positions of the axial bars determined for different angles of rotation of the crossed nicols. The results are plotted in the stereographic projections (figs. 14*a*, *b*), in which the axial bars are drawn for the two positions of the extinguishing plane of the upper nicol (−10° and +15°) as indicated by the dotted lines. The

[1] This Journal (4), xxix, 423, 1910.

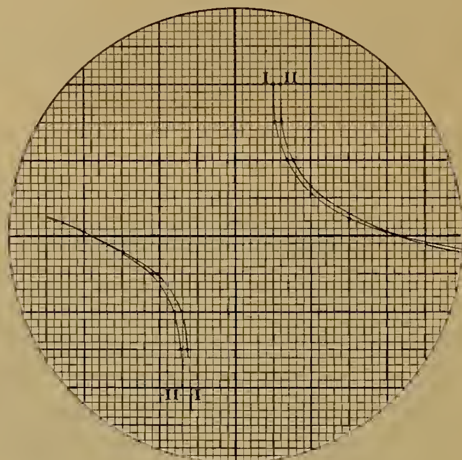
observations were made by using the cross grating ocular as shown in the microphotograph fig. 15. The observed coördinated values were reduced to their angular equivalents by use of the apertometer and these in turn reduced to the corresponding crystal angles by means of the sine formula and the refractive index β. The use of the refractive index β for all direction introduces an error, but experience has shown that this error is not great and in general may be disregarded.

Points were located as accurately as possible along each axial bar and then plotted in projection (indicated by small circles, figs. 14*a*, 14*b*). Although the axial bars were not perfectly sharp they were well defined and the points were taken along the central line of the bar, the position of each point being determinable to within about 1°, or less for certain positions. In fig. 14*a*, the results which were obtained from an unmounted cleavage plate are represented; in fig. 14*b*, the interference figure is that from the same plate mounted in Canada balsam between cover glass and object glass. In each of these figures, the positions of the line of vibration were determined graphically, both by the method of Professor Becke (indicated by small crosses) and by that of the writer (indicated by small circles). A comparison of the relative positions of these small circles and crosses relative to the dotted line which represents the position of extinguishing plane of the upper nicol shows that in a few instances the points as determined by Professor Becke's method are slightly more accurate than the equivalent points of the writer's method; in the majority of instances, however, the small circles are more nearly correct than the small crosses. As a general rule, it may be stated that the order of accuracy of the two methods is about the same, the writer's method having the single advantage of greater simplicity.

A critical comparison of the results of observation on mounted flakes with those on unmounted flakes show clearly the effect of rotation by the glass surface, causing the axial bars and axes to shift slightly, so that the direct reading of the optic axial angle is not quite the same in the two cases. The difference is not great, but it is noticeable, and is sufficient to make it advisable to use unmounted plates wherever possible, in optic axial measurements, if results of the highest accuracy are desired. Ordinarily, however, this precaution is unnecessary, since such accuracy is not required.

A rotation of the crossed nicols through 90° also generally produces a slight shift of the axial bars from mounted plates, as indicated by fig. 16, which is a direct record to scale of the observed phenomena. In each case the points along the central line of the axial bar were plotted. The position of this central line for an angle of rotation of 15° of the crossed nicols is indicated by the curve I, fig. 16; it sposition for an angle of rotation of 105° is shown by curve II. These two curves do not coincide, and although such measurements cannot be made very accurately, they show that a rotation of the crossed nicols

Fig. 16.



causes a slight shift of the axial bars of the interference figure of a mounted crystal plate. The amount of shifting rarely exceeds several degrees and is usually less, but it is often sufficient to be perceptible and shows the importance of referring the data, when plotting, to the correct position of the extinguishing plane of the upper nicol. It is, therefore, not immaterial which one of the principal nicol sections be chosen. If the observations themselves were of a higher order of accuracy, this fact would be a serious objection to Professor Becke's method.

Anhydrite.—A series of observations (figs. 17*a*, *b*) on a cleavage plate of anhydrite, unmounted (17*a*) and mounted (17*b*), corroborates the conclusions stated in the last paragraph. The degree of accuracy of the two methods in question is about the same here as in muscovite. A rotation of the crossed nicols through 90° also produced a slight shift of the axial bars on mounted plates, as in muscovite, and it is important, therefore, that the plotting be done with reference to the correct principal nicol section.

FIG. 17*a*.

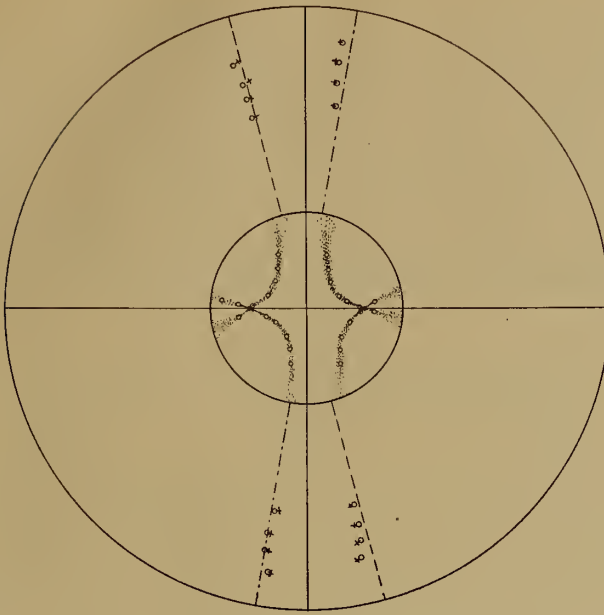
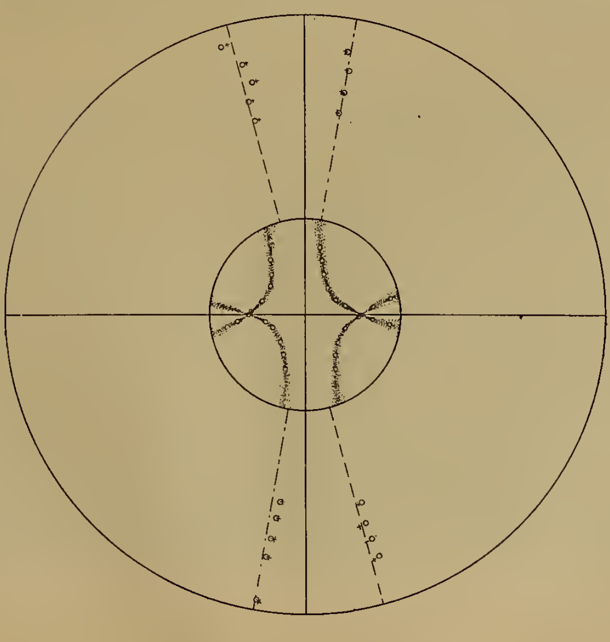


FIG. 17*b*.



A device to aid in the graphical solution of optical problems involving the use of the stereographic projection.

In the measurement of optic axial angles in convergent polarized light,[1] and also in all measurements by means of the universal stage methods, the stereographic projection plat of Prof. Wulff has proved a useful and necessary adjunct, the angular values of observation being plotted directly on thin transparent paper placed above the plat and held in the center by means of a needle. This needle, however, is not entirely satisfactory, since it does not hold its place rigidly and tends thereby to injure the stereographic plat below. To overcome this difficulty the writer has constructed the device of fig 18

Fig. 18.

(one-eighth actual size). A heavy brass bar fits into two end blocks of brass, A and B; at its center a small hollow brass rod, C, containing a needle backed by a spring is introduced. By this device the needle is rigidly supported in a vertical position, and as the distance between the end blocks A and B is 44^{cm}, there is more then sufficient space available for the projection plat and the overlying drawing. The writer has used this device for several years and has found it satisfactory and a time saver.[2]

Summary.

Minerals are determined under the microscope by the effects they produce on transmitted light waves. Plane polarized light waves are ordinarily used and examinations are made

[1] For determining the Mallard constant of the microsope, which is required in the measurement of optic axial angles by means of the microscope, Dr. J. S. Flett of London uses a Zeiss Abbe apertometer. His method is simple and accurate and is superior to any method yet suggested. He introduces the micrometer scale in the ocular as usual and then determines the divisions covered by the different angles of the apertometer. Since with this device any angle can be instantly set off. an objective can be calibrated rapidly for all possible angles within the field of vision, and an empirical, correct table prepared which is independent of the Mallard formula, thus obviating all errors due to a lack of correction in the objective lenses.

[2] Recently, Prof. Nikitin has had constructed a graduated porcelain hemisphere (made by R. Fuess, Steglitz, Berlin, Germany) which the writer has found very satisfactory in optic axial angle projections and slightly more accurate than the projection plats. chiefly because of its lack of distortion toward the margin and consequent acute angled intersections of great circles. This hemisphere has the advantage of serving as a model in the study of optical phenomena and is a useful piece of apparatus for the petrological laboratory.

partly with and partly without the aid of the upper nicol (analyzer). In anisotropic crystals the planes of polarization of light waves, transmitted along a given direction within the crystal, are prescribed by the crystal structure. On entering or emerging from a crystal plate, plane polarized light waves transmitted obliquely usually suffer a slight rotation of the azimuth of their plane of polarization. The amount of this rotation is rarely more than a few degrees. In practical microscope work but little attention has been given to this phenomenon, but in accurate work it is a factor which must be considered.

In the foregoing pages the attempt has been made in Part 1 to present, in terms of the electromagnetic theory of light, the general mathematical treatment of the transmission of light waves through a transparent inactive crystal plate, special attention being given to the rotatory effects of the boundary surfaces of the crystal plate on the plane of polarization of a transmitted wave. This problem was first solved in 1835 by J. MacCullagh and also by F. E. Neumann; since their time a number of investigators have made important contributions to its solution. Interest, however, has centered chiefly in the reflexion of light waves by crystal surfaces and no connected presentation of the mathematics covering the phenomena of refraction in crystal plates appears to have been made. This has been essayed in Part 1. The greater part of the ground covered therein is familiar, but several of the formulas derived appear to be new, notably (32*b*) and (37). Of these (37) is important and states that the uniradial azimuths of the plane of polarization of the emergent waves W'_1 and W'_2 are 90° from the uniradial azimuths of the entering waves which, on refraction, produce the waves W_2 and W_1. In other words, the positions of extinction on emergence for either one of the two possible refracted waves, W_1 or W_2, resulting from a single plane polarized light wave, incident at the surface of a crystal plate, are precisely 90° apart. The positions of extinction for the two waves do not, however, coincide and there is in general, therefore, no position of total extinction for waves transmitted obliquely through a crystal plate.

Both theory and the observations of Part 2 show that as a general rule, a uniradial, plane polarized light wave, after transmission through a bare crystal plate (preferably a cleavage plate so that the disturbing effects of surface films caused by polishing are not serious), is still plane polarized, but its plane of polarization has suffered a slight rotation depending on the direction of transmission, and if examined under crossed nicols does not appear perfectly dark in consequence. In thin crystal plates the two refracted waves W_1 and W_2 overlap to a large extent and there is no position of total extinction for the tilted crystal plate even if the upper nicol be rotated alone. In general it may be stated that from an incident plane polarized wave two refracted waves are formed, which on emergence from the plate are each still plane polarized, but their planes of polarization are not precisely 90° apart. The resultant light as observed through the analyzer is consequently elliptically polarized and there is no possible position of total extinction of the plate, but rather a region of minimum illumination which may extend over several degrees.

These relations have an important bearing on methods based on the determination of the positions of extinction of obliquely transmitted waves, and preclude at once a high order of accuracy in the measurements. If the observed crystal plates are mounted in Canada balsam, the rotatory influence of the surfaces of the glass and Canada balsam mount enter the problem and tend to complicate the phenomena still further.

The measurements of Part 2 show: (1) That a tilted glass plate may rotate the plane polarization of a transmitted plane polarized light wave several degrees, and that the amount of rotation increases with the angle of tilting; (2) that the observed uniradial azimuths of tilted cleavage plates of calcite agree closely with the calculated values; (3) that for the central areas of tilted plates of calcite, nephelite, muscovite, and aragonite, there are no positions of total extinction. If settings be made at the apparently darkest positions of the plate during the rotation of the microscope stage, these positions are often several degrees from 90° apart, and if the observed azimuths of the plane of polarization be taken as the azimuth of the refracted waves within the crystal, errors of several degrees are easily possible. (4) An obliquely transmitted wave will be extinguished provided its direction of vibration after emergence is contained in the extinguishing plane of the analyzer. The direction of vibration of an observed dark point on the axial bar of an interference figure is therefore the line of intersection of the extinguishing plane of the upper nicol with the polar plane of the given point. This construction, suggested by the writer, does not take into consideration the rotatory effects of the surfaces of crystal plate and glass mount, and is accordingly only an approximate method. Prof. Becke has suggested another method, which is, in effect, to find the intersection of the polar plane with the great circle in stereographic projection, which is tangent to a line parallel with the principal section of one of the nicols. The points obtained by Prof. Becke's method are slightly different from those obtained by the writer's method, but not sufficiently different to affect the degree of approximation obtainable by such methods. In principle, however, the two methods are fundamentally different, and a detailed discussion, together with a series of measurements on interference figures of muscovite and anhydrate, indicate the general validity of the principle on which the method proposed by the writer is based; in this method the rotatory effects of all boundary surfaces are disregarded and for this reason the results obtained by its use are only approximately correct.

Several devices are described which have been found serviceable in connection with this work: (1) An apparatus for securing an intense and constant sodium light. (2) A simple and accurate method for adjusting the petrographic microscope. (3) A device to aid in the work with the stereographic projection plat.

Geophysical Laboratory,
Carnegie Institution of Washington,
Washington, D. C., November, 1910.

ART. XX.—*The Separation and Estimation of Barium Associated with Calcium and Magnesium, by the Action of Acetyl Chloride in Acetone Upon the Mixed Chlorides;* by F. A. GOOCH and C. N. BOYNTON.

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

IN former papers from this laboratory* it has been shown that certain chlorides may be quantitatively precipitated for purposes of analysis by treating their water solutions with aqueous or gaseous hydrochloric acid and ether.

The present paper is an account of procedure for the precipitation of barium chloride from water solution and its separation from calcium and magnesium by the use of acetyl chloride to decompose the water of the solution according to the reaction $CH_3COCl + H_2O = CH_3COOH + HCl$, inconvenient violence of reaction being moderated by the addition of acetone which mixes in all proportions with both acetyl chloride and water and by itself exerts no appreciable solvent action upon barium chloride.

When a mixture of acetone and acetyl chloride, preferably 4:1, is added slowly to a very concentrated solution of barium chloride in water, the water is attacked at once, hydrogen chloride is liberated, and precipitation begins immediately. If the temperature is kept down during the process by immersing in cool running water the vessel in which reaction takes place, no more than a mere trace of barium can be detected by sulphuric acid in the residue left after evaporating the liquid separated from the precipitate by filtration through asbestos. When, however, the temperature is allowed to rise, in consequence of the heat liberated in the reaction, an appreciable amount of barium may be found by sulphuric acid in the filtrate. Below are given the data of experiments in which the residue obtained (*a*) by treating a solution of barium chloride in 1^{cm^3} of water with 30^{cm^3} of a 4:1 acetone-acetyl chloride mixture and collecting the precipitate upon asbestos in a perforated crucible, washing with acetone and with ether, was weighed after drying in air, then (*b*) treated on the asbestos for ten minutes with $15–20^{cm^3}$ of acetyl chloride, washed with acetone and with ether, dried in the air and weighed, then (*c*) digested for ten minutes with $20–25^{cm^3}$ of 2:1 acetone-acetyl chloride mixture, washed with acetone and with ether, dried in the air and weighed, and then (*d*) heated in the air-bath, or to low redness, and weighed.

* Mar, this Journal [3], xliii, 521; Havens, this Journal [4], ii, 416; iv, 111; vi, 45; vi, 396.

	Experiment I		Experiment II	
	Weight grm.	Loss grm.	Weight grm.	Loss grm.
$BaCl_2.2H_2O$ taken	0·1012	....	0·1000	....
(a) Residue after precipitation, washing, and drying in air,	0·1008	0·0004	0·0996	0·0004
(b) Residue after treatment with acetyl chloride, washing, and drying in air	0·1006	0·0002	0·0996	0·0000
(c) Residue after treatment with acetone-acetyl chloride mixture, washing, and drying in air	0·0985	0·0021	0·0981	0·0015
(d) Residue after heating, $BaCl_2$	0·0846*	....	0·0839†	....
$BaCl_2.2H_2O$ corresponding to $BaCl_2$ found	0·0993	....	0·0985	....
Loss of $BaCl_2.2H_2O$ due to solubility and dehydration	....	0·0027	....	0·0019
Loss of $BaCl_2.2H_2O$ due to solubility, calculated from $BaCl_2.2H_2O$ taken and $BaCl_2$ found	....	0·0019	....	0·0015
Loss by dehydration	....	0·0008	....	0·0004

* Heated to low redness. † Heated to 135° for 1½ hrs.

From these results it appears (*a*) that when the acetone-acetyl chloride mixture (4:1) acts upon the cooled concentrated water solution of barium chloride the precipitate is the hydrous chloride, $BaCl_2.2H_2O$, only the water in excess of that needed to form the hydrous salt being immediately attacked; (*b*) that acetyl chloride by itself produces only slight dehydration of the salt without marked solubility; and (*c*) that prolonged action of the acetone-acetyl chloride mixture (2:1) results in appreciable dehydration and considerably increased solubility of the salt. By further experimentation it was shown that when the acetone-acetyl chloride mixture is added without cooling to the water solution of barium chloride the heat of reaction favors dehydration of the hydrous salt, and the anhydrous salt may go into solution to the amount of several milligrams in 10^{cm^3} of the precipitating mixture. Upon filtering the mixture and treating the filtrate with acetone, with acetyl chloride, or with the acetone-acetyl chloride mixture the dissolved anhydrous salt is not thrown out of solution, but the addition of a drop of water is sufficient to induce immediate precipitation in the form of the hydrous salt.

Incidentally it is interesting to note that when water acts upon the colorless mixture of acetone and acetyl chloride the solution becomes yellow, and then reddish, and develops a distinctly fruity odor, condensation taking place between the acetone and acetyl chloride. The boiling points of the collected filtrates from a series of barium chloride precipitations after standing about a week ranged from 50·5° to 250°, and left a resinous residue at that temperature.

From the results of the experiments described, it may be inferred that the best conditions for the quantitative precipitation of barium chloride by the acetone-acetyl chloride mixture should be found in the use of minimum amounts of water, the preservation of ordinarily low temperature, a liberal proportion of acetone, and not too prolonged digestion of the precipitate in the excess of the precipitant. These conditions have been complied with in the quantitative tests.

Barium chloride was prepared for the work by precipitating it with strong hydrochloric acid from a water solution of the presumably pure salt, recrystallizing twice from water, and drying in the air. On gentle ignition the salt lost water corresponding to the ideal composition of the hydrous chloride, $BaCl_2.2H_2O$. In each test a portion of this salt was weighed out into a small beaker and dissolved in 1^{cm^3} of water. The beaker was cooled by immersion in a water-bath preferably supplied with running water at a temperature of about 15°. To the cooled solution, constantly shaken, the acetone-acetyl chloride mixture was added from a dropping funnel at the rate of five drops to the second. Other data of the experiments with barium chloride are given in Table I. The precipitate was filtered off upon asbestos in a perforated crucible, dried, or ignited, and weighed as the anhydrous chloride, $BaCl_2$. From these results it appears that the best of the conditions studied for the handling of 0·1 grm. of hydrous barium chloride are the solution of the salt in 1^{cm^3} of water, treatment with 30^{cm^3} of the 4:1 mixture of acetone and acetyl chloride, washing with acetone, and drying in the air-bath at 135° or at low redness.

The application of these conditions to the separation of barium from moderate amounts of calcium and magnesium proves to be easily feasible. When acetone is added to the concentrated solution of calcium chloride or magnesium chloride in water two liquid layers are formed, the acetone above and the aqueous layer below; but the addition of a few drops of acetyl chloride renders the liquids miscible while further addition causes no precipitation. When the 4:1 mixture of

TABLE I.

The Estimation of Barium.

$BaCl_2$ taken as $BaCl_2.2H_2O$ grm.	$BaCl_2$ found grm.	Error grm.	Water to dissolve $BaCl_2.2H_2O$	Amount of mixture and composition by volume: To precipitate	To wash
1–0·0859	0·0859	—0·0000†	1^{cm^3}	5^{cm^3} 2:1	10^{cm^3} 2:1
2–0·0861	0·0854	—0·0007†	"	5^{cm^3} 2:1	10^{cm^3} 2:1
3–0·0861	0·0858	—0·0003†	"	5^{cm^3} 2:1	10^{cm^3} 2:1
4–0·0862	0·0854	—0·0008*	"	6^{cm^3} 2:1	10^{cm^3} 2:1
5–0·0857	0·0854	—0·0003*	"	6^{cm^3} 2:1	10^{cm^3} 2:1
6–0·0858	0·0860	+0·0002*	"	6^{cm^3} 2:1	30^{cm^3} 4:1
7–0·0860	0·0859	—0·0001*	"	6^{cm^3} 2:1	30^{cm^3} 4:1
8–0·0853	0·0850	—0·0003*	"	6^{cm^3} 2:1	acetone
9–0·0854	0·0848	—0·0006*	"	6^{cm^3} 2:1	"
10–0·0852	0·0851	—0·0001*	"	6^{cm^3} 2:1	"
11–0·0857	0·0856	—0·0001†	"	6^{cm^3} 2:1	"
12–0·0852	0·0845	—0·0007†	"	6^{cm^3} 2:1	"
13–0·0855	0·0852	—0·0003†	"	6^{cm^3} 2:1	"
14–0·0862	0·0862	—0·0000†	"	30^{cm^3} 4:1	"
15–0·0868	0·0868	—0·0000†	"	30^{cm^3} 4:1	"

* Ignited at low redness. † Dried at 135° for 1½ hrs.

acetone and acetyl chloride is added at the rate of five drops in the second to the solution containing no more than 0·5 grm. of the calcium and magnesium salts, barium chloride is precipitated and calcium chloride and magnesium chloride are dissolved; but when the soluble chloride is present in the proportion of 1·0 grm. to 0·1 grm. of the barium chloride, the rate of addition of the precipitating mixture should not be greater than two drops in the second at the start in order to avoid inclusion of the soluble salt in the insoluble barium salt. Even in such cases the mixture may be added at the rate of five drops in the second, after the greater part of the barium is down. Tables II and III contain the data of experiments upon the separation of barium from calcium and magnesium. The results obtained in the separation of 0·1 grm. of the barium salt from 0·5 grm. of calcium and magnesium salts are excellent.

The separation of barium from strontium proves not to be so simple. When the 4:1 mixture of acetone and acetyl chloride is added to the concentrated water solution of 0·1 grm. of strontium chloride a partial precipitation takes place. When the precipitate thus produced was filtered off, washed with acetone and with ether, and dried in air, it lost water amounting to 19·93 per cent and 20·00 per cent of its weight on heating

TABLE II.

The Separation of Barium from Calcium.

$BaCl_2$ taken as $BaCl_2.2H_2O$ grm.	$CaCl_2.2H_2O$ taken grm.	$BaCl_2$ found grm	Error grm.	Water used to dissolve salts cm³.	Amount of mixture (4:1) used cm³.
1–0·0859	0·1000	0·0859	0·0000*	1	30
2–0·0867	0·1040	0·0867	0·0000*	1	30
3–0·0868	0·1022	0·0868	0·0000*	1	30
4–0·0865	0·1020	0·0865	0·0000*	1	30
5–0·0868	0·1017	0·0869	+0·0001*	1	30
6–0·0864	0·1016	0·0861	−0·0003*	1	30
7–0·0866	0·3025	0·0867	+0·0001*	1½	30
8–0·0859	0·5025	0·0859	0·0000*	2	30
9–0·0860	1·0020	0·0878	+0·0018*	3	30
10–0·0859	1·0020	0·0855	−0·0004†	2	30
11–0·0864	1·0035	0·0867	+0·0003†	2	30

* The precipitant was added at first at the rate of five drops in the second.
† The precipitant was added at the rate of two drops in the second at the outset and later of five drops in the second.

TABLE III.

The Separation of Barium from Magnesium.

$BaCl_2$ taken as $BaCl_2.2H_2O$ grm.	$MgCl_2.6H_2O$ taken grm.	$BaCl_2$ found grm.	Error grm.	Water used to dissolve salts cm³.	Amount of mixture (4:1) used cm³.
1–0·0858	0·1000	0·0857	−0·0001*	1	30
2–0·0869	0·1025	0·0870	+0·0001*	1	30
3–0·0858	0·1025	0·0858	0·0000*	1	30
4–0·0862	0·1010	0·0863	+0·0001*	1	30
5–0·0858	0·1006	0·0860	+0·0002*	1	30
6–0·0860	0·1020	0·0859	−0·0001*	1	30
7–0·0860	0·1010	0·0862	+0·0002*	1	30
8–0·0865	0·3010	0·0867	+0·0002*	1½	30
9–0·0864	0·5000	0·0867	+0·0003*	2	30
10–0·0868	1·0015	0·0878	+0·0010*	3	30
11–0·0853	1·0010	0·0854	+0·0001†	3	30

* The precipitant was added at the rate of five drops in the second.
† The precipitant was added at first at the rate of two drops in the second and later of five drops in the second.

to 135°. Obviously the salt was essentially $SrCl_2.2H_2O$, which should contain theoretically 18·51 per cent of water. This precipitate of $SrCl_2.2H_2O$ when treated with a mixture of acetone and acetyl chloride containing a larger proportion of the latter, goes into solution and is again partially precipitated upon increasing the proportion of acetone, essentially as $SrCl_2.2H_2O$.

When a mixture richer in acetyl chloride, the 2:1 mixture of acetone-acetyl chloride, is added to the concentrated water solution of strontium chloride, the precipitate first formed is slowly redissolved in a sufficient excess of the mixture and again partially precipitated upon the addition of more acetone. This second precipitate of $SrCl_2.2H_2O$ is not completely soluble, however, when the proportion of acetyl chloride is again increased, but will dissolve upon the addition of an acetone-acetyl chloride mixture to which a few drops of water have been previously added and which is, therefore, charged with hydrogen chloride. So it appears that the solubility of the strontium chloride, $SrCl_2.2H_2O$, depends to a very large extent upon the concentration of hydrogen chloride in the mixture.

In attempting the separation of barium from strontium, therefore, it was the 2:1 mixture of acetone with acetyl choride which, on account of its higher power as a solvent for $SrCl_2.2H_2O$, was added to the concentrated water solution of the barium chloride and strontium chloride, though this mixture has been shown to be somewhat less favorable to the complete precipitation of barium chloride than the (4:1) mixture containing the larger proportion of acetone, and the addition was made at the rate not greater than two drops in the second or 30^{cm^3} in ten minutes. The precipitate, filtered upon asbestos and washed with acetone, was dried at 135°. The data of these experiments are recorded in the table.

The separation of barium from strontium by the process

TABLE IV.

The Separation of Barium from Strontium.

$BaCl_2$ taken as $BaCl_2.2H_2O$ grm.	$SrCl_2$ taken grm.	$BaCl_2$ found grm.	Error grm.	Water used to dissolve salt cm^3.	Amount of mixture (2:1) used cm^3.
1–0·0867	0·0385	0·0923	+0·0056	1	30
2–0·0866	0·0304	0·0857	−0·0009	1	30
3–0·0860	0·0320	0·0861	+0·0001	1	30
4–0·0856	0·0315	0·0840	−0·0016	1	30
5–0·0856	0·0307	0·0848	−0·0008	1	30
6–0·0859	0·0304	0·0839	−0·0020	1	30
7–0·0862	0·0307	0·0859	−0·0003	1	30
8–0·0857	0·0315	0·1160	+0·0303	0·5	30
9–0·0857	0·0317	0·1058	+0·0201	0·5	30
10–0·0853	0·0315	0·1083	+0·0230	0·5	30
11–0·0869	0·0305	0·1043	+0·0174	0·5	30
12–0·0863	0·0307	0·0906	+0·0043	0·5	30
13–0·0859	0·0308	0·0849	−0·0010	0·5	30
14–0·0869	0·0108	0·0870	+0·0001	1	30
15–0·0865	0·0110	0·0858	−0·0007	1	30
16–0·0853	0·0115	0·0853	±0·0000	1	30
17–0·0861	0·0109	0·0870	+0·0009	1	30

described is obviously only approximate, some barium chloride going into solution in the 2:1 mixture of acetone and acetyl chloride, while the solubility of the strontium chloride turns upon the amount of water originally present—that is, upon the development of hydrogen chloride.

It appears, therefore, that the method which rests upon the action of a 4:1 mixture of acetone and acetyl chloride upon the concentrated solution of the chlorides affords easy and exact means for the separation and estimation of barium associated with calcium and magnesium. It is not recommended for the separation of barium from strontium.

Art. XXI.—*A Feldspar Aggregate Occurring in Nelson Co., Virginia*; by William M. Thornton, Jr.

Near Rose's Mill in Nelson Co., Virginia, the General Electric Company recently carried on some mining operations with the view of obtaining rutile, where it occurs as a rock-forming mineral in the unique rock type "nelsonite."* To give some idea of the nature of this peculiar rock, an analysis of the rutile phase is here inserted:

Analysis of Nelsonite.—General Electric Company's mine, 1½ miles northwest of Rose's Mill. Essential minerals:—Rutile (TiO_2) and apatite ($Ca_5FP_3O_{12}$). Accessory minerals:—Ilmenite ($FeTiO_3$), pyrite (FeS_2), and quartz (SiO_2).

SiO_2	0·67	per cent
Fe_2O_3	2·87	"
FeO	5·04	"
MgO	0·15	"
CaO	12·16	"
H_2O (at 110° C.)	0·09	"
H_2O (above 110° C.)	0·11	"
TiO_2	69·67	"
P_2O_5	9·41	"
Cl	trace	"
F	0·70	"
S	0·34	"
	101·21	
Excess O —	0·39	
Summation =	100·82	

At this place the narrow, well-defined dike of nelsonite intersects a metamorphosed pegmatite. The pegmatite is

*Name proposed by T. L. Watson, Director Virginia Geological Survey. See Mineral Resources of Virginia, 1907, p. 300.

composed essentially of feldspar and blue quartz and in places much hornblende. The accessory minerals ilmenite and pyrite and apatite are also present. The feldspar is by far the dominant portion of the rock; and, since it presents some unusual features, it was thought by the author that a study of its composition would prove of some interest. Of course the natural procedure would be to isolate mechanically the feldspathic portion and to analyze the most homogeneous material obtainable. But three analyses of the pegmatite were required for geological purposes; and since time was lacking in which to make a fourth of the feldspar alone, it was decided to employ the analysis of the extreme acidic phase for calculating the composition of the feldspar.

The color of the feldspar is light bluish gray. Under a magnifier of twenty diameters it appears decidedly transparent and glassy. The texture is one of very close crystalline aggregation. Specific gravity = 2·68. From all outward appearances one would suppose it to be a definite species; but the analysis and portioning of the molecules to form the respective feldspars in the accompanying table shows it to be a mixture of orthoclase and plagioclase, and that the plagioclase is made up of albite and anorthite in the ratio of 10 to 7. This is also confirmed by microscopic examination of thin sections.*

Pegmatite (feldspathic facies) near Rose's Mill, Nelson Co., Virginia.

	Per cent		Mo. wt.		Rel. no. mos.	Rel. no. feldspar mos.
SiO_2	59·92	÷	60	=	0·9987	$2KAlSi_3O_8$ = 0·03117
Al_2O_3	24·23	÷	102	=	0·2375	$2NaAlSi_3O_8$ = 0·081
Fe_2O_3	0·29					$CaAl_2Si_2O_8$ = ·1137
FeO	0·24					[$Ca_3P_2O_8$ = ·0006]
MgO	0·23					
CaO	6·47	÷	56	=	0·1155	∴ $NaAlSi_3O_8$: $CaAl_2Si_2O_8$ =
Na_2O	5·03	÷	62	=	0·081	2 : 14 = 10 : 7
K_2O	2·93	÷	94	=	0·03117	
H_2O (at 110° C.)	0·08					
H_2O (above 110° C.)	0·28					
CO_2	trace					
TiO_2	0·22					
P_2O_5	0·09	+	142	=	0·0006	
S	trace					
MnO	trace					
	100·01					

Pegmatite: = ∴ orthoclase — 17·337 per cent, plagioclase ($Ab_{10}An_7$) 74·057 per cent.

Composition of feldspar, aggregate: orthoclase 18·96 per cent; plagioclase ($Ab_{10}An_7$) 81·04 per cent = 100·00.

* Bull. 430–D, U. S. Geological Survey, p. 57. "The Virginia Rutile Deposits," by T. L. Watson and S. Taber.

After combining all the potash molecules with alumina and silica to form orthoclase and likewise all the soda molecules to form albite and all the lime molecules (except enough to satisfy the phosphoric anhydride to form apatite) to form anorthite, there is a little alumina in excess. This can be accounted for by assuming the hornblende to contain some alumina, which is probably the case, or by errors in the determinations.

In general the methods of analysis employed were those in use by chemists of the U. S. Geological Survey. In the determination of the alkalis the purest reagents of Dr. T. Schuchardt were used, and the filtrate from the first lime precipitation was concentrated in a silver basin; glass and porcelain vessels were avoided where any error might arise from their use.

Virginia Geological Survey,
University of Virginia, January 16, 1911.

Art. XXII.—*History of the Coconut Palm in America*; by O. F. Cook.*

Many scientific text-books and works of reference support the popular idea that the coconut palm is specially adapted to tropical seacoasts and is confined to maritime regions. No other example of special adaptations of plants to their environments has had longer currency or more confident belief. Nevertheless, it seems that the botanical romance of the coconut, protected by its thick husk and floated from island to island in advance of human habitation, must go the way of many other pleasing traditions. What natural agencies have been supposed to do for the coconut is now to be recognized as the work of primitive man. The truth proves again to be stranger than the fiction.

The coconut exists in the lowland tropics only as a product of cultivation. It does not plant or maintain or distribute itself on tropical seacoasts, and would entirely disappear from maritime localities if human care were withdrawn. The habits of the palm from the botanical standpoint, its significance in human history, and even its agricultural possibilities are misunderstood unless we are able to lay aside the maritime traditions.

An outline of the evidence for the American origin of the coconut palm and of its distribution by human agencies has been published in a previous number of the Contributions.† The present study carries the subject further in two principal directions. It brings additional facts to show that the coconut palm was already widely distributed in the New World before the arrival of the Europeans, and that it is not naturally a maritime or humid tropical species, but a native of drier and more temperate plateau regions in South America. A comparison of the habits of germination of the coconut with those of other related American palms shows other and very different uses for the characters that have been looked upon as special adaptations for maritime dissemination.

The huge seed with its immense store of food materials and its thick fibrous husk make it possible for the coconut to propagate itself in the relatively dry interior localities where it appears to have originated. The inability of the palm to withstand shade explains why it has been unable to establish

*Extracted from *Contributions from the U. S. National Herbarium*, vol. xiv, pt. 2, pp. 271–342, 1910. The portions here given are from the introduction and summary.

† The Origin and Distribution of the Cocoa Palm, *Cont. Nat. Herb.*, vol. vii, pp. 257–293, (1901.)

itself as a wild plant on any tropical seacoast. The application of these facts to cultural problems shows that the possibilities of an extratropical extension of the coconut palm are not to be realized on seacoasts, but in interior desert regions where larger amounts of heat and sunlight are to be obtained.

Though the biological evidence of the American origin of the coconut palm appears complete and adequate, recent years have brought to light several additional facts which may be of use to those whose training and habits of thought lead them to attach great weight to the historical arguments of De Candolle and other writers who believed in the Old World origin of this palm and its dissemination by the sea. The reader is impressed by De Candolle's references to many old and rare books, and will naturally remain loth to believe that so eminent an authority could have come to an erroneous conclusion, unless all the foundations of his opinions are carefully reexamined.

It is important to trace and clear away any mistakes or false deductions which obscure the early history of cultivated plants. Misconceptions regarding the origin and dissemination of any important economic species tend to distort human history as well as to mislead botanical and agricultural investigation. It is only when we view the past with the right perspective that we gain correct ideas of the factors which control our present interests and our future progress. Civilization itself is based on cultivated plants, and history may be written with as much propriety from the agricultural standpoint as from the military, political, or commercial.

Summary of Results.

The history of the coconut palm has relation to several different kinds of scientific questions, so that the facts require to be summarized from several different standpoints.

Botanical Conclusions.

All the palms that are related to the coconut, comprising about 20 genera and 200 species, are natives of America, with the possible exception of a single species, the West African oil palm. All the species of the genus Cocos and of the closely allied genera are natives of South America. The species of Cocos that are most related to the coconut are natives of the interior valleys and plateaus of the Andes, where the coconut also thrives, remote from the sea.

Comparison of the structure of the fruit and the method of germination of the coconut with those of the related palms indicates a high degree of specialization, but not for purposes of maritime distribution. The unusually large, heavy seed and the thick, fibrous husk are to be considered as adaptations for protecting the embryo, assisting in germination, and establishing the young plants in the dry climates of interior localities, the only conditions where this palm could be expected to maintain its existence in a wild state.

The habits of the coconut palm afford no indication that its original habitat was on the seacoast, and none of its closer relatives have maritime habits or maritime distribution. The coconut palm does not appear to be able to maintain itself under littoral conditions without the assistance of man. Though carried by man to all of the warmer parts of the earth, it has not been able to establish itself as a wild plant on any tropical coast, but is always crowded out by other vegetation after human care is withdrawn.

Wafer's circumstantial account of the existence of large numbers of coconut palms on the Cocos Islands, 300 miles west of Panama, in 1685, taken together with their almost complete disappearance at the present day, affords a striking illustration of the dependence of the coconut upon human assistance, not only for distribution, but for its continued existence on oceanic islands.

The dissemination of the coco palm along the tropical coasts is to be ascribed to the agency of primitive man, as with the sweet potato, banana, and other domesticated plants which were widely distributed in prehistoric times. The theory that it has been disseminated by ocean currents is gratuitous, unproved, and improbable.

The development of distinct varieties of the coconut has not been confined to the Polynesian and Malayan islands. Distinct varieties are also to be found in isolated localities in America, such as the Soconusco region of Mexico and the island of Porto Rico.

The existence of many and diverse varieties in the Malay region does not indicate that the species is native there, but the opposite, since the proximity of the wild stock of a species is likely to hinder the appearance and preservation of mutations among its cultivated representatives. The relative uniformity of the coconuts of America is in accord with the probability of an origin in this hemisphere. The discovery of distinct varieties in isolated localities in America accords with the probability that the Malayan varieties have arisen, like other cultivated varieties, through segregation and mutation rather than by gradual evolution and natural selection.

Historical Conclusions.

At the time of the discovery of America the coconut was not confined to the Pacific side of the Isthmus of Panama, as

De Candolle believed, but was already widely distributed along the Atlantic side of the American tropics. Early records show its presence in Cuba, Porto Rico, Brazil, and Colombia at dates so early as to preclude the idea of introduction by the Spaniards.

The statement of Pickering, frequently quoted in works of reference, to the effect that coconuts were reported by Columbus on the coast of Central America during his fourth voyage, proves to be erroneous. On the other hand, there appears to be a definite reference to the coconut in Cuba in the journal of the first voyage of Columbus.

De Candolle's inference from Acosta's report of coconuts in Porto Rico at the end of the sixteenth century, that they had recently been introduced by the Spaniards, proves to have no warrant in history and is directly opposed by the more extended reference to the coconut in Porto Rico by the Duke of Cumberland's chaplain, who visited the island only a few years after Acosta.

De Candolle's use of the testimony of Piso and Marcgrave to support the idea of the introduction of the coconut into Brazil by Europeans is also unwarranted, since those writers only indicated that the plant was cultivated. An earlier and more explicit record, unknown to De Candolle, gives an account of the coconut as one of the native products of Brazil.

The journal of Cieza de Leon, who accompanied the first Spanish expedition to the interior of Colombia, indicates the presence of the coconut palm in localities where it still continues to exist, as shown by the accounts of Velasco, Humboldt, and more recent travelers, down to the present decade.

Ethnological Conclusions.

The American origin of the coconut palm and the strict limitation of its status in maritime tropics to that of a cultivated plant are facts of ethnological significance. The wide distribution of the coconut in prehistoric times is evidence of the antiquity of agriculture in America and of very early communication across the Pacific.

The American origin of the coconut palm, along with its inability to maintain itself on tropical seacoasts without human assistance, compels us to believe that its trans-Pacific distribution was the work of primitive man. The dependency of the Pacific islanders upon the coconut may be taken to show that these islands could not have been occupied without the previous domestication and dissemination of the coconut.

In view of the fact that several other palms of unquestioned American origin have been domesticated by aborigines of the American tropics, no ethnological objection can be raised to the idea that the coconut palm was originally domesticated in ancient America.

The name "coco" does not appear to have been applied to the "Indian nut" till after the discovery of America and is to be considered as a word derived from the natives of the West Indies. Other native names for the coconut are found among primitive tribes of Costa Rica, as well as in Brazil.

The presence of large numbers of coconuts on Cocos Island in the time of Wafer (1685) and their subsequent disappearance should be considered as evidence that the island was formerly inhabited, or at least regularly visited, by the maritime natives of the adjacent mainland.

The fact that the coconut is largely restricted to islands and tropical countries of low elevation explains its importance among the preëminently maritime people of the Old World tropics and its relatively slight importance among the nonmaritime natives of the lowland tropics of America.

The evidence of the prehistoric dissemination of the coconut and other American cultivated plants across the Pacific Ocean is such as to warrant a careful consideration of other indications that agricultural civilization developed originally in America and was distributed to the shores of the Pacific and Indian oceans by a primitive people with agricultural and maritime habits, like those of the Polynesians and Malays.

The existence of a distinct tribe of frizzle-haired people near the Isthmus of Panama at the time of the discovery does not rest alone on Peter Martyr's casual mention of the finding of negroes, but is supported by Oviedo's contemporary history written directly from the testimony of Balboa and other members of his expedition, just after their return to Darien. The facts are not to be explained reasonably by assuming a chance arrival of African negroes, but indicate that prehistoric communication across the Pacific continued after the frizzle-haired Melanesian race had spread westward in the Pacific.

Such communication would account for the existence of the banana plant in America previous to the arrival of the Spaniards, as well as for the Old World distribution of the coconut palm and other cultivated plants of American origin. The banana plant is as evidently a native of the eastern continent as the coconut palm of the western. Evidence of these facts appears very definite and concrete from the biological standpoint, and is worthy of careful consideration by ethnologists.

Agricultural Conclusions.

The coconut is confined to seacoasts only in the humid lowlands of the Tropics; in dry regions it is not restricted to coasts, but thrives in many districts remote from the sea. The fact that it received scientific study only as a maritime plant should not longer obscure the fact that it is also adapted to interior localities with saline soils. The cultural problems of the coconut palm should be investigated quite apart from the idea of maritime habits and distribution.

The possibility of raising coconuts in frost-free localities outside the Tropics is not to be tested along the seacoast, but in interior districts where larger amounts of sunlight and heat are available, as in the valleys of southern California and Arizona. The coconut, like many other plants, is not tolerant of shade nor of long-continued cool and cloudy weather. Other species of Cocos that are less exacting in their requirements of sunlight and heat have been found to do well along the California coast.

The possibility of introducing coconut palms into southern California is not disproved by the absence of these palms from Egypt and Palestine. Though the climatic conditions are probably favorable, it does not appear that any adequate effort has been made to introduce the palms in those countries.

The ability of the coconut to thrive on seacoasts shows that its requirements of heat are not as great as those of the date palm. Though probably less hardy than the date palm, it is not impossible that the coconut may be able to exist in frost-free localities that have not enough heat for the ripening of dates.

The possibility of introducing the coconut palm into southern California and Arizona can not be fairly tested by the planting of the maritime varieties. The chances of success will be very much greater with the varieties that are adapted to the dry interior localities of the temperate plateaus of the Andes.

Art. XXIII.—*A New Mink from the Shell Heaps of Maine*; by F. B. Loomis.

During the summer of 1909 the Amherst Biological Expedition collecting in the shell heaps along the Maine coast, opened the heap on the east side of Flagg Island in Casco Bay, near South Harpswell. This heap is distinct from any of the others in several features, but especially in having large numbers of mink bones in it, the mink being, however, larger than any species now living in New England and markedly different from any that are known. It is as large as the largest species from Alaska.* In the course of the week spent in the Flagg Island heap no less than 45 individuals were found in which there were 10 upper and 34 lower jaws of males, and 2 upper and 11 lower jaws of females. Beside these 3 lower jaws of the same species were found in the heap on Sawyers Island near Boothbay, 2 in the Seward Island heap in Frenchman's bay, and one in the Winter Harbor heap. The other localities worked did not offer any of this mink; so that it would appear that Flagg Island was more or less overrun with these minks during the shell heap period, while they occurred also in small numbers along the coast to the east and north.

The exact time when they lived is difficult to estimate, but the heaps contain nothing of European origin, so they were accumulated before 1627 and are probably as much older as it took to build them up, perhaps 200 to 400 years more. The mink is not confined to any one level on Flagg Island but occurred all through the heap; so that it is to be thought of as having lived on the Maine coast for some hundreds of years.

None of the skeletons were found associated, nor were any of the skulls perfect. In every case the mink had served as food for the aboriginal campers, so that the carcass had been pulled to pieces and the bones thrown away in various directions. Every skull has the brain case broken and lost, the brain having apparently been used for food. The facial portion of each skull is, however, pretty much intact, indicating that the meat was simply picked off it. Many of the lower jaws are marked with tool scratches (see fig. 2) apparently made while removing the meat from the bones.

This form is much larger than any of the living New England species, being all of 25 per cent larger than *Lutreola (vison) lutreocephalus** Harlan, the large brown mink, and

* N. American Fauna, Dept. Agriculture, No. 19, 1900, p. 43.

† Bangs, North American Minks, Boston Soc. Nat. Hist., Proceedings, vol. xxvii, 1897, p. 1-6.

equal in size to the Alaskan *L. vison ingens* Osgood. This new form may be described as follows:

FIG. 1.

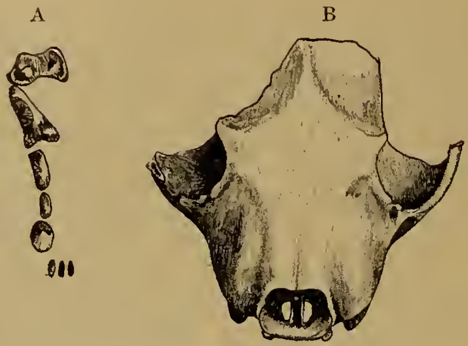


FIG. 1. A, the upper dental series of the type specimen, nat. size. B, the skull seen from above, nat. size.

Lutreola vison antiquus sp. nov.

The type is a male skull lacking the brain case together with an associated right lower jaw, numbered M 1401 in the

FIG. 2.

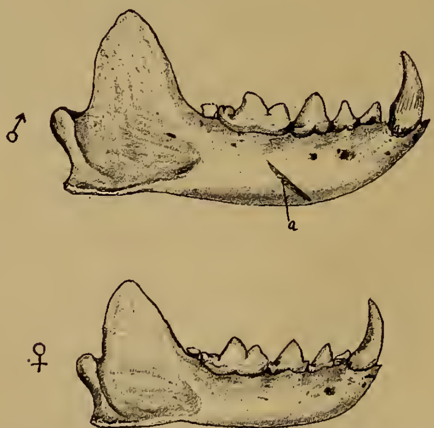


FIG. 2. ♂ lower jaw, nat. size; *a* is scratch made by aboriginal tool in removing the flesh. ♀ lower jaw of female, showing relative size.

Amherst Collections: and also a right lower jaw of a female numbered M 1402, both from Flagg Island shell heap.

The form is large and heavily built, the skull with a low sagittal crest and short wide postorbital processes. The frontal region is slightly arched between the orbits. The teeth are those typical of the genus but rather stonter and heavier than usual. The inner tubercle of the upper carnassial is single and rather small.

With this larger and typical form occur numerous individuals about 20 per cent smaller, but otherwise with the same characteristics, which I take to be the females, as there is in the family usually about this difference in size between the sexes.

The following measurements give the data for comparisons:

♂ upper dental series	29 1/2^{mm}
♀ " " "	25^{mm}
♂ lower dental series	30^{mm}
♀ " " "	26^{mm}
♂ upper carnassial	8 1/4^{mm}
♀ " "	7 3/4^{mm}
♂ width between the orbits	20^{mm}

For other measurements see figures, which are drawn to scale.

Amherst, Mass.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Mesothorium.*—The existence of this radio-active element as one of the products of thorium was established in 1907 by Hahn, who showed that its half decomposition period was about 5½ years, and that it was separated from thorium in the commercial extraction of the latter from its ores. Later, Hahn was able to find this substance in the residues from the extraction just mentioned, and he showed that it is not directly transformed into radiothorium, but that there is an intermediate product with a half-period of 6·2 hours, which he called mesothorium II. Hahn has recently been able to concentrate this last substance to such an extent that the radio-activity of the product is several times greater than that of pure radium salts.

W. Marckwald has now made some interesting observations in regard to these substances, for it appears that nothing has been published concerning the chemical properties of mesothorium I. He had occasion to examine a "radium preparation" which had been manufactured from the residues of uranium and thorium ores. This preparation, consisting chiefly of barium chloride, gave a γ-ray radiation corresponding to more than 1 per cent of radium chloride, but the radium emanation obtained from it corresponded to only about 0·2 per cent of radium. A further study of the product showed that about 80 per cent of the γ-radiation came from mesothorium II, for when an aqueous solution of the salt was treated with a trace of ferric chloride and made ammoniacal the mesothorium II was precipitated with the ferric hydroxide. The precipitate gave a strong γ-radiation, while the barium chloride recovered from the filtrate by evaporation had lost almost the whole of this radiation. However, while the precipitate lost its activity at the rate of one-half in about 6 hours, the salt regained the greater part of its activity within a day. The precipitate by ammonia must have contained also the radiothorium produced by the mesothorium, and in fact this was found to be the case, as the precipitate gave the α-rays of the thorium emanation after the disappearance of the mesothorium II. Mesothorium is evidently entirely analogous to radium in its chemical behavior, for Marckwald has been unable to find any means of separating the two. This is interesting in connection with the fact that no chemical method is known for separating the four elements, thorium, radiothorium, ionium and uranium X, and it appears that radium and mesothorium form a similar group, which possibly may contain other members also. It is evident that radium preparations are liable to be contaminated with mesothorium, and since radium has a period of existence about 300 times as long as the other, this contamination is of much importance. There is a possibility, not only of accidental contamination, but of wilful adulteration. The best means for testing radium preparations for mesothorium is to remove the radium emanation either by heating or by solution and evaporation; then the presence of γ-rays after a few hours shows the presence of mesothorium. The proportion of γ-rays before and after this treatment gives an indication of the amounts of the two radioactive substances present.—*Berichte*, xliii, 3420. H. L. W.

2. *The Combustion of Hydrocarbons.*—In a recent lecture before the British Association, W. A. BONE has given a review of the present knowledge of gaseous combustion, much of which is due to his own important researches. The opinion which formerly prevailed among chemists that in combustion the hydrogen of hydrocarbons is first attacked by oxygen with the formation of steam is incorrect. It has been known for a long time that when ethylene and acetylene are exploded with equal volumes of oxygen, carbon monoxide and hydrogen are practically the only products, as follows:

$$C_2H_4 + O_2 = 2CO + 2H_2$$
$$C_2H_2 + O_2 = 2CO + H_2$$

Bone has shown that the oxidation of the hydrocarbons at comparatively low temperatures proceeds by addition of oxygen to the molecule and the successive formation of hydroxyl products—alcohols, aldehydes, formic acid and finally carbonic acid. It appears that combustion at higher temperatures goes on in the same way, and it has been found that oxygen has a much greater affinity for the hydrocarbons than for hydrogen and carbon monoxide. For example, when detonating gas is exploded with acetylene in the proportion $C_2H_2 + 2H_2 + O_2$, there is absolutely no separation of carbon nor formation of steam, and practically the same thing holds good in the case of a mixture of ethylene, hydrogen and oxygen corresponding to $C_2H_4 + H_2 + O_2$. In the presence of a hydrocarbon, carbon monoxide is attacked by oxygen even less readily than is hydrogen. These observations have an important bearing on the chemistry of flames. Hitherto hydrogen has been considered as one of the most combustible of gases, but in reality it is very much less so than the hydrocarbons. It is probably not so much th eoriginal hydrocarbon as its hydroxylated molecule which decomposes in ordinary flames, and experimental evidence does not warrant the view, so often encountered in scientific literature, that hydrocarbons are resolved into their elements prior to being burnt.—*Chem. News*, cii, 309. H. L. W.

3. *Supposed Chemical Distinction between Orthoclase and Microcline.*—Two or three years ago the view was advanced by Barbier that orthoclase differs from microcline in the fact that the former contains traces of lithium and rubidium, while these elements are not found in the latter. It appears, however, that Ramage had previously found these alkali metals in a microcline from Dalkley in Ireland, and that Vernadsky, somewhat later,

found both rubidium and cæsium in the bluish-green microcline from Miask in the Ilmen mountains. In order to examine the matter more thoroughly, VÉRNADSKY and REVOUTSKY have now examined a number of samples of microcline spectroscopically, and have found the following elements present:

Miask, Russian,	K, Na, Rb, Li.
Arendal, Norway,	Ba, K, Na, Rb.
Pike's Peak, Colorado,	K, Na, Rb, Li, Cs.
Hunttila, Finland,	K, Na, Ba, Rb, Li.
Lojo, Finland,	K, Na, Ca, Li (Rb?).

These results were obtained by heating fragments of the mineral directly before the gas-oxygen blowpipe and observing the spectrum of the flame. The results show that Barbier's view is evidently incorrect.—*Comptes Rendus*, cli, 1372. H. L. W.

4. *Preparation of Argon.*—G. CLAUDE has found a convenient way to prepare large quantities of argon. As a starting point he uses the oxygen produced by the liquefaction of air, which may be obtained 95 per cent pure, and with argon as its principal impurity, amounting to about 3 per cent. This oxygen is, therefore, about three times richer in argon than ordinary air. The oxygen is absorbed by hot copper, and the nitrogen by hot magnesium, only a small amount of the latter being required. A tube of hot copper oxide serves finally to oxidize any hydrogen that may have been formed from moisture present in the materials employed.—*Comptes Rendus*, cli, 752. H. L. W.

5. *Die Stellung der neueren Physik zur mechanischen Naturanschauung;* von Dr. MAX PLANCK. Pp. 33. Leipzig, 1910 (S. Hirzel).—This pamphlet contains a lecture given before the eighty-second meeting of the German Scientists and Physicians, held in Königsberg, last September. It deals with the Theory of Relativity and with the philosophical views to which it leads in the minds of many German mathematicians and physicists. To the Anglo-Saxon mind, these views appear to touch the limits of philosophical idealism. Ether and matter, in fact all substance, is apparently discarded, and the physical universe consists of a vacuum mitigated by the presence of the Principle of Least Action, and Maxwell's Equations; the "building stones," of which the physical world is constructed, are no longer material particles but the so-called universal constants: the velocity of light, the charge and mass of the electron, the "elementare Wirkungsquantum," etc. H. A. B.

6. *History of the Cavendish Laboratory, 1871–1910.* Pp. x, 342. London, 1910 (Longmans, Green & Co.).—This volume has been prepared in commemoration of the twenty-fifth anniversary of Sir J. J. Thomson's election to the Cavendish Professorship of Physics in the University of Cambridge. It is the work of several different authors, each period of the history of the laboratory being treated by one who was intimately connected with it during the time in question. Messrs. Fitzpatrick and

Whetham deal with the building of the laboratory ; Professor Schuster, with the Clerk Maxwell period ; Mr. Glazebrook, with the years during which Lord Rayleigh was professor ; and Sir J. J. Thomson, himself, gives a general survey of the past twenty-five years. In chapters V to VIII the activities of the laboratory during these twenty-five years, are discussed in greater detail. Professor Newall gives an account of the researches conducted between 1885 and 1894 : Professor Rutherford recounts the memorable achievements which marked the years 1895–1898 : C. T. R. Wilson deals with the period from 1899 to 1902, and N. R. Campbell completes the record to 1909. Chapter IX by Professor Wilberforce of the University of Liverpool deals with the development of the teaching of physics in Cambridge, a development which has had great influence upon physics teaching throughout the world. The volume closes with a list of memoirs containing accounts of research performed in the Cavendish Laboratory, and a list of those who have worked there.

The volume cannot fail to be of great interest to all students of physics ; it is a valuable contribution to the recent history of the science, and a more appropriate way of celebrating Sir J. J. Thomson's twenty-fifth anniversary could scarcely have been found. H. A. B.

7. *The Principles and Methods of Geometrical Optics, especially as applied to the theory of Optical Instruments ;* by James P. C. Southall. Pp. xxiii, 626, with 169 figures. New York, 1910 (The Macmillan Company).—This is a notable book which surpasses all others in the English language treating of the same subjects. The very great number of propositions in geometrical optics are presented clearly, in a carefully studied notation, which is, except in a few cases where other considerations are of greater weight, consistent and lucid. The diagrams are sufficient in number and very clear, with the too rare quality of good taste in respect to all the details which determine the character of such illustrations. Most excellent features of the book are its bibliography and historical notes, which are very complete. The only striking omission observed is that of the admirably convenient—perhaps the most convenient of all—collection of formulas for rigid computation of the constants of a system of centered lenses by P. A. Hansen. These features make the volume invaluable to one who seeks a knowledge of what has been accomplished in this field during the three centuries in which the problems of geometrical optics have been continuously increasing in importance.

When we come, however, to consider the utility of the methods and equations deduced in the text to the designer of optical apparatus, we must give more restricted praise, since they emphasize what is relatively unimportant in practice and thrust more or less into the background those features which are essential. Excellent examples in support of this assertion are afforded by the only numerical calculations in the book, namely, the calculations of some of the optical constants of a 12-inch Taylor telescope objective. The geometrical data are given to three-figure accuracy and are susceptible, perhaps, to a maximum of ten times this precision. The calculations of focal lengths are carried out to seven-figure accuracy, that is to some 1000 times the precision warranted by the data ; it is three or four hundred thousand times as great precision as is deemed important by the designer himself, if we infer that he expected to make the ratio of focal length to aperture the standard for telescopes of this size. Nevertheless, this incommensurate labor of calculations is necessary in order to deduce a sufficient value, to two figures only, of the spherical aberration.

The other case is equally striking. The spherical aberration of the same objective is calculated to a two-figure precision, which is all that is of practical significance, by a tedious computation with seven-figure logarithms by application of Seidel's analysis and with the disappointing error of one hundred per cent. These considerations are enough to show that there is some radical defect in a method which demands such efforts for such meager returns. Probably there is no hope of material improvement until the mathematician informs himself thoroughly as to the relative importance of the magnitudes which enter his analysis and then deals with the physical realities of wave surfaces and refracting surfaces instead of the unnecessary fictions of rays and of radii of lens surfaces. C. S. H.

8. *Chemische Krystallographie;* von P. GROTH. Dritter Teil. Aliphatische und Hydroaromatische Kohlenstoff-verbindungen. Pp. iv, 804, mit 648. Text figuren. Leipzig, 1910 (Wilhelm Engelmann).—This monumental work on Chemical Crystallography begun in 1906 has now reached its third part, or as estimated, three-quarters of the whole. It is devoted to the aliphatic and hydroaromatic hydrocarbons. The whole makes a work of 800 pages, with perhaps 1200 or more individual compounds, whose crystallographic and optical constants are given with great thoroughness. In a large number of cases the crystal form is illustrated by figures. The congratulations of those immediately interested are due to the veteran author for his success in carrying through a work of such magnitude and importance.

II. GEOLOGY AND NATURAL HISTORY.

1. *United States Geological Survey, Thirty-first Annual Report (1909–1910) of the Director*, GEORGE O. SMITH. Pp. 131 with two plates. Washington, 1911.—This report contains a statement of the work done by the various divisions of the Survey during the fiscal year ending June 30, 1910. The progress in land classification consisted in, first, the preparation of withdrawals covering power sites and coal, oil, gas, and phosphate lands ; second, the classification of withdrawn lands and

restoration of such as were found to be not underlaid by valuable deposits. The work involves also the performance of various executive and advisory functions connected with the classification and valuation of the public lands.

The mining and technologic work of the Survey, which in the last few years has assumed large importance, was transferred on July 1, 1910, to the newly established Bureau of Mines (see v. xxx, pp. 292, 419). Thus another child of the Geological Survey, having grown to adult proportions and demonstrated its usefulness, has been launched on an independent career. No small part of the great value which the Survey has been to the nation consists in the foresight, efficiency, and high scientific grade with which new branches of government work have been developed under the care of that organization. The increase in the correspondence of the Geological Survey and in the distribution of its publications is a measure of the increasing appreciation by the people of the work which is done. The correspondence increased more than 20 per cent over that of the previous year and the total number of reports and maps distributed has increased more than 13 per cent. The publications of the Survey during the year measure a part of its returns for the money expended. They consisted of 4 professional papers, 47 bulletins, 18 water supply papers, one volume on mineral resources, 6 geologic folios and 94 topographic maps. J. B.

2. *Publications of the U. S. Geological Survey.*—Recent publications of the U. S. Geological Survey are noted in the following list (continued from vol. xxx, p. 417). The thirty-first Annual Report of the Director is noticed above.

Topographic Atlas.—Seventy-three sheets.

Folio, No. 174. Johnstown Folio, Pennsylvania; by W. C. Phalen. Pp. 15, with 1 columnar section, and 3 maps.

Sacramento Folio, California; by W. Lindgren. Pp. 3, 4 maps.

Professional Paper, No. 72. Denudation and Erosion in the Southern Appalachian Basin; by Leonidas C. Glenn. Pp. 137, 21 plates, 1 figure.

Bulletins.—No. 430. Contributions to Economic Geology (Short Papers and Preliminary Reports, in part earlier issued as separates.) 1909. Part I. Metals and Nonmetals except Fuels. C. W. Hayes and Waldemar Lindgren, geologists in charge. Pp. 653, 14 plates, 75 figures.

No. 431-A. Advance Chapter from Contributions to Economic Geology, 1909. Petroleum and Natural Gas; by A. G. Leonard, H. E. Gregory, C. W. Washburne, and Robert Anderson. Pp. 83, 3 plates, 1 figure.

No. 433. Geology and Mineral Resources of the Solomon and Casadepaga Quadrangles, Seward Peninsula, Alaska; by Philip S. Smith. Pp. 234, 16 plates, 26 figures.

No. 436. The Fauna of the Phosphate Beds of the Park City Formation in Idaho, Wyoming, and Utah; by George H. Girty. Pp. 82, 7 plates.

No. 440. Results of Triangulation and Primary Traverse for the years 1906, 1907, and 1908. R. B. Marshall, chief geographer. Pp. 688, 1 plate.

No. 441. Results of Spirit Leveling in Alabama, Georgia, North Carolina, South Carolina, and Tennessee, 1896 to 1909, inclusive. R. B. Marshall, chief geographer. Work done in coöperation with the State of Alabama during 1899 to 1905, inclusive; with the State of North Carolina during 1896 and from 1902 to 1909, inclusive. Pp. 145.

No. 442. Mineral Resources of Alaska. Report on Progress of Investigations in 1909; by Alfred H. Brooke and others. Pp. 426, 7 plates, 8 figures.

No. 470–A. Advance Chapter from Contributions to Economic Geology, 1910. Phosphates in Montana; by Hoyt S. Gale. Pp. 9, 2 figures.

Water Supply Papers.—No. 254. The Underground Waters of North-Central Indiana; by Stephen R. Capps, with a chapter on The Chemical Character of the Water, by R. B. Dole. Pp. 279, 7 plates, 12 figures.

Nos. 262, 264.—Surface Water Supply of the United States, 1909 [prepared under the direction of M. O. Leighton]. No. 262. Part II, South Atlantic and Eastern Gulf of Mexico; by M. R. Hall and R. H. Bolster. Pp. 150, 5 plates. No. 264. Part IV, St. Lawrence River Basin; by C. C. Covert, A. H. Horton and R. H. Bolster. Pp. 130, 5 plates.

3. *Bureau of Mines*, Joseph A. Holmes, Director.—Four additional bulletins have been recently issued; these are as follows: Bulletin 2, North Dakota Lignite as a Fuel for power-plant Boilers; by D. T. Randall and Henry Kreisinger. Pp. 42, 1 plate, 7 figures. Bulletin 3, The Coke Industry of the United States as related to the Foundry; by Richard Moldenke. Pp. 32. Bulletin 4, Features of Producer-Gas Power-Plant Development in Europe; by R. H. Fernald. Pp. 27, 4 plates, 7 figures. Bulletin 5, Washing and Coking Tests of Coal, at the Fuel-Testing Plant, Denver, Colorado, July 1, 1908, to June 30, 1909; by A. W. Belden, G. R. Delamater, J. W. Groves, and K. M. Way. Pp. 62, 1 figure.

Miners' Circulars Nos. 1 and 2 have also just been issued; they are the first of a series to be written in plain, non-technical language for the benefit of the miner. They contain the names of the permissible explosives tested by the bureau at its Pittsburg station up to November 15, 1910, and gives precautions as to their use.

4. *Florida State Geological Survey. Third Annual Report, 1909–1910.* E. H. Sellards, State Geologist. Pp. 397 with numerous plates and figures. Tallahassee, Fla., 1910.—This report, like the preceding of the series, is of high scientific as well as practical value. The scientific interest lies in the unique character of the geologic province of Florida as compared with other portions of the United States and the way in which the subjects have been treated. The value to the citizens

of Florida lies in the information which it contains on the mineral and water resources of the State. The volume contains, besides the administrative report and index, the following papers: A Preliminary Paper on the Florida Phosphate Deposits, by E. H. Sellards; Some Florida Lakes and Lake Basins, by E. H. Sellards; The Artesian Water Supply of Eastern Florida, by E. H. Sellards and Herman Gunter; A Preliminary Report on the Florida Peat Deposits, by Roland M. Harper. J. B.

5. *The Badland Formations of the Black Hills Region;* by Cleophas C. O'Harra. 144 pp., 50 pls., 20 figs. South Dakota School of Mines, Bulletin No. 9, Department of Geology. Rapid City, South Dakota, November, 1910.—The "badlands" of South Dakota form one of the most interesting physiographic subprovinces in the world, and taken in connection with the Black Hills, forms a type area which in many respects is unique. While the structure and stratigraphy are not complicated, yet the details are so important as to fully justify the prominent place given to this area in the literature. Heretofore students have had to search through widely scattered technical reports in order to obtain information regarding the origin and topographic development of the badlands, as well as of the large and interesting collection of fossils. Thanks to Professor O'Harra, we now have a single volume accessible to students and amateurs wishing to become acquainted with this country,—a volume which does not require advanced scientific training to understand. From an educational standpoint the publication is, therefore, abundantly justified in spite of the absence of essential facts and interpretations new to science.

6. *West Virginia Geological Survey*, I. C. White, State Geologist. Bulletin 2. Pp. 358. Morgantown, 1911.—Following Bulletin No. 1, which gives a bibliography of the state, the West Virginia Survey has now issued a volume containing tables of levels and distances, and also coal and coke analyses. The levels are compiled from records of the State and Federal Surveys, and have been supplemented by data collected by the various West Virginia railways. The analytical tables contain results of tests of coal made from all the economic horizons of importance,—namely, the Pottsville, Kanawha, Allegheny, Conemaugh, Monongahela, and Dunkard series. The estimated coal production for 1910 is 65,000,000 short tons. H. E. G.

7. *New Zealand Geological Survey, J. M. Bell, Director. Bulletin No. 9 (New Series), The Geology of the Whatatutu Subdivision, Raukumara Division, Poverty Bay;* by James Henry Adams. 1910. Pp. iii and 46, 3 ills., 5 maps.—In age the rocks included within this subdivision are upper Miocene and consist of shales, argillites, sandstones, with coarse sandstones and conglomerates in the upper portion. Pumiceous deposits, possibly of Pliocene age, also occur. An interesting problem is presented by the fact that many of the igneous pebbles in the conglomerate are unlike any rocks thus far discovered in the

north island of New Zealand. The fossils collected in this area have been studied by Professor Marshall of Otago University. He finds that out of a total of forty-four species of mollusca recent species number twelve, and the conclusion is reached that the strata are Upper Miocene in age rather than partly Cretaceous, as previously assumed. In the Whatatutu area the terraces developed along the streams at 200 and 400 feet give a clue as to the amount of elevation since the end of Miocene time. A much dissected coastal plain at an elevation of 3000 feet is indicated by the structure and attitude of Tutamoe ridge. Owing to the economic importance of this field the structure has been studied in detail. It is found that the rocks have been folded into broad anticlines and that accompanying the folds are faults of slight dislocation. The existence of fourteen oil seeps attracted attention to the Waitangi hill as early as 1874, but later developments have not led to discoveries of oil or gas in quantities sufficiently large to be of commercial importance.

Bulletin No. 10 (New Series), The Geology of the Thames Subdivisions, Hauraki, Auckland; by Colin Fraser. 1910. Pp. iii and 129, 9 ills., 19 maps and sections.—The Thames section in the northern island of New Zealand was brought into prominence by the discovery of gold in 1865. By 1871 the production had reached about $5,940,000, and this largely from one bonanza. The production at the present time is below the $500,000 mark, and the main hope is in exploiting lower levels. The oldest rocks of the area, the Tokatea Hill series, consist of argillites and graywackes of pre-Jurassic age. The Manaia Hill series (Jurassic) overlies unconformably the older terranes. A long interval, during which folding and faulting occurred and a submarine topography was developed, elapsed between the Jurassic and the Eocene. Three periods of volcanic eruptions are revealed by an examination of the Tertiary strata. The upper Eocene and Miocene volcanics consist of andesitic and dacitic tuffs, breccias, conglomerates and lavas, while the Pliocene eruptions were rhyolitic in nature. Large and small folds have been observed in the district, and have been found to be of direct economic importance. The great Moanataiari fault with a down-thrust of 595 feet is represented topographically by a partially dissected fault scarp. Pages 50-115 of this report are devoted to detailed descriptions of existing mines and mining areas. H. E. G.

8. *Geological Survey of Western Australia. Bulletin No. 33, Geological Investigations in parts of the Gascoyne, Ashburton and West Pilbara Goldfields;* by A. Gibb Maitland. 1909. Pp. 77, 13 maps and 65 figures.—The area covered by this report is the extreme western portion of Australia including the coast line from Port Hedland to the mouth of the Wooramel River. The geological sketch-map shows the Gascoyne beds (Carboniferous) well developed in the lower Gascoyne River; the Bangemall beds (Nullagine ?) from Frederick River to Mount Flora; and the Ashburton beds (age undetermined), chiefly in the neighborhood of Ashburton and Hardey Rivers. There are also small

areas of pre-Carboniferous granite and gneiss. The relations and character of the formations near the coast line are revealed by a 3011 foot well at Carnarvon, which shows 1211 feet of Mesozoic, 1650 feet of Carboniferous. The Carboniferous section in the Arthur River valley consists of (1) grits and fine conglomerate, (2) fossiliferous limestone, (3) limestone conglomerate, (4) glacial bowlder bed, (5) sandy and flaggy limestones. This glacial bowlder bed is well exposed at a number of localities and in the Wyndham River valley contains Spirifera, Productus, Polyzoa, and Aviculopecten. The Carboniferous series as a whole rests upon metamorphosed sedimentary rocks of unknown age. Owing to the economic importance of this part of West Australia somewhat detailed studies of structural relations were made. In the vicinity of Bangemall slates, limestones, quartzites and diabase are arranged in a denuded anticlinal fold and are intersected by numerous quartz reefs. Mount Augustus, one of the most conspicuous scenic features of West Australia, was found to be a sharp monoclinal fold of schist and conglomerate. Both normal and thrust faulting are revealed at Coorabooka Gap, and the position of this gap as well as the arrangement of the drainage lines suggests interesting physiographic studies. In the Uaroo copper district of Ashburton the rocks are sedimentaries of unknown age and have undergone deformation since mineralization.

A chapter on petrography by J. Allan Thomas contains a discussion of dolomite and cherts, pyroxenites and amphibolites, together with conclusions regarding magmatic sequence. Sixty-nine slides are described in detail accompanied by a list of eighteen analyses. While this bulletin is chiefly devoted to economic studies, it adds considerable to the meager information regarding the geology of this interesting country.

Bulletin 38, The Irwin River Coalfield; by W. D. CAMPBELL. 1910. Pp. 101, 7 plates and 53 figures.—The pre-Carboniferous rocks of the Irwin River district are gneisses and granites "traversed by dikes of diabase, basalt, and norite, and lodes of lead and copper in addition to quartz veins." This crystalline complex was greatly eroded before the deposition of extensive beds of quartz conglomerates and submarine tuffs of pre-Carboniferous age. The Carboniferous rocks are fossiliferous and consist of clays, shales, sandstones and limestones. One important stratum is the glacial bowlder bed which has been recognized at several localities in Western Australia. In the area under discussion this bowlder bed is found within the Carboniferous and not at its base. Jurassic strata, 300 feet in thickness and containing lignite, rest upon the denuded surface of the Carboniferous. Tertiary limestones and sandstones seems to overlie unconformably the Jurassic rocks of the Hutt River district.

H. E. G.

9. *Palæontological Contributions to the Geology of Western Australia.* Geol. Surv. Western Australia, Bull. 36, Pt. III, pp. 133 and 12 pls. 1910.—A series of eight papers is here

included, as follows:—(1) Hinde on isolated sponge spicules that are "newer than the Cretaceous"; (2) Arber on some Jurassic plants; (3) Etheridge on 19 Oolitic invertebrates; (4) Glaubert on a fossil cave marsupial, *Sthenurus occidentalis*, (5) on a list of West Australian pre-Tertiary fossils known to the end of 1908, (6) on Paleozoic fossil plants, (7) on Devonian fossils, and (8) on Cretaceous chalk and fossils. C. S.

10. *Report of the Vermont State Geologist for 1909–1910*; by GEORGE H. PERKINS. Pp. xii, 361, pls. 71. 1910 [Jan. 1911].—The volume opens with an account of the History and Conditions of the State Cabinet, by the State Geologist. The granites of the state are described by T. Nelson Dale, in an article which is practically a reprint of a bulletin of the U. S. Geological Survey. C. H. Hitchcock has a chapter on the Surfacial Geology of the Champlain Basin and Percy E. Raymond brings together all that is known about the trilobites of the Chazy formation in Vermont. The latter comprise 36 species, all of which are illustrated. Professor Perkins describes the geology of the Burlington Quadrangle and Professor Seely has a preliminary report on the Geology of Addison County. Asbestos in Vermont is treated by C. H. Richardson and the mineral resources by the State Geologist. C. S.

11. *A Contribution to the Geologic History of the Floridian Plateau*; by THOMAS WAYLAND VAUGHAN. Carnegie Institution of Washington, Publication 133, pp. 99–185, 15 pls., 6 text figs. 1910.—This well written and very interesting work should be studied by all stratigraphers and geologists because here we have worked out with care the present conditions of deposition and geologic work now going on in the Floridian region as a basis toward a proper interpretation of the Tertiary history of the peninsula. The author first describes the topography of the Floridian Plateau and then goes into considerable detail in regard to the marine bottom deposits forming in the bays and sounds behind the keys. Limestones are here being made by precipitation from the sea water as amorphous calcium carbonate and are apparently not of detrital origin. It is a soft ooze into which a rod can be forced down ten feet or more; in fact, the depth of this soft material has not been determined.

Vaughan then discusses the transporting agents (currents and winds) of the Florida coast and their effects. The smaller half of the work treats of the geologic history of the Floridian Plateau. The history is worked out in some detail and the book is abundantly illustrated by maps, one of which presents the geologic formations of the state. There are also many photogravures of vegetation, sea shores, and geological deposits. C. S.

12. *Recent Discoveries Bearing on the Antiquity of Man in Europe*; by GEORGE GRANT MACCURDY. Smithsonian Report for 1909, pages 531–583, pls. 1–18. 1910.—The author brings together here the accounts of the many wonderful discoveries that have been made in the past ten years bearing upon the

antiquity of man in Europe. It seems that the oldest undisputed flint implements of man go baek to the Upper Mioeene and the oldest bone, a jaw (*Homo heidelbergensis*), has been found near the base of the Quaternary. Man, as man, has lived, therefore, in western Europe at least throughout the entire Glaeial period, developing into *Homo primigenius*, a stocky robust type, of low stature, and with relatively short arms and legs mueh as in the Eskimo. In the Upper Quaternary, or at least 30,000 years ago, there eame into western Europe, probably from the East, a more intelleetual raee of men, the Aurignaeians, and it is these people who sculptured, engraved, and freseoed the walls of the eaverns and their tools and ornaments. Their descendants, the Magdalenians, introdueed the rudiments of writing, and this seemingly was more than 10,000 years ago, if we may judge by the time standards accepted by geologists for the duration of time sinee the last glaeial elimate. The negroid people also passed into western Europe, possibly by way of Gibraltar, probably soon after the arrival of the Aurignacians. It is also beeoming more and more certain that man did not originate out of any of the existing ape stoeks, but rather that the human stock is as old as any of the tailless primates. Aeeording to Professor Klaatseh, *Homo primigenius* is more elosely related to the gorilla of Afriea, while *Homo aurignacensis* has closer affinities with the chimpanzee of Asia. All of these stocks had their origin in the far distant past, certainly not less than one million years ago.

C. S.

13. *On the Fossil Faunas of St. Helen's Breccias;* by HENRY S. WILLIAMS. Trans. Royal Soe. Canada, III, pp. 205–246, pls. 1–4, 1910.—The Devonian faunas of St. Helen's island near Montreal have long perplexed students of fossils as to the exaet age of these fossil horizons when compared with similar formations in New York. Professor Adams of McGill University had quarried out from three isolated limestone masses underlying the agglomerates of the island about three-fourths of a ton of material whieh Williams has here subjected to a detailed study. The author, therefore, has had far greater advantages than any other paleontologist studying these early Devonian biotas.

The older fauna of about 30 species is of Helderbergian age and apparently of about Becraft time. Williams names it the *Gypidula pseudogaleata* fauna. The age is clearly seen in the following speeies: *Schizophoria multistriata*, *Stropheodonta planulata*, *Gypidula pseudogaleata*, *Camarotœchia ventricosa*, *Spirifer concinnus*, and *Meristella princeps*. The faunal relations are elearly with New York and nothing exaetly like it is known farther northeast in the Gaspé region.

The younger fauna is from another isolated limestone mass, and is the one furnishing mueh new information. Williams ealls it the *Spirifer arenosus* fauna and ascribes to it 25 speeies. The more striking forms are: 1 *Dalmanella subcarinata*, 2 *Eodevonaria hudsonicus gaspensis*, 3 *Chonetes striatissimus* (near *C. can-*

alensis), 4 *Rhynchonella eminens*, 5 *Eatonia peculiaris*, 6 *E.* cf. *whitfieldi*, 7 *Spirifer arenosus*, 8 *S. gaspensis*, 9 *S. montrealensis* n. sp. (look almost like genuine *S. granulosus*), 10 *S. cumberlandiæ*, 11 *S. pennatus helenæ*, 12 *Metaplasia pyxidata*, and 13 *Cyrtina rostrata*. To these must be added 14 *Chonostrophia montrealensis* described by Schuchert but not seen by Williams. In the light of our American Devonian assemblages we see here a very much mixed fauna. Numbers 1 and 4 are Helderbergian forms, while 9 and 11 are decided early Hamilton reminders. The remainder of the fauna suggests later Oriskanian. In the Oriskany of Cumberland, Md., the reviewer has also collected shells of the type of *S. montrealensis*, but these are by no means so near the Hamilton *S. granulosus* as seemingly are the St. Helen's specimens. Further, the reviewer, while collecting on the island in 1900, noted that the two species 9 and 11 occurred together, but he then saw no other forms in the "flat block of limestone" in the agglomerate. For this reason he held their age to be Onondaga. It was Mr. Ardley who directed him to these fossils and associations and Williams' *S. arenosus* fauna of 25 species has since been quarried out of this same block. The majority of the fauna is undoubtedly Oriskanian and yet the aspect is more recent than any fauna of this series in the Appalachian–New York area.

Williams clearly recognizes that the St. Helen's *Spirifer arenosus* fauna is unique and believes it to be somewhat younger than any Oriskanian fauna of New York but older than the Onondaga. Faunas of the same age as that of St. Helen's but of another basin, linking more directly with the European Coblenzian, he holds are those of Nictaux, Nova Scotia, York river, Gaspé, and Moose river, Maine, in which " are seen traces of the . . . Hamiltonian magnafauna." He further holds that the Onondaga fauna came in along the western side of the Cincinnati axis, finally spreading to the St. Lawrence valley and there met and mixed with the northern Atlantic fauna " on the American border at the time of the departure of the Oriskanian element rather than at the opening of the Hamilton epoch. This interpretation is in harmony with the mingling of these same two magnafaunas [lower Devonian and Hamilton] in the lower Devonian (Coblenzian) of Europe."

The reviewer agrees with Williams that the Oriskanian faunas of the maritime province of eastern Canada are considerably Coblenzian in faunal aspect and that the Hamilton aspect appears earlier in this European assemblage, but he still believes that the York river fauna near the base of the Gaspé sandstone as described by Clarke (1908) is considerably younger than the *Spirifer arenosus* fauna, for the reason that the latter assemblage at Gaspé occurs at a very much lower horizon, in fact, at the base of the Grande Grève limestone. C. SCHUCHERT.

14. *Palæontologia Universalis*, ser. III, fasc. II, 46 sheets, July 26, 1910.—In this new part of the Palæontologia Univer-

salis there are redescribed and well figured 20 Lamarckian species of mollusks and corals described by him between 1801–1819. The studies were made by Dollfus, Boussac, Pervinquière, Cossmann, Lemoine, and Germain. C. S.

15. *Eine Botanische Tropenreise, Indo-Malayische Vegetationsbilder und Reiseskizzen;* by Prof. Dr. G. HABERLANDT. Second edition. Pp. viii, 296; 12 plates and 48 text-figures. Leipzig, 1910 (Wilhelm Engelmann).—The first edition of Professor Haberlandt's book appeared in 1893 and soon became widely and favorably known on account of its graphic and satisfactory descriptions of various types of tropical vegetation. The work is based on the author's personal observations, most of which were made during a visit to the famous botanical garden at Buitenzorg in Java. Among the many interesting chapters those dealing with tropical trees, tropical leaves, vines, epiphytes, and mangroves should perhaps be especially mentioned, although several of the others treat subjects of equal importance. The twelve plates in the second edition are all new; nine are made from photographs, while the three others, in color, are reproduced from water-color sketches by the author. A. W. E.

16. *Plant Anatomy, from the Standpoint of the Development of the Tissues, and Handbook of Micro-technic;* by WILLIAM CHASE STEVENS, Professor of Botany in the University of Kansas. Second edition. Pp. xv, 379, with 152 text-figures. Philadelphia, 1910 (P. Blakiston's Son & Co.).—The first edition of this excellent work appeared in 1907, and was reviewed in this Journal for April, 1908 (xxv, 363). The most important new matter in the second edition is the chapter on reproduction, which includes discussions of the following topics: the reduction of chromosomes, the behavior of hybrids interpreted according to Mendel's Laws, the bearers of hereditary characters, and the theory of pangeneic exchange. A. W. E.

17. *A Text-Book of Botany and Pharmacognosy;* by HENRY KRAEMER, Ph.D., Professor of Botany and Pharmacognosy in the Philadelphia College of Pharmacy. Fourth edition. Pp. viii, 888, with 344 figures, mostly in the text. Philadelphia and London, 1910 (J. B. Lippincott Company, price $5.00 net).—The first edition of the present text-book appeared in 1902 and contained 384 pages; the second edition, of 1907, had already been enlarged to 840 pages; while the third edition, of 1908, numbered 850 pages. The rapid succession of new editions proves conclusively that there is a strong demand for a work of this character by students of pharmacognosy and that the book in question is well fitted to their needs. In the first part, entitled "Botany," the morphology and classification of plants are clearly treated, with special reference to medicinal plants. In the second part, "Pharmacognosy," detailed descriptions of important drugs are given, their minute structure being fully illustrated by figures. The third and fourth parts are much shorter than the others. The third deals with "Reagents and Microtechnic," and the fourth,

which is new to this edition, discusses "Micro-Analysis." The eighteen figures illustrating the fourth part are reproduced from microphotographs of crystals. A. W. E.

18. *Biology: general and medical;* by JOSEPH MCFARLAND, M.D. Pp. 440, with 160 illustrations. Philadelphia and London, 1910 (W. B. Saunders Company).—This book differs widely from most of the other elementary text-books in biology, which have recently appeared, in subordinating the morphological almost entirely to the physiological aspects of the subject. It is essentially a treatise on general physiology, with such descriptions of the anatomical structures as are absolutely necessary for the understanding of the processes concerned. For elementary courses in colleges and universities where large numbers of students elect biology as a general culture study, and where the laboratory work is necessarily confined mainly to the morphological side of the subject, the book forms an admirable supplement to the laboratory and lecture portions of the course.

The immediate adoption of this book by some of our largest universities shows the need that has been felt for a work of this kind. There are, however, certain defects which appear when the book is subjected to the test of the classroom. Numerous instances of statements that are misleading or actually erroneous are brought to light, and complaint is made that an unnecessarily formidable array of technical medical terms is introduced. The general excellence of the plan of treatment, however, more than compensates for such emendations as the experienced teacher is required to make in the classroom.

The properties of living matter, cells, and their arrangement in different groups of organisms, reproduction, ontogenesis, conformity to type, divergence, structural and blood relationships, parasitism, infection and immunity, mutilation and regeneration, grafting, senescence, decadence and death, indicate the subjects of the principal chapters into which the book is divided.

W. R. C.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Carnegie Institution of Washington. Year-Book, No. 9.* 1910. Pp. xvi, 258, 5 plates. Washington, January, 1911.—Especial interest is connected with the appearance of the ninth Year-Book of the Carnegie Institution because of the recent gift by Mr. Carnegie of an additional $10,000,000 to the Institution, making its total fund equal to $25,000,000. This addition to its resources is particularly opportune at this time, since in the present volume Dr. Woodward calls attention to the serious effect of increase of prices as limiting the future income available for promoting research. The Institution was organized in 1902 and since that time the magnitude and importance of the work it has accomplished are truly remarkable. The total amount of money

expended up to date is $4,590,000, of which a little more than one-half has been applied directly to the prosecution of research, and about one-third is represented in land, buildings, and other permanent forms; about 8 per cent has been used for expenses of administration and somewhat less for publications. Twelve hundred individuals have contributed towards the researches and publications undertaken by it. The volumes already published are 167 in number, and aggregate more than 40,000 printed pages. Twenty-five additional volumes are now in press: further, some 1200 shorter papers have been contributed to current scientific periodicals by those working under the Carnegie foundation.

Of particular importance in the work of the past year is the occupation of the new administration building, which was dedicated in December, 1909, and has proved in all respects a thoroughly satisfactory and dignified permanent home for the Institution. During 1910, also, the non-magnetic ship *Carnegie* completed its first voyage of 8,000 miles with important results, and a second cruise, planned to last three years, was begun on June 29th: at present the vessel is off the coast of Brazil. As is now generally known, there are ten departments, to the support of which the income of the Institution is chiefly devoted, the total sum appropriated towards them amounting to $450,000. A considerable number of minor grants have been made in addition, although these are few as compared with the situation earlier in the history of the Institution. For these last, the aggregate amount allotted was about $70,000. In the opening pages of the present volume, Dr. Woodward gives a very interesting résumé of the investigations of the present year, particularly in connection with the ten lines of work already alluded to. This same subject is discussed in detail on pages 53–204 by the Directors of the different departments. It is impossible here to go into details in regard to these special lines. Some of the most interesting concern the work of the Geophysical Laboratory, under Dr. A. L. Day; the Department of Marine Biology at Tortugas, Florida, under Dr. A. G. Mayer; and the Solar Observatory at Mt. Wilson, California, now represented by W. S. Adams, Acting Director during the absence of Professor Hale. Dr. Bauer also gives a summary of the work accomplished in terrestrial magnetism, with a chart showing the projected cruise of the "Carnegie" alluded to above. The volume closes with brief statements, thirty-four in number, as to the results accomplished in the various lines of investigation represented by the minor grants.

2. *Publications of the Carnegie Institution.*—Recent publications of the Carnegie Institution are noted in the following list (continued from vol. xxx, 295):

No. 74. The Vulgate Version of the Arthurian Romances, edited from manuscripts in the British Museum; by H. Oskar Sommer. Volume III. Le Livre de Lancelot del Lac. Part I. Pp. 430.

No. 88. Dynamic Meteorology and Hydrography; by V. Bjerknes and different collaborators. Part I, Statics by V. Bjerknes and J. W. Sandström. Pp. 146 and appendixes, 31 figures.

No. 119. Determination of the Solar Parallax, from photographs of Eros made with the Crossley Reflector of the Lick Observatory, University of California; by Charles D. Perrine, Harold K. Palmer, Frederic C. Moore, Adelaide M. Hobe. Pp. 98. See p. 153.

No. 120. The Symmetric Function Tables of the Fifteenthic including an Historical Summary of Symmetric Functions as relating to Symmetric Function Tables; by Floyd Fiske Decker. Pp. 16, 5 large tables.

No. 127. Superheated Steam in Locomotive Service; by William F. M. Goss. Pp. 144, 1 plate, 108 figures.

No. 130. A Study of the Absorption Spectra of Solutions of Certain Salts of Potassium, Cobalt, Nickel, Copper, Chromium, Erbium, Proseodymium, Neodymium, and Uranium as affected by Chemical Agents and by Temperature; by Harry C. Jones and W. W. Strong. Pp. ix, 159, 98 plates.

No. 132. Department of Marine Biology, Alfred G. Mayer, Director. Papers from the Tortugas Laboratory. Volume III, pp. 1–152, 17 plates, 38 figures. Contains twelve papers by different authors.

No. 133. Department of Marine Biology, Alfred G. Mayer, Director. Papers from the Tortugas Laboratory. Volume IV, pp. 1–186, 43 plates, 17 figures. Contains three papers by Henry S. Pratt, Edwin Linton and T. W. Vaughan. Pp. 185.

No. 135. Researches upon the Atomic Weights of Cadmium, Manganese, Bromine, Lead, Arsenic, Iodine, Silver, Chromium, and Phosphorus; by Gregory Paul Baxter, in collaboration with M. A. Hines, H. L. Frevert, et al.

No. 136. Metabolism in Diabetes Mellitus; by Francis G. Benedict and Elliott P. Joslin. Pp. vi, 234.

No. 141. The Water Balance of Succulent Plants; by D. T. MacDougal and E. S. Spalding. Pp. iii, 77, 8 plates.

3. *Annual Report of the Board of Regents of the Smithsonian Institution*, showing the operations, expenditures and condition of the Institution for the year ending June 30, 1909. Pp. x, 751, 73 plates, 1 map. Washington, 1910.—The Annual Volume of the Smithsonian Institution for 1909 opens with the Report of the Secretary, Dr. Walcott, issued in advance about a year since, and at that time noticed in this Journal (vol. xxix, 196). It also contains, in the General Appendix (pp. 119–751), the usual series of well-selected papers devoted to a wide range of subjects, many of them republished from foreign journals. These papers are all more or less popular in method of presentation, so that they appeal to the intelligent public, which finds here a remarkable résumé of recent scientific progress not to be found in so convenient a form elsewhere. Among them may be mentioned one on Radio-telegraphy by J. A. Fleming; another by Marchis on

the production of Low Temperatures and Refrigeration; on the return of Halley's Comet, by W. W. Campbell; on the British Antarctic Expedition of 1909, by Lieut. Shackleton; on the Antiquity of Man in Europe, by G. G. MacCurdy; on Panama and its People, by Eleanor Y. Bell; on the Natural Resistance to Disease, by Simon Flexner.

The following are recent Bulletins issued by the Bureau of Ethnology of the Smithsonian Institution:

No. 30. Handbook of American Indians North of Mexico; edited by FREDERICK WEBB HODGE. In two parts. Part 2, N–Z. Pp. iv, 1221. See vol. xxiv, p. 91.

No. 37. Antiquities of Central and Southeastern Missouri, by GERARD FOWKE. (Report on Explorations made in 1906–07 under the auspices of the Archæological Institute of America.) Pp. vii, 116, 19 plates, 20 figures.

No. 45. Chippewa Music; by FRANCES DENSMORE. Pp. xix, 216, 12 plates, 8 figures.

No. 49. List of Publications of the Bureau of American Ethnology with Index to Authors and Titles. Pp. 32.

4. *Publications of the Allegheny Observatory of the University of Pittsburgh;* edited by FRANK SCHLESINGER.—The following have recently been issued:

Vol. I, No. 23. The Orbits of the Spectroscopic Components of ν Andromedæ; by FRANK C. JORDAN. Pp. 191–201. Also title page and contents of volume I.

Vol. II. No. 1. A Description of the Mellon Spectrograph; by FRANK SCHLESINGER. Pp. 1–12, two figs. No. 2. On the Relative Motions in 61 Cygni and similar Stars; by FRANK SCHLESINGER and DINSMORE ALTER. Pp. 13–16. No. 3. The Orbits of the Spectroscopic Components of ϵ Herculis; by ROBERT H. BAKER. Pp. 17–23. No. 4. The Orbit of I H. Cassiopeiæ; by ROBERT H. BAKER. Pp. 25–28. No. 5. The Orbit of 30 H. Ursæ Majoris; by ROBERT H. BAKER. No. 6. The Orbits of the Spectroscopic Components of 57 Cygni; by ROBERT H. BAKER. No. 7. Further Observations of θ Aquilæ; by ROBERT H. BAKER. No. 8. The Orbit of π Andromedæ; by FRANK C. JORDAN. No. 9. The Eclipsing Variable u Herculis; by FRANK SCHLESINGER and ROBERT H. BAKER. Pp. 51–62. No. 10. The Spectrum and Orbit of o Persei; by FRANK C. JORDAN. Pp. 63–71.

5. *Bref och Skrifvelser af och till Carl von Linné.* Part IV. Pp. iv, 365. Stockholm, 1910.—The fourth part of the correspondence of Linnæus (see vol. xxix, 200), published under the auspices of the Upsala University, contains a very interesting series of letters to and from Abraham Bäck, dating from 1741 to 1755.

6. *Seismological Society of America.*—The Seismological society, of which Prof. J. C. Branner is president, has decided to issue a Bulletin, the first number of which is about to be issued; it will be sent to all members. The dues of the society are $2.00 per year; life membership, $25.00.

7. *Das Electrokardiogramm des gesunden und Kranken Menschen;* von Prof. Dr. FREIDRICH KRAUS und Prof. Dr. GEORG

Nicolai. Pp. xxii, 322. Leipzig, 1910 (Veit & Co.).—This volume represents the first more elaborate attempt at a systematic presentation of the scientific basis and latest technic of the electrocardiographic method applied to the study of heart functions in animals and man. The authors have particularly emphasized the possibilities of the electrocardiogram as an aid in clinical diagnosis, and have furnished a review of the rapidly growing literature on the subject. Such pioneer work deserves commendatory mention and will assist many physiologists and clinicians in orienting themselves in the newer methods of research. L. B. M.

8. *Plane Trigonometry;* by Edward R. Robbins, Senior Mathematical Master in the William Penn Charter School. Pp. 166. New York, 1910 (The American Book Company).—The only valid excuse for an addition to the multitude of text-books in Trigonometry is that it be written by a teacher of Trigonometry in order to minimize his labor of teaching by giving to his pupils his own methods in print instead of by dictation. Mr. Robbins has in this way recorded the economies that he has secured by 15 years' experience. He seems to have systematized the work in elementary plane Trigonometry a little better than any of his predecessors, and thereby in so much diminished the labor of thinking for his pupils. W. B.

9. *Shop Problems in Mathematics;* by W. E. Breckenridge, S. F. Mersereau, and C. F. Moore. Pp. 280. Boston (Ginn & Co.).—This volume is designed for students in trade schools. It discusses materials and machines for both wood and metal work, and outlines construction work of various kinds. Mathematics, including trigonometry, is also reviewed with particular reference to usefulness in shop practice. A large number of problems drawn from practical work are given. D. A. K.

10. *Ostwald's Klassiker der Exakten Wissenschaften.* Leipzig, 1910 (Wilhelm Engelmann).—Recent volumes in this important series are the following: Nr. 176. Mikroskopische Untersuchungen uber die Übereinstimmung in der Struktur und dem Wachstume der Tiere und Pflanzen, von Th. Schwann. Herausgegeben von F. Hünseler. Pp. 242.

Nr. 177. Untersuchungen über Gegenstände der höheren Geodäsie; von Carl Friedrich Gauss. Herausgegeben von J. Frischauf. Pp, 111.

Nr. 178. Physikalisch-chemische Abhandlungen; M. W. Lomonossows, 1741–1752. Aus dem Lateinischen und Russischen mit Anmerkungen herausgegeben von B. N. Menschutkin und Max Speter. Pp. 61.

Obituary.

Sir Francis Galton, the veteran English explorer and contributor to many departments of science, died on January 17 at the age of seventy-nine years. His most important writings were those on Heredity, but his activities extended into a remarkable number of different fields involving the application of quantitative methods to science.

Dr. M. Wilhelm Meyer, the German astronomer, died two months since, at Meran, at the age of fifty-eight years.

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Art. XXIV.—*On the Ionization of Different Gases by the Alpha Particles from Polonium and the Relative Amounts of Energy Required to Produce an Ion*; by T. S. Taylor.

Introduction.

In previous papers,* the writer has shown that the air-equivalents† of metal foils decrease with the speed of the alpha particles entering the foils. For sheets of different metals of equal air-equivalents, the rates of decrease are approximately proportional to the square roots of the respective atomic weights. On the contrary, the air-equivalents of hydrogen sheets increase while the hydrogen-equivalents of air sheets decrease with the speed of the entering alpha particles, and at such a rate as to be in agreement with the square-root law observed for the decrease of the air-equivalents of the metal sheets.

A comparison of the Bragg ionization curves, obtained in atmospheres of air and hydrogen, when the pressure of the air was so reduced that the range of the alpha particles from polonium was the same in air as it was in hydrogen at atmospheric pressure, showed differences which are sufficient to account for the variations in the air-equivalents of the hydrogen sheets with the speed of the alpha particles. These differences between the Bragg ionization curves in air and hydrogen suggested that some such differences might be found between the ionization curves obtained in other gases, and it was for the purpose of making a detailed comparison of the ionization

* This Journal, vol. xxvi, pp. 169–179, Sept. 1908; ibid., vol. xxviii, pp. 357–372, Oct. 1909. Phil. Mag., vol. xviii, p. 604, Oct. 1909.

† By air-equivalent is meant the amount by which the range of the alpha particle is cut down by its passage through the foil.

curves obtained in different gases that the present experiments were begun.

Continuation of Experiments.

The apparatus used was the same as had been used in the previous experiments.* The sheet iron case, enclosing the apparatus proper, was replaced by a solid iron case which could be readily exhausted. Polonium was used as the source of rays and was placed in a brass cylinder of such dimensions that the rays emerging from the cylinder fell well within the limits of the ionization chamber for all available distances of the source of rays from the ionization chamber.

In the determination of the ionization curve in any gas, the vessel enclosing the apparatus was first evacuated and then the gas admitted very slowly till the pressure it exerted was such that the range of the alpha particles was exactly 11·1 centi-

Fig. 1.

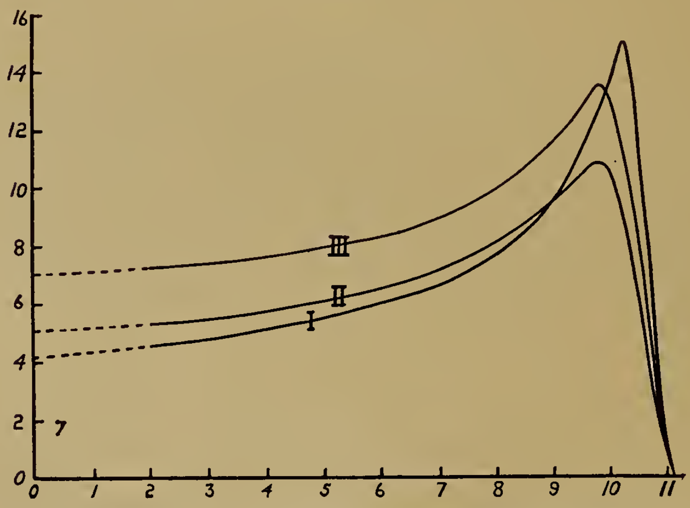


Fig. 1. The ordinates are the deflections in millimeters of the electrometer needle per second. The abscissas are the distances in centimeters of the polonium from the ionization chamber. Curves I, II, and III were obtained when the maximum range of the alpha particle was exactly 11·1 centimeters in hydrogen, air, and methyl iodide, respectively.

meters, which was the maximum range available with the apparatus. The Bragg ionization curve was then obtained in the usual manner by observing the deflection of the needle of the Dolezalek electrometer in scale divisions per second for

* Loc. cit.

various distances of the source of rays from the ionization chamber. In this manner, the Bragg ionization curves were obtained in the gases and vapors given in Table I. The curves

FIG. 2.

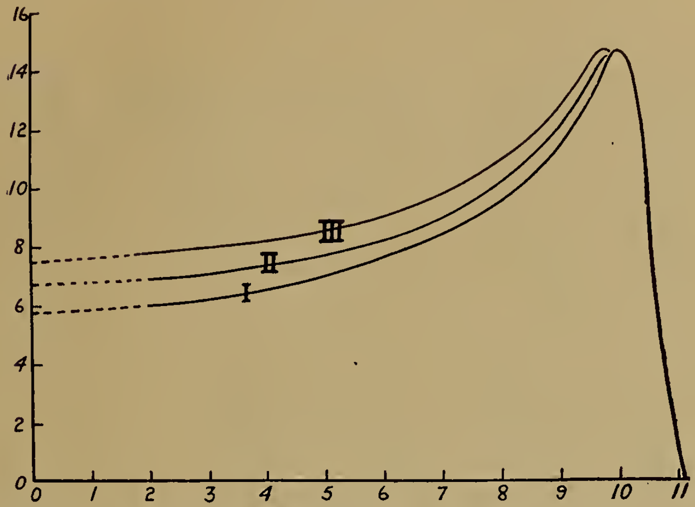


FIG. 2. The ordinates are the deflections in millimeters of the electrometer needle per second. The abscissas are the distances in centimeters of the polonium from the ionization chamber. Curves I, II, and III were obtained when the maximum range of the alpha particle was exactly 11·1 centimeters in methane, ethyl chloride, and carbon disulphide, respectively.

in figures 1 and 2 and the dotted ones in figure 3 represent the ionization curves obtained in the above manner in the gases as indicated below the figures, respectively. The dotted portion of each curve in figures 1 and 2 is assumed to be the form it would take were it possible to move the polonium entirely up to the ionization chamber. At any rate, such assumed portions of the curves can differ but little from the actual curves. It is to be noted, that the ionization curves shown in figures 1 and 2 are plotted differently from the regular Bragg ionization curve in that the values of ionization are taken as ordinates and distances of the source of rays from the chamber as abscissas, instead of *vice versa* as is usually done.

Although the curves in figures 1, 2, and 3 represent some differences from one another in regard to the relative amounts of ionization for corresponding distances of the source of rays from the ionization chamber, all of them are of the same general form. From a re-determination of the velocity of the alpha particle at different points in its path, and the assumption that the ionization produced at any point in the path of the particle is proportional to the energy consumed, Geiger* has shown that the ionization I at any point in the path is given by the relation

$$I = \frac{c}{(r-x)^{1/3}}$$

where c and r are constants and x is the distance from the source of rays. By comparing this theoretical ionization curve with the experimental curve obtained in hydrogen for a pencil of rays, Geiger found the two to agree very closely.

This theoretical curve has been compared with the experimental curves obtained in each of the gases and vapors given in Table I and a very close agreement between theoretical and experimental curves was found for each gas. To make this comparison, it was necessary to determine the constants r and c for each gas. For the value of r, Geiger used the average range of the alpha particles in the pencil of rays. Since the maximum range of the alpha particles in the cone of rays used in the present experiments was always 11·1 centimeters, the average range of the alpha particles in this cone of rays emerging from the cylinder containing the polonium was slightly less than 11·1 centimeters. Consequently 10·8 centimeters were taken as the value of the average range of the alpha particle, that is, 10·8 centimeters are supposed to represent the average distance the alpha particles traveled in each gas before losing their power of producing ions. In order to determine c for any one gas, the ionization (ordinate of the ionization curve figures 1, 2, and 3) and the corresponding distance x of the source of rays from the ionization chamber (abscissa of curve) were substituted in the equation

$$I = \frac{c}{(10{\cdot}8-x)^{1/3}}$$

and the equation solved for c. Separate values of c were thus obtained for various distances of the source of rays from the ionization chamber between $x = 0$ and 9·5 centimeters, and the mean value of these separate determinations found for each gas. The mean values of c as found in the above manner for all the gases and vapors used are recorded in column 2, Table I.

* Proc. Royal Society, Series A, vol. lxxxiii, No. A 565, p. 505.

FIG. 3.

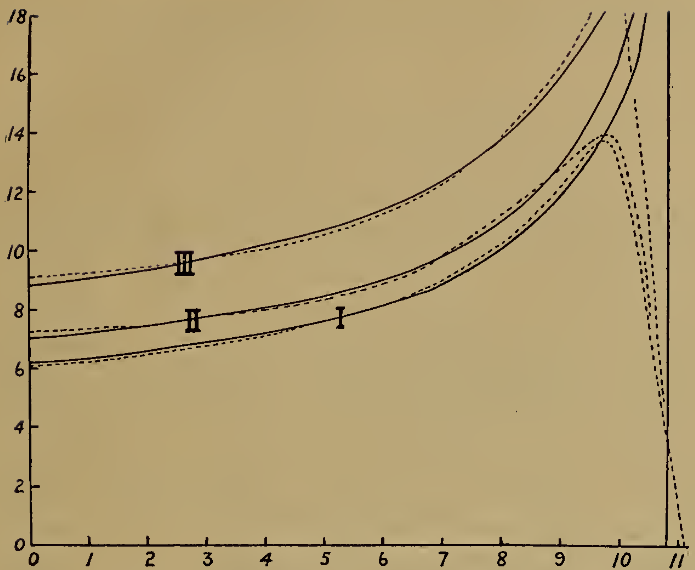


FIG. 3. The full line curves I, II, and III are the theoretical ionization curves for nitrogen, sulphur dioxide, and ether, respectively, as obtained by substituting the corresponding values of c given in column 2, Table I, in the equation

$$I = \frac{c}{(r-x)^{1/3}} \text{ where } r = 10{\cdot}8.$$

The dotted curves I, II, and III are the experimental ionization curves for nitrogen, sulphur dioxide, and ether, respectively, and are plotted similarly to the curves in figures 1 and 2.

The full line curves, I, II, and III in figure 3 represent the theoretical curves for nitrogen, sulphur dioxide, and ether, respectively, as obtained by using the values of c as recorded in column 2, Table I, for the respective gases. The dotted curves are the corresponding experimental curves and, as can be seen, agree very well with the theoretical curves. The agreement between the theoretical and the experimental curves for the other gases was equally as good as it was for those given in figure 3. In some cases the agreement was much closer. This agreement between theoretical and experimental curves confirms the assumption that the energy assumed is proportional to the ionization produced.

The ionization at any point of the path of the particle being given by the relation

$$I = \frac{c}{(r-x)^{1/3}},$$

the total area under this theoretical curve is a measure of the total ionization produced by the alpha particle in the gas. If A_t represents the area under the theoretical curve, then

$$A_t = \int_0^r I\,dx = \int_0^r \frac{c\,dx}{(r-x)^{1/3}}$$

$$= 3/2\, c(r)^{2/3} = 7{\cdot}33\, c$$

(r being equal to 10·8 centimeters). Hence c is 3/22 of the area under the theoretical curve when the average range of

TABLE I.

Gas or Vapor	c or area under theoretical curve divided by 7·33.	Area under experimental curve as measured with planimeter.	Ratio of area under experimental curve to c.	Ratio of the total ionization in the gas to that in air. Taylor.	Bragg.	Relative energy required to produce an ion.
Air	11·24	980	87	..	..	1·00
H_2	10·00	966	96	0·99	1·00	1·01
CH_3I	14·73	1301	88	1·33	1·33	0·75
CH_4	12·65	1156	91	1·18		0·85
C_2H_5Cl	14·05	1251	89	1·29	1·32	0·77
CS_2	15·60	1355	87	1·38	1·37	0·73
Air	14·64	1249	85	..	..	1·00
N_2	13·81	1206	87	0·96	0·96	1·04
CO_2	15·01	1262	84	1·01	1·08	0·99
O_2	16·72	1415	85	1·13	1·09	0·88
$C_4H_{10}O$	19·42	1702	88	1·36	1·33	0·74
Air	13·27	1182	89	..	..	1·00
SO_2	15·30	1223	80	1·03	..	0·97
HCl	17·70	1530	86	1·29	..	0·77
HBr	18·32	1527	83	1·29	..	0·77
Air	13·36	1190	89	..	..	1·00
HI	17·68	1535	87	1·29	..	0·77

the alpha particle is 10·8 centimeters in any gas whatever. The values of c recorded in column 2 of Table I are then 3/22 of the area under the theoretical ionization curves in the respective gases.

The areas under the ionization curves being proportional to the energies consumed in the production of ions in the respective gases, the value of c in any one gas depends upon the total ionization produced in the gas, and consequently upon the energy required to produce an ion in the gas. Then the ratio of the area under the experimental curve to c should be a constant. By dividing the areas under the experimental curves as measured with a planimeter and recorded in column 3, Table I, by the values of c for the corresponding gases, the values recorded in column 4 were obtained and, as can be seen, are approximately constant.

The areas under the ionization curves being the measures of the relative ionizations produced in the gases, the ratios of the total ionization produced in the gases to that produced in air were determined by finding the ratio under each curve to the area under the corresponding comparison air curve. After the determination of the ionization curve in each gas, the ionization curve was always obtained in air to be used as a basis of comparison. The ratios of the ionizations produced in the different gases to that produced in air are recorded in column 5 of Table I. Bragg,* by a less direct process, determined the ratio of the total ionizations in gases to that in air and his values are recorded in column 6. There is a fairly good agreement between the values as found by Bragg and those found by a more direct process of measurement of the area enclosed by the axes of references and the ionization curve for each gas.

Since the energy of the alpha particle is entirely consumed before it ceases to produce ions, the energy required to produce an ion in any given substance will vary inversely as the ratio of the total ionization in the substance to the total ionization in air if the energy required to produce an ion in air is always taken as the basis of comparison. The values of column 5 of the table are the ratios of the total ionizations produced in the gases as compared with the total ionization produced in air. Consequently the reciprocals of these ratios are the relative amounts of energy required to produce an ion in the substance as compared with the energy required to produce an ion in air. The values recorded in column 7 are these reciprocals of the values in column 5, and hence are the relative amounts of energy required to produce an ion in the gases as compared with that required to produce an ion in air. These values indicate a considerable variation of the energy required to produce an ion. The heavier and more complex molecules are apparently more readily ionized than the lighter and less complex ones. This is probably due to the electrons in the heavier and more complex molecules being in a less stable arrangement than they are in the lighter and less complex molecules and hence more readily drawn out.

In conclusion, I wish to express my thanks to Professor Bumstead for his valuable suggestions in connection with the work and for loaning me the apparatus. I am also indebted to Professor Boltwood for furnishing me the preparation of polonium.

* Bragg, Phil. Mag., vol. xiii, pp. 333–357, March, 1907.

Results.

1. The ionization curve obtained in various gases and vapors with polonium as the source of rays is of the general form

$$I=\frac{c}{(r-x)^{1/3}}$$

where I is the ionization; c is a constant for any one gas depending upon the total ionization produced, and consequently upon the energy required to produce an ion in the given gas; r is the average range of the alpha particles in the cone of rays; and x is the distance from the source of rays.

2. The agreement between the theoretical and the experimental curves confirms the assumption made in previous papers by the writer* and by Geiger,† that the ionization produced by the alpha particle is proportional to the energy consumed.

3. The values of the ratio of the total ionization produced by the alpha particle in different gases to the total ionization produced in air as found by Bragg have been confirmed by a more direct process.

4. The energy of the alpha particle consumed in the production of an ion depends upon the nature of the molecule ionized. It apparently requires less energy to produce an ion in the gases or vapors which have heavy or relatively complex molecules than it does in those gases of lighter or less complex molecules.

Laboratory of Physics, University of Illinois,
Urbana, Illinois, January 28, 1911.

* Loc cit. † Loc cit.

Art. XXV.—*On the Heat Generated by Radio-active Substances*; by William Duane.

Since the discovery of radio-activity questions relating to the source and the transformations of the energy involved in the processes have been considered of prime importance. Early in the history of the subject Curie and Laborde* discovered that radium generates heat continually, and also that the heat effect increases as the emanation accumulates. A little later Rutherford and Barnes† found that the emanation and the first few products of radium that form its induced activity produce their shares of heat, and more recently still Pegram and Webb‡ have succeeded in detecting a small heat effect in a large mass (about four kilograms) of thorium oxide.

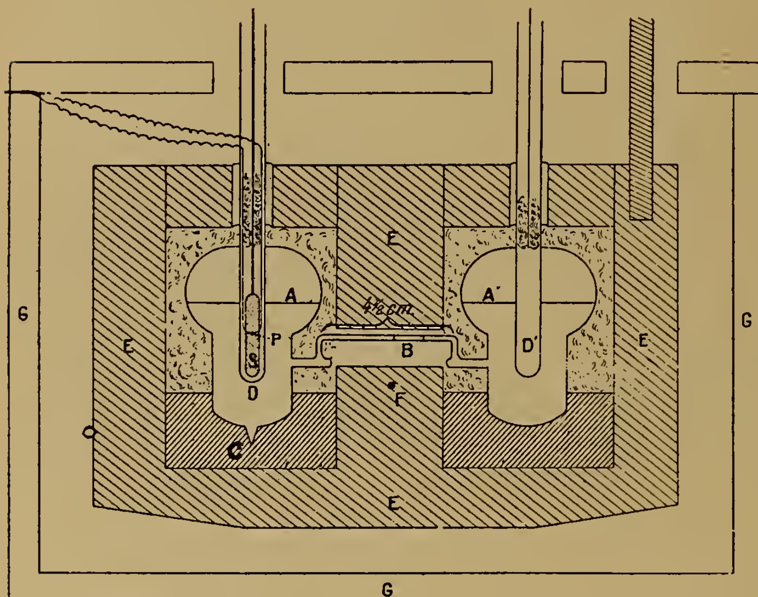
The ordinary methods of measuring heat (an ice calorimeter for instance) are sufficiently sensitive to detect and measure the heat generated by the quantities of radium, its emanation and its induced activity now at our disposal. I have made recently a number of experiments on the heat effects of other radio-active substances, and in these I have had to use special methods. At first I employed a modification of the differential air calorimeter devised by Rutherford and Barnes (l. c.), but this was not sensitive enough and I then constructed a new instrument which is considerably more sensitive than the differential air calorimeter. The method is based on the rapid increase in the vapor tension of a very volatile liquid when the temperature rises. A and A′ (fig. 1) represent two glass vessels, which are joined by the capillary tube B. The vessels are half filled with the volatile liquid, and almost all the air is pumped out by means of a water aspirator through the tube C, which is then sealed off. A small bubble formed out of the residual air left in the vessels is inserted in the tube B, and the displacement of this bubble is observed by means of a reading telescope or by projection with a lamp, lens and scale. I usually employ the latter method, and the displacement of the image on the scale is about eight times that of the bubble in the tube.

It is not difficult to place a bubble of any desired length in the tube B. It is sufficient to turn the apparatus upside down, and let the liquid run out of the tube. Then on replacing the apparatus right side up one finds the tube more or less completely filled with air. The bubble is

* Comptes rendus, cxxxvi, p. 673, 1903.
† Nature, Oct. 29, 1903; Phil. Mag., Feb., 1904.
‡ Science, 1904; Le Radium, 1908.

usually much too long, and to reduce its length all that is necessary is to tilt the apparatus up a little so as to cause a current of the liquid to pass through the tube. This current pushes the bubble down into the portion of tube below and at the side, which is larger than the capillary portion. The bubble remains in this portion of the tube, and the current of the liquid passing it carries along the air little by little, thus reducing the bubble's volume. On repeating this process,

Fig. 1.



causing the current to flow first in one direction and then in the other, one can reduce the bubble to any desired length.

After the bubble has been replaced in the tube, and the apparatus has been prepared for the experiment, the bubble remains in the horizontal part of the tube. It never descends into the large portion, no matter how much the temperature of the room may vary: but it slowly disappears. The air in the bubble dissolves in the liquid more or less rapidly according to the nature of the liquid, the pressure of the air and the dimensions of the apparatus. In my experiments it is necessary to renew the bubble once in two or three weeks: and this is a process requiring about five minutes time.

The form and dimensions of the capillary tube B have been carefully studied. The length of the horizontal part is $4\frac{1}{2}^{cm}$

and the internal diameter is a little more than $\cdot 5^{mm}$. The internal diameter of the two large parts is about 3^{mm}, and the vertical parts joining the horizontal with the larger parts should not have a larger diameter than the horizontal capillary part. It is easier to control the movement of the bubble, while placing it in the tube and reducing its size, if the capillary tube is not joined to the ends of the larger parts, but to the tops as indicated in the figure.

The volume of each vessel is about 50^{cm^3}.

The interior of the vessels and of the tube must be cleaned most carefully. The least dirt or grease stops the bubble, and in the experiments it is well to choose the part of the tube where the bubble moves most freely.

If a source generating heat is introduced into the tube D, the vapor tension is increased and the liquid pushes the bubble toward the vessel A′. The instrument is very sensitive. In my experiment I found that $1\cdot 5 \times 10^{-4}$ gram-calorie of heat displaced the image of the bubble 1^{mm} on the scale. This sensitiveness is due to the rapid increase of the vapor tension with the temperature. Among the liquids I have tried, ether seems to be the best. Ether cleans and wets the surface of the glass well, it has very little viscosity and its vapor tension increases rapidly with the temperature, about 17^{mm} of mercury per degree centigrade at ordinary temperatures. Ethel chloride works well also but is much less easily manipulated.

The sensitiveness of the instrument varies a great deal with the quantity of air in the vessels. If there is very little air the displacement of the liquid does not change the pressure of the gas much (saturated vapor tensions depending only on the temperature), and an increase of pressure in A due to a slight production of heat is opposed only by a change of level of the liquid in A and A′. As ether is a light liquid, this change of level opposes only a slight force to the displacement of the bubble. For great sensitiveness, therefore, one must remove almost all the air from the vessels, leaving only enough to form the bubble. The sensitiveness depends also upon the ratio of the cross-section of the capillary tube to the surface of the liquid in the vessels. A decrease in the cross-section increases the sensitiveness. I have found, however, that (if the liquid is ether) a tube of less than $\cdot 5^{mm}$ internal diameter does not work well on account of the capillary forces.

Further, the displacement of the image of the bubble is increased by the lens (or reading telescope). It is not desirable, however, to multiply the displacement more than eight or ten times, as the loss in sharpness of image counterbalances the advantage of increased displacement.

In actual practice the protection of the instrument against outside thermal disturbances is just as important as great sensitiveness. In my earlier experiments I imbedded the two vessels in a block, E (fig. 1), of lead (weighing 25 kilograms). The vessels were held in place by a layer of paraffine, which filled the space between them and the lead at the bottom. At the top this space was filled with cotton wool. Two metal rods, F (normal to the plane of the figure) support the block of lead inside a brass box, G. These rods serve as axles about which the lead can be turned, and thus the bubble of air shifted to any desired position in the capillary tube. The box G was completely enveloped in cotton wool contained in a second box of zinc (not represented in the figure). This system of good conducting metal screens separated by spaces filled with non-conducting material furnished excellent protection against thermal disturbances, but was not sufficient where the greatest sensitiveness was required. The whole apparatus, therefore, was placed in an electrical thermostat similar to the one described some years ago in this Journal.*

In my later experiments I have replaced the cotton wool with eider down, and I have added two large blocks of lead on top of the box G. These blocks equalize the variations of temperature coming from above. They are placed one beside the other, leaving just enough space between them for the tubes by which the substances to be examined are lowered into the calorimeter. With these modifications I have found it unnecessary to set the thermostat going, except on those days when the temperature of the room undergoes wide fluctuations.

Very often the heat due to the radio-active processes is produced in relatively large masses of matter. In these cases it is necessary to leave the substance to be examined for a long time in the upper part of the tube by which it enters the calorimeter, in order to be sure that its temperature is as nearly equal to that of the calorimeter as possible. This part of the tube should lie between the two large blocks of lead, and should be of metal to facilitate the equalization of temperatures.

If the generation of heat by the source is relatively large, an appreciable quantity of it may be conducted down the column of air into the calorimeter. In order to avoid this a small quantity of eider down fastened to the end of a very fine glass rod may be inserted into the tube just above the calorimeter. In making an experiment the eider down is removed, the substance to be examined lowered into the calorimeter and the eider down quickly replaced.

Any one of several methods may be used in measuring the heat generated by the source. On lowering the source into the calorimeter one can wait until a sort of thermal equilib-

* Duane and Lory, this Journal, 1900.

rium is reached, when the heat conducted away from the calorimeter equals that given it per second by the source, and observe the maximum displacement of the bubble of air. This method works well provided the instrument is not arranged for very great sensitiveness.

If, however, the apparatus is very sensitive it is better to take the velocity of the bubble as a measure of the heat generated per second. Although the instrument is well protected against thermal disturbances from the outside, yet the bubble does not stay in the same place. The zero of the instrument is not fixed. Nevertheless, if the apparatus has remained undisturbed for a long time, and the temperature throughout has become as nearly equalized as possible, the natural drift of the bubble is slow and regular, and the change in its velocity due to the heat from the source, when it is lowered into the calorimeter, can be measured with considerable precision.

A third method is to compensate the effect of the heat generated in the tube D by generating a known quantity of heat in the corresponding tube D′ (figure 1).

The best method, however, is to compensate the heat effect by absorbing the heat in the tube D itself as fast as it is generated. This can be done by means of a current of electricity flowing across the junction of two metals. Peltier discovered that if the current passes in one direction heat is generated, and if in the opposite direction heat is absorbed at the junction.

In my earlier experiments I inserted a thermo-couple P of iron and nickel wires into the tube D, and I determined the current that absorbed the heat as fast as it was generated, by varying the strength of the current until the velocity of the bubble was the same as its natural drift. In the later experiments I have replaced the simple thermo-couple by a metal tube. The walls of the tube are 1^{mm} thick, and its external diameter is just enough less than the diameter of the tube D to allow of its being inserted easily into the latter. The length of the metal tube is about 4^{cm}, so that the entire tube lies inside the calorimeter. Half of the tube is of iron and the other half of nickel, the two surfaces between the two metals being vertical and parallel to the axis of the tube. An iron wire is soldered to the outer edge of the iron half of the tube and a nickel wire to that of the nickel half, so that a current of electricity descending by the iron wire into the iron half of the tube can pass across the joints into the nickel half and ascend by the nickel wire. With this arrangement, when a source of heat is lowered into the middle of the iron-nickel tube, it is surrounded by a good conductor of heat, and the distribution and compensation of the heat takes place easily and quickly. Thus the thermal equilibrium of the apparatus is not disturbed much by the heat generated by the source.

This method is capable of considerable precision and can be used, without changing the apparatus, to measure heat effects varying from ·001 gram-calorie to 2 gram-calories per hour. Larger heat effects could be measured by increasing the thickness of the iron-nickel tube and iron and nickel wires so as to decrease their electrical resistance and the heat generated in them according to Joule's law.

The iron-nickel tube has been carefully standardized by inserting a small coil of manganine wire of known resistance into the tube, by heating this with a known electric current, and by determining the current in the tube that would exactly absorb the heat produced.

The electric currents were produced by small storage batteries, and their intensities were varied by changing the resistances in plug resistance boxes contained in the circuits. The resistances in these boxes, as well as the other resistances in the circuits, were carefully measured by a standard Wheatstone's bridge. The electric currents were measured by comparing the electromotive forces of the storage cells with that of a standard Weston cell by the potentiometer method, and by dividing these electromotive forces by the total resistance in the circuits.

The following table contains the data obtained in standardizing the iron-nickel tube. The resistance of the small coil inserted into the calorimeter was 9·20 ohms, and that of the lead wires attached to it was negligible. The electromotive force of the standard Weston cell was 1,018 volts, and that of the two cells forming the storage battery 4,153 volts.

Table 1.

Total resistance in heating circuit. Ohms	Heat produced in heating circuit calories per hour	Current in iron-nickel tube. Ampere		Heat absorbed per hour per ampere
		Observed	Corrected	
480	·593	·0716	·0716	8 29
550	·450	·0540	·0542	8·30
650	·324	·0392	·0393	8·25
910	·165	·0200	·0197	8·37

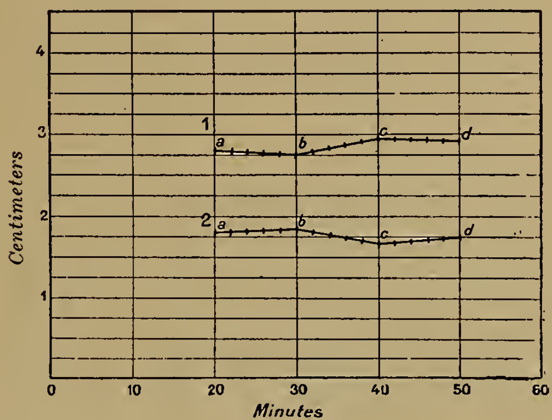
The compensations were not always exact, and a small correction was made in the values of the current in the iron-nickel tube. This correction was determined by observing the velocity of the bubble of air.

The heat effect in the iron-nickel tube is due to two causes. Firstly, the heat generated or absorbed at the junctions of the metals according to the direction of the current (Peltier effect), and, secondly, the heat generated according to Joule's law, which is proportional to the square of the current and to the resistance. The fifth column in the table contains the heat absorbed per hour and per ampere by the tube, and it appears that this quantity is independent of the current in the tube. This means that the absorption of heat is proportional to the intensity of the cooling current, i. e., the resistance of the tube is so small that the heat generated according to Joule's law is inappreciable, if the cooling is no larger than ·6 calorie per hour.

The mean value of the heat absorbed (or generated) per hour and per ampere in the iron-nickel tube is 8·3 gram-calories. I found 8·2 calories for the couple used in the earlier experiments.

It is interesting to note that the electromotive force in the

Fig. 2.



surface between the iron and the nickel must be about ·00055 volt to produce this effect.

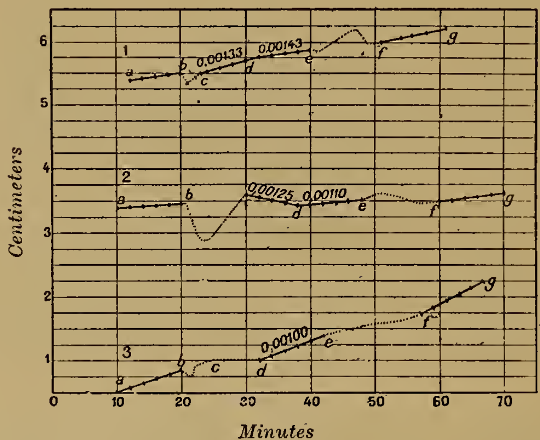
In order to determine the sensitiveness of the instrument I sent a very small current through the iron-nickel tube, and observed the change in the velocity of the bubble due to the heat absorbed or generated. The curves in figure 2 represent the displacements of the image of the bubble. The lines *ab* and *cd* represent the bubble's natural drift. The abscissas of the points *b* are the instants at which the electric current commenced to flow through the tube, and the abscissas of the points *e* are those at which the current was broken. For the first curve the direction of the current was such as to generate heat, and for the second to absorb it. It appears that the displacement of the bubble due to the current was about the same in the two cases but in opposite directions. This confirms Peltier's law, and indicates that the Joule effect is negligible.

The strength of the electric current was ·00019 ampere, and the heat generated or absorbed ·0016 calorie per hour. In ten minutes ·00027 calorie was generated or absorbed and this quantity of heat displaced the image of the bubble about 1·6^{mm}. It follows that one millimeter displacement of the image corresponds with ·00017 calorie of heat absorbed or generated.

In some other experiments I have found that the displacement of the bubble is proportional to the quantity of heat absorbed or generated, *provided that* the absorption or generation is not too rapid.

These results are used in estimating the small correction that must be applied, if the value of the current that exactly absorbs the heat generated by a source has been determined only approximately.

Fig. 3.



I have measured the heat generated by radiothorium and by polonium. These experiments were described in two notes presented to the Paris Academy of Sciences on June 1 and June 21, 1909.

Since the first experiments I have measured the heat generated by the polonium several times to see if the heat effect decreased with the time according to the law of decay of polonium. Half a given quantity of polonium disappears in about 142 days.

The curves in figure 3 represent the displacement of the bubble in these experiments, the dates being for curve 1 the 4th of May; for curve 2 the 4th of June, and for curve 3 the 25th of June. In each case the lines *ab* and *fg* represent the natural drift of the bubble. The abscissas of the points *b* are the instants at which the polonium was lowered into the calorimeter, and the abscissas of the points *f* are the instants at which the polonium was raised again. The numbers written near the lines *cd* and *de* are the electric currents in amperes which were flowing through the iron-nickel thermo-couple during the corresponding intervals of time.

Between the points *b* and *e* I was searching for the proper value of the current to counterbalance the heat effect, and between the points *e* and *f* I was reducing the current to zero. The last experiment was not as good as the others, because the natural drift of the bubble was large and changed a little during the experiment.

I compared the ionization due to the polonium when spread out in a thin layer on a disk of platinum (*b e*) with that due to a thin layer of radium. The results of the experiments appear in Table 2.

TABLE 2.

Date of experiment 1909	Current that compensated heat effect. Ampere	Heat produced calorie per hour	Ionization current due to polonium	Weight of $RaBr^{-2}$ that has same activity as polonium g.	Heat effect of this quantity of radium calorie per hour
May 4	·00143	·012	$1{\cdot}3 \times 10^{-7}$	·75	·0110
June 4	·00110	·009	$1{\cdot}19 + 10^{-7}$	·66	·0095
June 25	·00100	·008	$\cdot 99 \times 10^{-7}$	·57	·0084

It is evident that the generation of heat and the ionization current due to the polonium decrease with the time. The ionization current decreases at a rate indicating decay to half value in 136 days, which is very close to the value previously found by other experimenters. The heat effect decays a trifle faster than this, but the differences are not greater than one would expect considering the magnitude of the quantities of heat evolved. It follows from this that the heat effect was certainly due to the polonium.

On account of the difficulty of obtaining saturation in measuring the ionization of the radium and of the polonium, the method of comparing the activities of the two substances must be regarded as approximate only. Remembering this, it appears that the heat generated by the polonium is very close to that generated by the quantity of radium that would produce the same ionization as the polonium.

I have made a number of experiments on phosphorescent salts to see if they generate heat when in the phosphorescent state. Every time I examined such a salt one or two hours after it had been withdrawn from the light of the sun (or of an ultra-violet ray arc lamp), I found a small but measurable generation of heat. Twenty-four hours later not the slightest effect could be detected in the majority of cases, but a few times I observed a small generation of heat and on withdrawing the salt from the calorimeter found that the phosphorescent light had disappeared. It is impossible to affirm, therefore, that the heat effect is directly related to the emission of *visible* phosphorescent light. It may be due to the emission of visible and invisible rays together, or it may be caused by some reaction of a secondary nature.

These researches, however, have suggested to me the following question: if a quantity of radium is mixed with a phosphorescent salt, causing it to phosphoresce brilliantly, does the mixture generate the same quantity of heat as the radium would generate alone? There appear to be three possibilities: (*a*) the energy of the rays is absorbed (at least in part) in producing chemical reactions in the phosphorescent salt. In this case the heat effect of the mixture should be less than that of the radium alone, at least at first. (*b*) the radium rays acting on the atoms and molecules of the salt liberate a part of their chemical or subatomic energy. In this case the heat produced by the mixture should be larger than that produced by the radium alone. (*c*) the energy of the radium rays is rapidly transformed (in part) into the energy of the phosphorescent light without producing other reactions, and in this case, if all the light is absorbed in the vessel containing the mixture, the heat produced should be the same as that due to the radium alone.

In order to investigate this question I made the following experiments. On December 3d, 1909, a certain quantity of a salt containing finely pulverized radium chloride and barium chloride was divided into two parts. One part, A, weighed ·0314 gram and was sealed into a small glass tube. The other part, B, weighing ·0206 gram, was thoroughly mixed with ·267 gram of phosphorescent zinc sulphide, and then sealed in a second glass tube similar to the first.

Several times during the five weeks following the sealing of the tubes I measured the heat effects of each of them, and I also compared the intensity of the γ-radiation emitted by them with that due to a standard tube containing 26·5 grams of radium chloride. The following table (3) contains the results of these experiments:

TABLE 3.

Date of experiment	Quantity of $RaCl^{-2}$ that produces the same γ-rays		Production of heat calories per hour		Ratio $\frac{A}{B}$
	A	B	A	B	
December 7	1·66	1·07	----	----	1·55
December 7	----	----	·152	·098	1·55
December 21	2·37	1·57	----	----	1·51
December 21	----	----	·199	·129	1·54
January 5	2·39	1·56	----	----	1·53
January 6	----	----	·201	·127	1·58

The γ-radiation and the generation of heat increased between the 7th and the 21st of December, but after that no increase was perceptible. This was due to the accumulation of the emanation and the induced activity, which after three weeks attained approximately their saturation values.

The sixth column contains the ratios between the tubes A and B. It appears that these ratios are the same no matter what the date of the experiment was and no matter whether the γ-rays or the heat effect was measured. It follows that the presence of the phosphorescent salt does not appreciably change the rate of generation of heat by the radium.

The following facts may be noticed in passing: The phosphorescence of the mixture has become less intense than at first but is still brilliant. The light has also changed its color, becoming more orange.

In order to investigate the heat effect in the case where the phosphorescence is produced by the β and γ rays in willemite and in platinum-barium cyanide, I arranged the following experiment: A long, fine tube is inserted into tube B of the calorimeter and around the end of this tube is packed the phosphorescent salt. A very small glass capsule hermetically sealed containing radium can be lowered down the fine tube to the center of the salt. The walls of the tube and capsule are so thin that under these conditions the salt phosphoresces brilliantly.

I compared twice the γ-rays from the capsule with those from the standard and found that the quantity of radium in the capsule corresponded with 1·91 and 1·92 mg. of $RaCl_2$.

The heat effects observed on lowering the radium to the center of the phosphorescent salt were the following:

TABLE 4.

Salt used	Heat calorie per hour
·67 gr Platinum-barium cyanide	·170
1·19 gr. Willemite	·172
No phosphorescent salt	·171
No phosphorescent salt	·169

It is evident that the generation of heat is the same whether the phosphorescent salt is present or not. It follows from these two series of experiments that there is no appreciable absorption of energy in producing chemical reactions, and that the rays do not liberate an appreciable amount of chemical subatomic energy.

These results are interesting from the point of view of the amount of energy necessary to effect the organs of sight.

In the first series of experiments the phosphorescence was produced for the most part by the a-rays of the radium. We know that each a-particle that strikes the phosphorescent zinc sulphide produces enough light to affect the eye, and it follows from the experiments described above that the energy of this light is no larger than the energy of the a-particle. The smallest velocity of an a-particle that has been measured and at the same time detected by its scintillation is $5 \times 10^8 \frac{\text{cm.}}{\text{sec.}}$, and the kinetic energy of the a-particle at this velocity is 8×10^{-7} erg. This energy is about that required to raise $\frac{1}{100}$ of a millegram $\frac{1}{1000}$ of a millimeter. The energy necessary to produce the sensation of sight is less than the above quantity, since only a part of the total light energy enters the eye, and since probably the whole energy of the a-particle is not transformed into luminous energy.

The heat generated by one gram of pure radium can be calculated from the data of Table 3. It is for tube A 110 and for tube B 108 calories per hour. The difference between these two numbers is not greater than the errors of experiment.

The heat effect of one gram of radium calculated from the data of Table 4 is 117 calories per hour, a value considerably larger than the preceding values. This difference cannot be explained by errors of experiment. It is probably due to the fact that the radium employed in the second series of experiments is several years older than that employed in the first series, and contains, therefore, more of the disintegration products of the radium, especially polonium, which generate heat.

I have made a number of attempts to measure the heat produced by the rays from radium at a distance from their source. In the first experiments a thermopile, a bolometer, and a radiometer were tried, but none of these instruments gave satisfactory results. A modified form of differential gas thermometer gave positive indications of a heating effect, but the only instrument that proved satisfactory was the differential calorimeter described in the present paper. I hope shortly to publish some details of these experiments, but will state here simply that the problem is somewhat different from that of measuring the energy of ordinary radiations (at least as far as the penetrating radium rays is concerned), because a relatively large amount of matter is required to stop these penetrating rays, and the heat is generated throughout the mass of this matter.

Art. XXVI.—*Contributions to the Geology of New Hampshire, IV. Geology of Tripyramid Mountain;* by L. V. Pirsson and Wm. North Rice.*

Introductory.—Tripyramid Mountain is in the southern part of the White Mountains in New Hampshire. The point formed by the intersection of 44° N. and 71° 30′ W. is about two miles northwest of its northwest lower slope. It is entirely within the township of Waterville and a little east of its center. Surrounded by other mountains, Osceola, Kancamagus, Passaconaway, Whiteface, Sandwich Dome and Tecumseh, peaks which rise 3–6 miles distant, it is much concealed, and there are not many places where it can be observed in its full proportions from below. The retired character of its situation is much enhanced by the wild and heavily wooded nature of the region in which it stands, the only habitations in the upper valley of Mad River, which drains the township, being a summer resort hotel and a few scattered farm houses. The eastern slopes of the mountain are drained by headwater branches of Swift River, whose upper basin is a similarly wild and heavily forested region. Consequently its summit is not easily accessible and is little visited by tourists, especially as the view is largely circumscribed by the neighboring peaks and obscured by the thick growth of spruce scrub covering it. The best point to reach it from is the hotel at Waterville, which is 12 miles from the railway at Campton. A walk of about four miles, partly on trails through the forest and partly a scramble up rough and overgrown mountain brook beds, brings one to the lower slopes and the slides described beyond.

Topography.—Tripyramid Mountain is a roughly oval mass which rises about 2000 feet above the floors of the valleys about it. It is crested by three peaks with saddles between, called the North, Mid, and South Pyramids, to which it owes its name. Its appearance from the west is seen in the accompanying view, which we owe to the kindness of Mr. A. L. Goodrich. It was taken looking across the meadows above the old lumber dam at a place on Slide Brook called Swazeytown, below the junction with it of Cascade Brook.

On the north the mountain is connected with the peaks of Kancamagus by a high ridge with an intervening point upon

*Some years since one of us (L. V. P.) went to Waterville, N. H., to see the occurrence of the "ossipite" mentioned in this paper and to collect material. While engaged in this he found W. N. R. had also studied the Tripyramid rocks in the field. We joined forces and the present paper is the result. It is proposed to follow this with one dealing with the petrology of the rocks.

it, sometimes called Fourth Pyramid. On the south it descends to a bench, or roughly level area, known as Flat Mountain, whose elevation is about 2500 feet above sea level and which in turn again descends into the valley of Cold River. North Pyramid is about 4200 feet above the sea, the other pyramids are a little lower. The mass, as thus defined, is over two miles long, by about one and a half broad; the

Fig. 1.

Fig. 1. View of Tripyramid Mountain.

Looking east from above the Swazeytown Dam. The North Slide and Ravine of Avalanches are seen to the left, the South Slide on the right.

distance between the North and South Pyramids about a mile along the crest. The details of the topography are shown on the accompanying map, which has been compiled from various sources, the approximate expression of the topography of the older map of the Hitchcock Geological State Survey being corrected in details by later maps of parts of the area made by the Yale School of Forestry under the direction of Mr. Henry Gannett and Prof. H. H. Chapman, by Mr. C. W. Blood, and one of trails and stream courses by Mr. A. L. Goodrich, and to these gentlemen we desire to express our indebtedness for the use of this material. The western two-thirds of the map has been made chiefly from these sources, the eastern third is from the older state map. We have added a few corrections of our own.

Nearly everywhere the mountain, and also for the most part the surrounding area, are covered with a dense forest growth. On the slopes of the mountain and on its top this is composed of a thicket of small spruce trees which rise through a floor mat composed of intermingled dead and fallen tree trunks, more or less decayed, accumulations of spruce needles, shrubs and moss, into which one often sinks to the waist, and through which progress is extremely difficult. On the lower slopes the kinds of vegetation are somewhat different but the character of the thicket remains the same and the mantle is often swampy in addition. Were it not for the slides and the channels of the streams running from them, the underlying rocks, except on the summit, would be completely concealed by this vegetable growth and deposit, which on a rainy day, to one immersed in it, calls to mind Darwin's description of Terra del Fuego.

The Slides.—The most interesting features of the mountain are what are locally known as the "slides." These are two tremendous landslides, or avalanches, which have occurred, one on its north, the other on its south slope. The North Slide has left a bare face of underlying rock extending from the narrow Ravine of Avalanches, which separates the mountain from the next peak to the north, upward for half a mile along the slope and with over a thousand feet of elevation, with an average angle to the horizontal of 30°. Starting at a point not far below the summit, it gradually widens until at its base nearly the whole north face of the mountain, up into the head of the Ravine of Avalanches, is exposed. The naked rock surface left by this, which is about as steep and smooth as one can comfortably climb upon, is interrupted here and there by piles and trains of rock débris and lines of small trees and shrubs growing in crevices. The most conspicuous lanes of rock face exposed are separated from several minor similar ones east of them on the north slope and these from each other, by long strips of soil and forest. The exposed rock of these smaller eastern lanes appears quite weathered. Minor slides have also occurred from the opposite slope of the neighboring elevation into the Ravine of Avalanches, which appears to be well named; see fig 1. A view of the chief double lane of sliding of 1885 is seen in fig. 3, taken from the opposite mountain side by Prof. E. L. Rice. Small drainages pass down these lanes and empty into Avalanche Brook, which heads below.

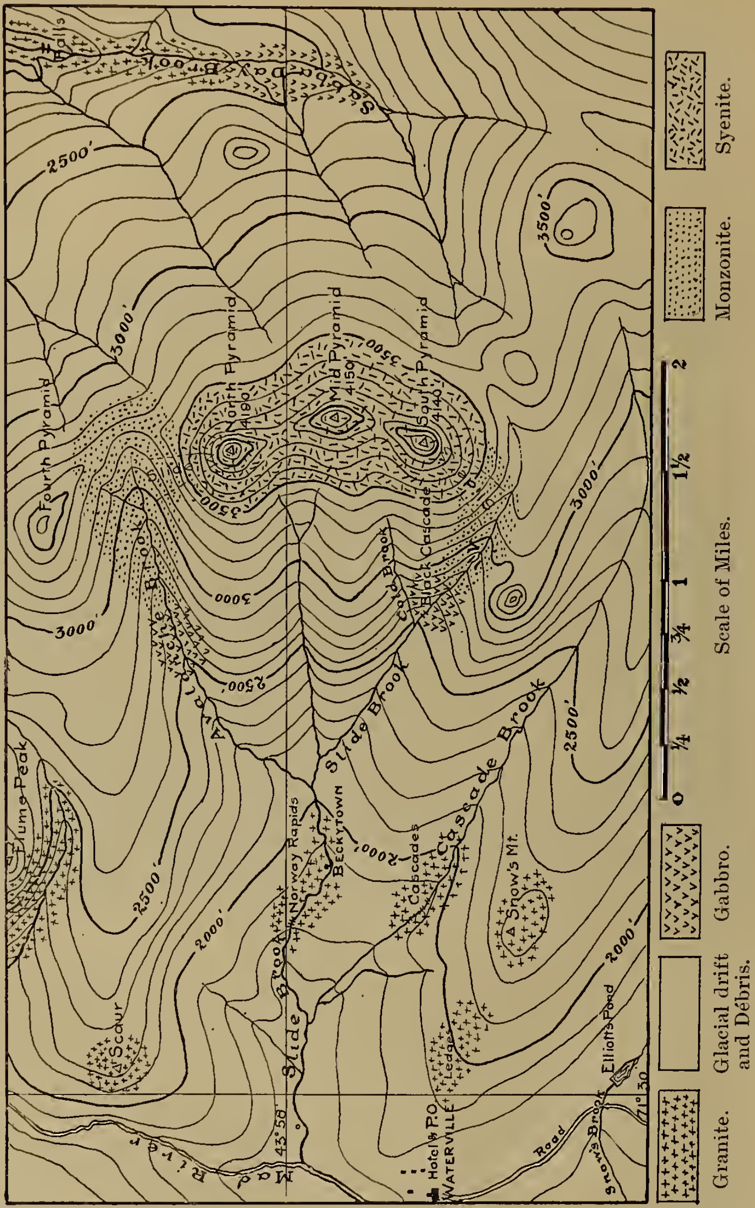


Fig. 2. Topographic and Geologic Map of Tripyramid Mountain and Vicinity.

That the covering of earth, stones, etc., swept away in these slides was a comparatively shallow one is shown by the thinness of soil on either side still remaining, and by the rather

Fig. 3.

Fig. 3. View of the North Slide from the south slope of Fourth Pyramid.

small amount of débris spread down the ravine below, compared with the extent of surface denuded.

The condition which has caused the slides appears to be the steep and smooth rock surfaces on which the accumulating layers of largely organic deposits rested. When these became heavy enough, at a time when they were saturated with water after long and torrential rains, which also lubricated the underlying rock surface, they broke away and slid down. The steepness and smoothness of the bed rock is occasioned by a certain sheeting which it possesses and which is discussed later. Judging from the conditions, and from what has occurred, it seems possible that other slides may occur in the future. *The South Slide* is in essential respects, as to size, height, etc., quite comparable to the North one, only in this case the thickness of the débris of soil, rocks, etc., which moved, was apparently greater. Thus the underlying rock is exposed only at the upper part of the slide, the earth mantles the middle part and increases in thickness as one descends, while the glen below in which the Slide Brook heads is choked with the accumulated material that moved down into it. This lower part has the hummocky surface characteristic of landslides and is furrowed by shallow ravines which the drainage has cut into it. Many large blocks of rock, some of them 8–10 feet long, are exposed in these ravines; most of them are of syenite from the mountain above, but others are of black trap, porphyritic granite, dark gabbro, etc., and are evidently transported glacial erratics. This avalanche occurred on Oct. 4th, 1869, and a second one on Aug. 13th, 1885, as a sequence to the terrible downpour which also caused the largest North Slide. It can be just seen in fig. 1 to the right as a white line showing through the dark forest. An admirable account of these slides and the causes which produced them has been given by Mr. A. A. Butler.*

History.—The first mention of the geology of Tripyramid Mountain that we have been able to find is in a description of the South Slide by Prof. G. H. Perkins† written shortly after its occurrence. The mountain is called by him Passaconaway; there appears at that time to have been some confusion in regard to the use of this name, and later it became fixed to the mountain east of Tripyramid, which now bears it. In his description of the slide he states that the upper part of the mountain is composed of a gray syenite. As this term was then used it bore reference to the fact that the rock contained hornblende, it did not mean that it was free from quartz, or nearly so. The name, however, proves correct as

* Appalachia, vol. iv, No. 3, p. 177, 1886.
† This Journal (2), vol. xlix, p. 158, 1870.

used in the former, or in the later, petrographic sense, as will be shown later. He speaks also of the presence of trap dikes in it from an inch or two up to a foot in thickness. He does not mention their color, so it is uncertain whether this refers to aplitic or lamprophyric dikes, or to both, but the use of the word trap suggests the latter. He speaks also of extensive layers of black hornblendic rock a mile below the slide on the stream ; this evidently refers to the gabbro mentioned later.

The next account bearing on Tripyramid is found in Hitchcock's Geology of New Hampshire.* In this, references to the mountain, to its rocks and geology, are made in a number of places, and in vol. II, p. 211 and following, a general description of its geology is given. As we shall have occasion in

FIG. 4.

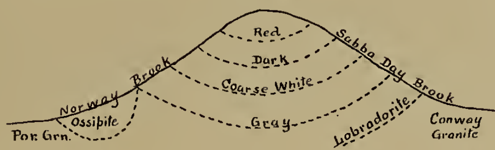


FIG. 4. Generalized section of Tripyramid according to Hitchcock (fig. 19).

several places to refer more specifically to Hitchcock's work we shall content ourselves here with a brief summary of his account. It should be borne in mind that in the seventies, when this was written, certain views in regard to the origin and relations of rocks that we now regard as unquestionably igneous, such as granite, were then prevalent, and had great influence in his interpretation of the geology of the White Mountains. We may add also, that where through a knowledge of the local geology we are able to disentangle the facts, observed in the field by Hitchcock himself, from these hypothetical views and from the observations and views of other people, not infrequently incorrect, with which they are more or less mingled, they are generally confirmed by our own studies. Hitchcock's understanding of its geology is most easily explained by the aid of the generalized section which he gives and which we have reproduced in fig. 4. His results were obtained by a traverse up Slide Brook, whose rock bed had been largely laid bare by the then recent avalanche. This stream he calls Norway Brook, for a reason mentioned later. He found the porphyritic granite of the lower valley floor succeeded by an area of a labradorite feldspar rock, which is called "ossipite"; this is succeeded by "syenite," which changes in character as one proceeds

* The Geology of New Hampshire, by C. H. Hitchcock, 3 vols, 1877.

upward according to the arrangement shown in fig. 4. On the east side of the mountain the rocks occur in the same order ascending from Sabba Day Brook. Labradorite rock occurs on this stream also, on the authority of his assistant, Prof. J. H. Huntington, and is in contact with granite of the Conway type.

The occurrences and contacts as seen appealed to Hitchcock as irruptive ones and he suggests clearly that the syenite is an eruptive mass; but, influenced by the theoretical views previously mentioned, he attempts to classify ossipite (gabbro) and porphyritic granite as "formations" with the equivalence of sedimentary beds.* Through, and upon these, if we understand his view correctly, successive layers of syenite were poured out and the whole then slightly folded. Thus the section is drawn as given and he considers the mountain to be a syncline in its structure. Leaving aside this interpretation, which in light of our present knowledge is impossible, and with a minor change, we shall show later that Hitchcock's idea of the general structure of the mountain is a possible one which must be considered in any discussion of its geology.

Geology.

Our geological field work within the area shown on the map has been confined to the western two-thirds, including the north and south slopes of Tripyramid, traverses of its crest line and exploration generally of the western half of the area. The ridge leading southeast from Tripyramid to Whiteface Mountain, beyond the limits of the map, has also been traversed; but combinations of want of time, bad weather and lack of camping equipage have prevented us from exploring the lower eastern slopes of the mountain in the valley of Sabba Day Brook and we have here been obliged to fall back on the observations of Prof. J. H. Huntington, as given in Hitchcock's report and mentioned later. The manner in which the geology is concealed and the difficulty of traversing parts of the area have been already alluded to, and one might say here that the true petrological history of large areas of the White Mountains cannot, under existing conditions, be adequately deciphered, the covering of glacial drift, débris and vegetation is so complete. Most interesting problems are suggested by many exposures and occurrences, but the data for their solution cannot be obtained.

What we have learned concerning the area covered by the map is put down upon it and the conclusions we have drawn

* Later (op. cit., vol. II, p. 667) Hitchcock appears to have considered it possible that the gabbro was eruptive and that the "Labrador formation" may not exist in New Hampshire.

will be given later. With this preliminary statement the details of the local geology follow.

The Granite.—In the western half of the mapped area, wherever we have been able to find the underlying country rock exposed, it proves always to be of granite. Thus in the "Ledges" above the hotel at Waterville and along the ridge; in Snow's Mountain; in the cascades on Cascade Brook; in the areas of bed-rock exposed in the lower course of Slide Brook, as at Norway Rapids; in the exposures at the Scaur and in the Flume this is always the case. We infer from this that the western part of the mapped area is underlain by granite. This is only part of the great granite mass which extends northward into the peaks of Osceola and Kancamagus, southward into Sandwich Dome as far as Noon Peak and Jennings Peak, and westward to the base of Mount Tecumseh* where it is succeeded by mica schists not yet eroded. It is a part of what we consider the great batholith which forms this southern part of the White Mountains, and it seems to us a reasonable conjecture that upon its descending southern slope the mica schists still rest in irregular manner, and represent the upturned beds, which, by folding, metamorphism, and the intrusion of the granite, have been converted into gneisses and schists.

The granite itself is of a common type, a coarse-grained mixture of flesh-colored alkalic feldspar and gray quartz with a little biotite, and it is usually more or less altered in the visible exposures. In places, as at Norway Rapids, the granite is porphyritic with larger distinct phenocrysts of orthoclase feldspar, and in Snow's Mountain to the southern edge of the map and beyond this character is persistent. Hitchcock on his geological map makes a distinct boundary between the two varieties of granite, but we do not feel that the amount of evidence we could obtain warrants this. We do not know whether the porphyritic variety is a textural phase of the batholith, or whether there are two granites of different periods of invasion present, and, if so, which is the younger. Either assumption appears a possible one. On the eastern edge of the area covered by the map Prof. Huntington found that the falls on Sabba Day Brook are cut in granite of the "Conway" type and that this is the "common rock of the country." It extends upward for a mile and is succeeded by gabbro, as discussed later. From this survey then it appears that the general mass of Tripyramid is known to be surrounded on all sides by granite, except on the southeast, where possibly there may be a continuation of its igneous rock into Mt. Whiteface, which is also a syenite.

* The map accompanying the Hitchcock report shows Mount Tecumseh as composed of granite, but this is wrong, for certainly the greater part of it is mica schist.

The actual contact of its rocks with the granite has, however, nowhere been seen by us. It is also notable that topographically the mass rises everywhere high above the granite immediately about it, though elsewhere the granite, as in Mt. Osceola a few miles to the northwest, rises to similar elevations.

Avalanche Brook and the North Slide.—The narrow valley of Avalanche Brook is in general cut in glacial drift and the narrow stream bed is of transported blocks and pebbles. But about a mile above its mouth there is exposed a very heavy ledge of coarse black gabbro, sloping down stream, over which the brook descends. The length of the exposed area is about 100 feet. It shows a thick heavy sheeting with strike approximately N. 70° E. and a dip of 25° NW. The slope of the surface is about parallel to the sheet jointing, which apparently conditions it. The rock is identical in all respects with the gabbro, or "ossipite" of Hitchcock, from the Black Cascade on Slide Brook, mentioned later. It also appears as a ledge in the wood road south of the stream on the bench above, but in the woods no outcrops have been observed.

Above this for a quarter of a mile, or less, there are no exposures until the foot of the North Slide is reached. From here almost to the very top of the North Pyramid is a continuous surface of naked rock which extends far up to the head of the gulch and also shows in massive outcrops on the lower slopes of the opposite Fourth Pyramid.

The rock forming the lower portion of the exposed mass is a moderately coarse-grained, yellowish gray monzonite, which is more or less altered; the biotite which it contains resists weathering somewhat better than the hornblende, the latter being dull in luster, or even converted into earthy spots of iron oxide. This rock persists up the Slide to an elevation of about 400 feet above the stream, as determined by the aneroid, where it gives place to a flesh-colored syenite which extends from here to the top of the peak.

The contact between the two rock types runs E. and W. magnetic across the slope, and thus descends from a higher point on the eastern side diagonally downward to a lower one on the western, a fact whose significance will be considered later. The contact plane appears nearly vertical, so far down as it can be seen. In the years immediately following the slide and the exposure of the fresh rock surface, this contact, or rather the contrast in color of the red syenite above and the gray monzonite below, as seen in mass at a distance, was a very noticeable feature. Since then weathering has dulled the colors and the growth of mosses and lichens upon the rocks renders them much alike in appearance. When close at hand, however, the contact was then, and is now, discovered with difficulty. As traced along the slope it shows little or no endomorphic effect in either type of rock, except that in the syenite there is a narrow zone of two or three inches in thickness in which the grain is a little finer and in which it is enriched in spots with hornblende. Apart from this there is no change in texture, nor anything that would indicate a contact except the abrupt change in mineral composition. Another interesting feature in this connection is that the great mass exposed in the Slide shows everywhere a sheet jointing, similar to that seen in the gabbro previously described, and this sheeting, sometimes thick and heavy, sometimes thin and shelly, passes through both rock varieties and across the contact, as if it were in a unit mass of one rock type. The apparent significance of this is discussed later. This sheeting, which is seen in fig. 2, conditions the naked rock slopes seen on the Slide, which for long distances are parallel to it, with a dip of about 25°–30°. It is also of interest that the monzonite in the higher exposures in the head of the Ravine of Avalanches and on the south slopes of Fourth Pyramid, where it appears in massive outcrops, is quite fine-textured.

Above the monzonite, the syenite, as already mentioned, extends to the top of the pyramid. Along the surface of the Slide the rock is fairly fresh and solid, but the top consists of broken blocks and débris in place, and is more altered. The three pyramids and the whole top of the mountain are composed of this flesh-colored syenite, always in this state of broken blocks and débris, and everywhere covered with a more or less dense thicket of spruce. These conditions make its lower limit uncertain, but it pretty surely extends down as far as the 3500 contour line and is thus shown on the map.

South Slide and Brook.—On Slide Brook and above its junction with Avalanche Brook the first rock in place is found at the Black Cascade, a very short distance above the mouth of Cold Brook. Here the stream pours over a low cliff of gabbro, forming a fall some 15–20 feet high. The gabbro is a black, heavy, very coarse-grained rock, quite similar to that seen on Avalanche Brook, but of somewhat coarser texture. This is the original "ossipite" of Hitchcock,* which because of its containing labradorite was placed in the "Labrador System" in the New Hampshire report (according to Sterry Hunt's classification of the Azoic formations, which was followed by Hitchcock at that time, but later considered by him as doubtful). A chemical study of the rock was made by E. S. Dana,† who deduced that it consisted chiefly of labradorite, with some olivine, and a little ilmenite; and as it

* Op. cit., vol. i, pp. 37–40, vol. ii, pp. 213 et seq.
† This Journal, 3d series, vol. iii, pp. 48-50, 1872.

was thought to be a new rock kind the above name was given to it. This was before the microscope had been used to study thin rock sections in this country and the presence of pyroxene in the rock remained undetected. Thus it is actually a gabbro, though a very feldspathic one, as will be shown in the later paper on the petrography of the area.

The rock formed part of the "Norian system" of Hitchcock, a term that was later supplanted by "Labrador system," and from the name "Norian" the stream was called "Norway Brook" by him.

This black gabbro extends up stream, forming an exposure about 500 feet long in the brook bed, where it is found in a massive, sloping, smooth-surfaced outcrop in contact with a rock of very different appearance. This is brownish to reddish gray in color, and, on a freshly fractured surface, is evenly mottled light and dark with feldspathic and ferromagnesian constituents, and is of medium granular texture. The petrographical study shows it to consist chiefly of plagioclase, hypersthene and iron ore, with some augite and biotite. It is, therefore, a norite, and chemically is closely related to the adjoining gabbro, but the contrast between the two in color and appearance is striking.

The contact of the two types is clearly shown for many yards on a smooth surface, kept clean and bright by the stream washing over it. Its general course is about N. and S. It is not an even line but a broken one with offsets. The contact appears at first sight irruptive and it seems that one of the masses must have broken through the other. But on close study it is found difficult to say definitely which is the older. The contact is firmly welded, and both types come up to it without change in texture or minerals, so no endomorphic effects are visible. Nor does careful search show clearly definite fragments of the one type enclosed in the other. In one place the gabbro is penetrated by light-colored material in a small dikelet which may be norite or aplite, its altered condition making it difficult to decide which. In addition the rock-mass has a massive sheet-jointing which passes through both and crosses the contact as if in a rock of uniform composition. It has a northerly dip varying from N. 45° W. to N. 25° E. Both kinds have been much cracked and the cracks healed by a later pneumatolytic deposit which shows as fine, whitish aplitic stringers, often as thin as cardboard, but sometimes widening out to narrow dikes and then in some cases assuming a pegmatitic aspect. In one place for a number of feet a crack has occurred along the contact, or closely adjacent, and this is filled like the rest.

While one cannot pronounce with the certainty that is desirable which is the younger of the two rocks, the study leaves a feeling and belief that the norite is, and this is confirmed in considerable measure by the micro-study of the norite, given in detail later, which shows its feldspar crystals bent and broken near the contact from movement under pressure along the gabbro boundary, while crystallizing. If this is so, then the gabbro must have been still very hot when the norite came against it, and yet sufficiently stiff, or solidified, to retain after the movement the broken angular border which characterizes it.

Ascending the stream bed from here the outcrops of norite after a short distance give place to exposures of monzonite. This monzonite is precisely similar to that found at the base of the North Slide, as previously mentioned. It is usually moderately coarse-grained but varies in places to rather fine grain; weathers brownish, but on a fresh fracture is rather thickly mottled with ferromagnesian minerals which are dull in luster and more or less altered. It resembles surprisingly a specimen of the more feldspathic monzonite from Monzoni in appearance and texture. It is composed of about equal parts of orthoclase and plagioclase, with hornblende, some augite and biotite, and a little quartz.

No contact between the norite and monzonite is visible; if such exists it is covered with débris. We are uncertain, therefore, whether there is a sharp contact, as between the gabbro and norite, or whether the norite grades into the monzonite.

Outcrops of monzonite are seen at intervals following up the stream, the best exposures being at the little gorge known as the "V." As in the other types of rocks, it has a heavy sheet jointing which dips away from the mountain mass. The stream, following along the strike of this, has cut away the rock so that one wall is made by the jointing planes, the other by cross erosion, and this makes a steeply descending gorge. Long surfaces of naked rock are exposed over which the stream descends and into which it has cut pot-holes.

Above this no rock in place is seen until the South Slide is reached. The stream bed is in débris and drift material and filled with bowlders of many rock types, the syenite and monzonite of the mountain being mixed with glacial erratics. Among them some blocks of black gabbro were noticed, and it is thought that these may have been brought over the western slope of the mountain from the direction of Avalanche Brook by the southward movement of the ice.

The lowest outcrops of rock on the South Slide are about half-way up, and are of syenite similar to that of the North Slide and it is all syenite from here to the top of the South Pyramid.

Eastern Side of the Mountain.—The lower eastern slope of Tripyramid and the valley of Sabba Day Brook were not visited by us for reasons stated, and we are here compelled to fall back on the observations of Huntington and Hitchcock. They state that at the falls on Sabba Day Brook, as previously mentioned, the exposures are of granite of the Conway type, which is the common rock of the country.* It appears on the brook, but about a mile higher up it is replaced by an area of "labrador" rock. This is stated to have the large cleavable feldspars which show the opalescence characteristic of this variety. As both Hitchcock and Huntington had visited the gabbro (ossipite) locality on Slide Brook and were well acquainted with that rock, there can be no reasonable doubt but that this area is composed of gabbro similar to the areas of it on the western side of the mountain. Apparently the reason why Hitchcock did not name it ossipite was because, as he states, chrysolite (olivine) was not visible in it (megascopically of course). We have, therefore, shown an area of it on the geological map similar in a general way to that given in the atlas accompanying his report. According to his statement this area is bounded to the southeast, south, and southwest by the porphyritic granite, or gneiss, as he calls it; as no exposures are specified we have not attempted to show this on the map. In the same place Hitchcock says that on the North Tripyramid the syenitic rocks appear in the same order as on Slide Brook, "apparently cutting the labradorites." Though he does not mention specific exposures, it seems clear from this that he means that the monzonite (his gray syenite) occurs also on this side of the mountain, and his section, previously given, is drawn in accordance with this idea.

Dikes.—No very large or important dikes have been seen by us in the areas of exposed bed-rock. The largest are two black dikes of altered camptonite, about 6–8 feet thick, which, at right angles to one another, cut the porphyritic granite at Norway Rapids, and whose presence in fact conditions the small fall in Slide Brook to which this name has been given. On the other hand, small dikes and dikelets are very common. Thus the gabbro at the Black Cascade is cut by a number of dikes of a gray-black, dense trap, varying from a few inches to a foot in thickness. One of these is exposed for a hundred feet or thereabouts in the rock bed of the stream. The petrographic study shows these are micro-gabbros. A short distance above the contact of the norite with the gabbro the bed-rock in the brook is cut by a dike of syenite about 6 feet in thickness with trend N. 70° W. In minerals, texture, and appearance

* Op. cit., vol. ii, p. 217.

this dike is quite similar to the main mass of syenite. On the south wall, against the monzonite, there is no special evidence of endomorphic result from the contact, but on the north side there is a definite fine-grained band, about two feet wide, appearing like aplite. The two rocks seem to grade into each other. This dike is of importance in considering the genesis of the Tripyramid complex, as will be seen later.

Narrow dikes of aplite consisting of alkalic feldspar and quartz, with a small quantity of biotite, are very common and cut all the other rocks of the complex. When of some thickness, that is from a few inches up to two feet, they have the sugar-granular texture of ordinary aplites; when less than this they may become quite dense and felsitic. The coarser ones may be grayish or brownish white, but usually they are a strong flesh-pink. One of these, about 6 inches thick, cuts both gabbro and norite at the contact on Slide Brook, and another of two feet in width traverses the monzonite in the rock bed of the stream just above the "V." Narrow stringers and dikelets are very numerous and may be seen traversing the surface of the North Slide.

No general system of trend has been observed among the dikes, only in limited areas the parallel and reticulated arrangement of aplitic stringers shows quite clearly that they fill joint systems, which have been cemented and healed by them, as in the norite and gabbro exposed at the contact on Slide Brook.

Jointing.—The jointing of the rock masses composing the complex of Tripyramid has been alluded to in several places. It is a matter of importance because, when considered in general, it is seen that, except locally near the Black Cascade, it follows the surface of an oval dome, considerably eroded, of which the Pyramids may be considered the present highest points. This ovate sheeting, or onion-like structure, is one not infrequently seen in granitic stocks and massifs, and is one often referred to initial stages of weathering, that is to the shearing effect of alternate contraction and expansion produced by exposure of bare rock surfaces to the cold of winter and the heat of summer. We do not, in the present case, believe it has been produced in this way, because it is too regular and massive, and because it is just as well developed under heavy coatings of glacial till as on exposed surfaces, as may be seen on Avalanche and Slide brooks. During the period of the ice invasion all the superficial effects of pre-glacial weathering must have been swept away, and the rock surfaces bitten into rather deeply, and at its close certain areas were left exposed to weathering, while others were protected by heavy mantles of till left upon them. It is suggested that the upper part of the mountain was comparatively bare and the glacial deposits mostly left upon the lower slopes; and, in accordance with this, we find the syenite, although appearing firm and solid in the material on the Slides, yet somewhat affected by weathering when seen under the microscope, and the monzonite very much more altered, while the gabbro and norite are very fresh and unchanged.

For these reasons we do not ascribe the sheet jointing to exposure, but believe that the explanation for it is to be sought in the jointing phenomena incident to the cooling and contraction of an intruded igneous mass. In a dome-surfaced intrusion, as the planes of cooling descend into the mass, the ensuing contraction would produce a sheet jointing, or onion-like structure, parallel to its surface. That this is so is well shown in some of the more massive of the laccoliths of the west. It is not our purpose here to discuss the jointing phenomena which ensue in various kinds of intrusions and under various conditions, for the subject is too extensive for treatment in this place; we merely wish to point out that this is one type of jointing which characterizes such intrusions, the proof being not merely theoretical, but actual.* And on the other hand, the possession of this kind of jointing by an igneous mass may be legitimately used to help in deducing the original form of the intrusion.

Structure and Origin.

From what has been said in the foregoing and by reference to the geologic map, it will be seen that, accepting the field observations of Hitchcock and Huntington on the eastern side, we have three sections up the mountain, one on the north-northwest slope, one on the south-southwest slope, and one on the east; that is roughly, in a general way, at 120° from one another. Disregarding the narrow norite phase on Slide Brook, each of these gives the same sequence of rock types, as follows: first, the general granite of the region, which at about 2,500 feet elevation is succeeded by a coarse-grained black gabbro; this gives way to monzonite, which at 3,500 feet (on the North Slide) is in turn replaced by the syenite which forms the upper part of Tripyramid. Thus the succession reads granite, gabbro, monzonite, syenite. It is this succession which led Hitchcock to draw the section we have previously given and to consider the mountain as of synclinal structure. It is evident from his remarks that his observations led him to consider it, aside from the gabbro, as an eruptive mass. Disregarding the views about stratification in the gabbro and syn-

* As in Square Butte in the Highwood Mts. of Montana, referred to later. Conf. also Ramsay, Das Nephelinsyenitgebiet auf der Halbinsel Kola, Fennia, xi, No. 2, p. 81, 1894.

clinal folding, Hitchcock's section suggests one interpretation for the structure of Tripyramid which at first thought appears possible, that is, it may consist of successive layers of gabbro, monzonite and syenite erupted through the granite and on top of one another in the order named, and beneath some cover which has since disappeared, with the semblance to a sedimentary succession.

We do not believe this view is tenable; it is negatived by the character of the contacts, which where visible are vertical or approximately so, by the dome-jointing, and by the direction of the contact between the monzonite and syenite on the North Slide, which in this case, instead of striking diagonally

Fig. 5.

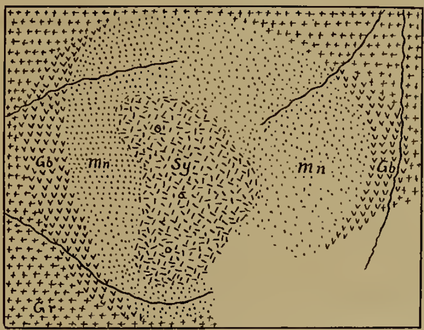


Fig. 5. Inferred geological map of Tripyramid intrusion. Legend as before.

down the slope to the west, as it does, should follow round the mountain on a contour line.

The sequences referred to suggest very naturally that Tripyramid is a differentiated mass of igneous rock, and, as has been found to be so commonly the case elsewhere, it begins with an outer basic border, succeeded by a less basic inner part which in turn gives way to an acid interior core. If we take into account the facts as observed and imagine to ourselves the geology of bed-rock that would be exposed if all the overlying material should be removed, we should have the relations shown in fig. 5, adjoining. In this, the southeast corner has been left indefinite for the reason, previously stated, that we do not know whether the Tripyramid mass is definitely cut off from that of Mt. Whiteface by the granite, or not. It is to be understood that these boundaries are *not* to be taken in a hard and fast way, as representing everywhere what we believe to be the exact location of definite geological contact lines. They only show in a general, or diagrammatic, manner what we believe best accords with the ascertained facts. It is, of course, possible that the monzonite is entirely surrounded by gabbro, but we have no proof of this and have thus shown it only on the two sides where the outcrops have been seen, or are reported. The relative sizes of the different areas may vary considerably from what we have shown, but this is a detail which does not affect in principle the correct understanding of the structure and petrologic relations of the complex.

Concentrically arranged complexes of igneous rocks similar to this have been described from numerous localities, and of alkalic types. Confining examples to North America, they have been shown to be common among the linear groups of elevations running southwardly from Montreal and termed the Monteregian Hills by Professor Adams, which have been described by him and other Canadian geologists.* Washington has shown this arrangement exists at Magnet Cove, Arkansas, and also in the complex in Essex County, Mass.† Other examples have been described from several localities in Montana.‡ Still others might be mentioned, but the dozen here cited are sufficient to illustrate this mode of occurrence and serve as a basis for discussion.

On the grounds of the field evidence obtained the authors cited have in some of these cases considered the occurrence as a laccolith within which subsequent differentiation has produced the concentric complex; in others they have held them to be stocks, or volcanic necks, in which differentiation has occurred, sometimes with subsequent movement of the differentiated bodies of magma. At Square Butte and the Shonkin Sag the field evidence as to the laccolithic character of the intrusions is ample and decisive, as it seems to be also that Mt. Johnson is a volcanic neck and Yogo Peak an intrusive stock. In other cases the evidence is less clear, and the nature of the intrusion is largely inferred; thus Harker§ questions Washington's interpretation of Magnet Cove as a single differentiated laccolith, and suggests the alternative view that it may consist of two thin, superposed laccoliths of different composition, which

* Adams, F. D., The Monteregian Hills, Jour. Geol., xi, p. 239, 1903. Dresser, T. A., Geology and Petrog. of Shefford Mt., Quebec, Ann. Rep. Canad. Geol. Surv., xiii, pt. L, 1902. Geology of Brome Mt., this Journal, xvii, p. 347, 1904. Young, G. A., Geology and Petrog. of Mt. Yamaska, Quebec; Ann. Rep. Canad. Geol. Surv., xvi, pt. H, 1906.

† Washington, H. S., Igneous Complex at Magnet Cove, Bull. Geol. Soc. Amer., xl, p. 389, 1900. Foyaite-Iolite Series of Magnet Cove, Jour. Geol., ix, p. 607, 1901. Petrog. Province of Essex Co., Mass., ibid., viii, p. 473, 1899.

‡ Weed and Pirsson, Highwood Mts. of Montana, Geol. Soc. Bull. Amer., vi, p. 400, 1895. Igneous Rocks of Yogo Peak, Montana, this Journal, l, p. 467, 1895; 20th Ann. Rep. U. S. Geol. Surv., pt. III, p. 563, 1900. Bearpaw Mts. of Montana, this Journal, i, p. 351, 1896. Shonkin Sag and Palisade Butte Laccoliths, ibid., xii, p. 1, 1901.

§ Geol. Mag., Dec. iv, vol. ix, p. 177, 1902.

have been subsequently domed by quaquaversal uplift and then eroded, thus producing the concentric arrangement.

In this connection the nature of the contacts, or of the transition of one type of rock in the complex into another type, is of importance though generally little is said upon this matter. At first thought it might appear that, if the intrusion were a laccolith in which differentiation had taken place *in situ* after the magma had come to rest, the transition of one type into another would be gradual and extended over some distance, while if the change of one kind of rock into another takes place abruptly, as in an ordinary contact, this would be evidence that the intrusions of magma were successive. The matter is not, however, so simple as might be inferred from the above statement. Cases of transition there undoubtedly are, but at Square Butte the transition zone reduces to a few inches, or even less, while in the Shonkin Sag laccolith, one of the most evident instances of differentiation in place that we know of, the change is very abrupt and quite like an ordinary contact, except, of course, that there are no endomorphic effects in either type. It is conceivable that differentiation in the liquid form may be so complete as to yield fluid masses which come together in contact with definite surfaces, like oil and water for example. And on the other hand, if the differentiation is due to fractional crystallization about the borders of a closed chamber, it might happen that a certain set of components would separate out until a definite relation, possibly eutectic, was established among those composing the rest of the fluid, whereupon an abrupt change in the crystallizing minerals would occur.

Therefore, to our minds, the fact that the transitions from one rock type to the other in the Tripyramid complex are abrupt as in ordinary contacts is not in itself an absolute proof that the differentiation did not take place *in situ*, or that there must have been successive intrusions of magmas of different composition from below upward, although they naturally suggest this.

Considering first some of the hypotheses that have been offered to explain concentric igneous masses, it appears that Harker's suggestion that this arrangement at Magnet Cove may be due to the doming and erosion of superposed sheets is not applicable to Tripyramid for reasons already mentioned, namely, the attitude of the contact planes, and the common jointing, and also the following one. Accepting this view the gabbro would be the top sheet, next the monzonite and the syenite at the bottom. Now the gabbro is coarse-grained, the monzonite medium or fine-grained, the syenite, by comparison with the gabbro, fine-grained; and we should thus be presented with the anomaly that when the mass is deeply penetrated the grain becomes finer, which would be contrary to experience.

It has been sometimes suggested that the zonal arrangement of different rock-types in an intruded mass may be due to the absorption and assimilation of the surrounding country rock. In the present case the enclosing rocks were of acidic types, granite below, mica-schists and perhaps gneisses above, while the border facies of the intrusion is the basic gabbro. We should, therefore, have to imagine that in some manner a body of gabbro was intruded which was not affected at its border, but which assimilated more and more foreign material towards its center, so that the gabbro became a monzonite and the monzonite syenite. Apart from the mechanical difficulty of such an operation it is to be noted that the gabbro, as shown by analysis, contains 11·5 per cent of lime, the syenite 2·5; therefore, even if we make the most favorable assumption that the granite, or schist, absorbed contained no lime, it would require that the gabbro should make a thorough absorption and mixing of between four and five times its own weight of country rock to produce the syenite. In the upper (and outer) parts of the syenite we have observed in several places small areas from a few feet across down to several inches where the rock differs from the main type in finer grain, more ferromagnesian minerals and a streaky appearance, and it is possible that these may represent blocks from the roof which sank into the mass and have been mostly resorbed and charged with syenite magma; but the view that the whole body of syenite could have been made from the gabbro by such a process, the above considerations, it seems to us, are sufficient to refute.

After a review of these alternative hypotheses it is now in order to seek one which will best fit all of the varied facts which have been presented concerning the geology of Tripyramid. Briefly stated the facts are as follows: First, the concentric arrangement with the most basic rock at the margin and the most acidic inside; second, the abrupt transition of one type into another, with angular broken contact line in places, and yet with very slight though perceptible evidences of contact metamorphic effects; third, probable intrusion of the gabbro by the norite and positive intrusion of the monzonite norite by the syenite as shown by the dikes above the contact on Slide Brook*; fourth, the common sheet jointing which passes through contacts as in a unit mass; fifth, the final intrusion of aplite dikes.

The concentric arrangement naturally suggests a differentiation of a body of magma in place, as at the Square Butte and

* A bowlder of gabbro on Slide Brook was noticed to be cut apparently by a dike of fine-grained monzonite, about 10 inches wide. Not being in place it cannot be regarded as conclusive evidence but tends to confirm the view that the gabbro solidified first.

Shonkin Sag laccoliths, but this is negatived by the contacts and the syenite dike. The latter suggest a series of successive intrusions; but the zonal arrangement, the common sheet jointing and the small amount of endomorphic effect show that this could not have been of the ordinary character.

Between the differentiation of a unitary body of injected magma at one extreme and a series of successive intrusions, as one ordinarily finds such a process evinced, at the other, which might give rise to an igneous complex, it is easily possible to imagine a whole chain of gradations. It appears to us that what best explains Tripyramid is a process of intermediate nature, in which both differentiation and repeated intrusions, separated by only short intervals, took place. We might imagine this to be somewhat as follows: First, the intrusion of a body of monzonitic magma through the granite and between it and a cover of schists; second, differentiation in the body with production of basic border masses, either by diffusion of the femic molecules to the margin, or by their crystallization at the edge, or both, with production of the gabbro and cooling in this region until the latter had acquired a certain solidity; third, an upward movement of magma from below with ruptures along the inner border of the gabbro and the bringing of material of a somewhat different composition against it; fourth, differentiation continuing with formation of the inner body of syenite and progressive solidification of the main monzonite body from the margins and from above inwardly; fifth, further upward movement of magma from below, rupturing along the edges of the solidified monzonite, bringing syenite magma against it with the injection in places of syenite dikes into it; sixth, cooling and solidification of the syenite, and, lastly, injection of the final, most highly differentiated and acid product from within and below, upward and outward into the consolidated parts with formation of aplite dikes.

We therefore think that the two upward movements here indicated were not of sufficient amount, or volume, to destroy the zonal effects of differentiation, but sufficient to modify it in the manner indicated, and they must have produced a further doming of the upper surface of the intruded mass. We suggest that they occurred while the already solidified parts were still hot, and before jointing from contraction had taken place; this would explain the small amount of endomorphism seen and the fact that the subsequent jointing took place as in a unit rock body. It is possible that still another uplift of magma may be indicated by a contact between the norite and monzonite on Slide Brook, or they may grade into one another, but upon this point, for reasons previously stated, the evidence is wanting.

The lamprophyric dikes may be regarded as complementary to the syenite-aplite and their peripheral situation in the gabbro and contiguous granite is the customary one.

In regard to the roof of the intrusion, it is known that a few miles to the south and to the west the granite batholith gives place to mica schists beneath which it may reasonably be supposed to descend, as previously stated. We suggest that this roof had once a greater extension to the northward over the now exposed granite, and that the Tripyramid mass was, in large part, intruded between the uneven surface of the granite and the mica schists, doming up the latter, as indicated in fig. 6, in a purely diagrammatic way.

Fig. 6.

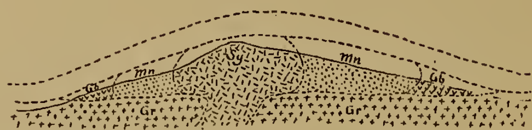


Fig. 6. Diagrammatic section to illustrate the probable origin and structure of Tripyramid Mt.

This conception makes the intrusion laccolithic in its nature. We do not desire to insist too strongly on this point because we know so little of the relation of the igneous mass to the surrounding granite beyond the fact that at three different points on its edges the gabbro begins at about the same elevation. And we are also uncertain concerning the boundary on the southeastern side. But it seems rather strongly indicated, from the present shape of the mass and its sheet jointing, that its upper surface had the domed form seen in laccoliths; and, as this view of its structure seems the one best fitted to bring into harmonious relation the varied parts and correlate it with similar occurrences elsewhere, it seems natural to adopt it. According to this conception the sheeted jointing merely represents the effects of contraction, as the planes of cooling parallel to the domed surface descended into the solidified but still heated mass, as has been already discussed.

We are quite conscious, in provisionally adopting this hypothesis and in fact endeavoring to elucidate the structure of Tripyramid, that more and better evidence would be desirable, but, considering the facts that we have been able to obtain, this on the whole seems the most accordant with them.

Summary.

Tripyramid Mountain is an igneous intrusion consisting of several rock types concentrically arranged. On the outer borders are masses of coarse-grained gabbro which are succeeded inwardly and above by monzonite and these by an inner core of syenite. Where these are seen to meet there is a sharp transition line but only slight endomorphic evidence of contact. The mass is surrounded with granite, but no contacts with this have been found. It is characterized by a parting or sheet jointing, common to all the rock types parallel to a dome surface. The study has led to the conclusion that it is probably laccolithic and that the different rock types have been formed by a combination of differentiation and repeated upward movements of magma, a process intermediate between differentiation *in situ* and successive separated intrusions. Finally a rather full discussion of the bearing of the contacts and of the jointing on various hypotheses is given, not alone for the purpose of elucidating the origin and structure of the mountain, but also to invite consideration and discussion of these as criteria in judging of the nature of complex intrusions.

New Haven and Middletown, Conn., Dec. 1910.

Art. XXVII.—*Note on a Method in Teaching Optical Mineralogy*; by F. W. McNair.

The writer has for some years given a short non-mathematical course in polarized light as related to crystals, for the purpose of preparing students to take up optical mineralogy, the latter being applied in turn to the study of rocks. The course has been necessarily very brief, non-mathematical, and confined to the bare essentials needed to develop its applications. Under these conditions an attempt has been made to give the student a logical basis for his conclusions, to develop in him some ability to reason about observed phenomena, and so to render him as far as may be independent of mere rules of procedure.

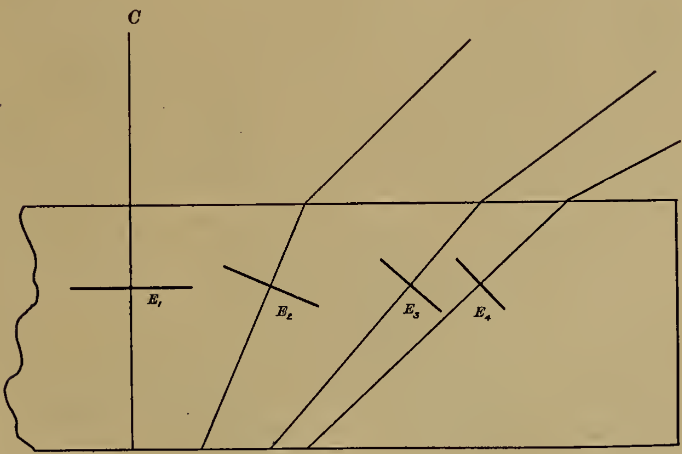
In the effort to condense the course, and to base its entire structure on the smallest possible number of new ideas, the form of the wave shell and the deductions therefrom have been rested as directly as possible upon the so-called reciprocal ellipsoid, as introduced by McCullagh. It will be remembered that this ellipsoid, whose equation is

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1,$$

is constructed on semi-axes proportional to the square roots of the elasticities in the three principal directions. In the usual notation, these axes are named so that $a>b>c$ and their directions are labeled respectively A, B and C. This ellipsoid gives the wave shell, or ray surface, by the following construction: if through the center perpendicular to a given ray direction a plane is passed, the section is an ellipse, and if on the ray direction, distances be laid off proportional to the semi-axes of the ellipse the locus of all points so determined is the wave shell. Furthermore, the vibration directions belonging to the given ray lie in planes determined by the ray and the axes of the elliptical section.

If one may judge by the text books, the ellipsoid, whether that of Fresnel or this of McCullagh, is used in the non-mathematical presentations of this subject to obtain the wave shell, or rather its three principal sections, and is then immediately abandoned. The device which occurred to me some years since, and which I have found useful in obtaining results with my students, is to carry the use of the ellipsoid into a considerable number of the applications of the theory to the properties of crystals. The "section cut from the ellipsoid" is used at once in accounting for the phenomena exhibited by thin crystal plates between crossed nicols. It is applied next to the simple cases of superposition of plates of even thickness, then to those cases in which the plates are not of even thickness. By its use the average student gains some facility in predicting the phenomena which will be observed in a given case, such, say, as that of an even plate over one shaped like a convex lens. Afterward the method is applied to crystal plates in convergent plane polarized light and perhaps the most conspicuous example of its usefulness lies in its application to the distinction between positive and negative crystals in the convergent beam of plane polarized light.

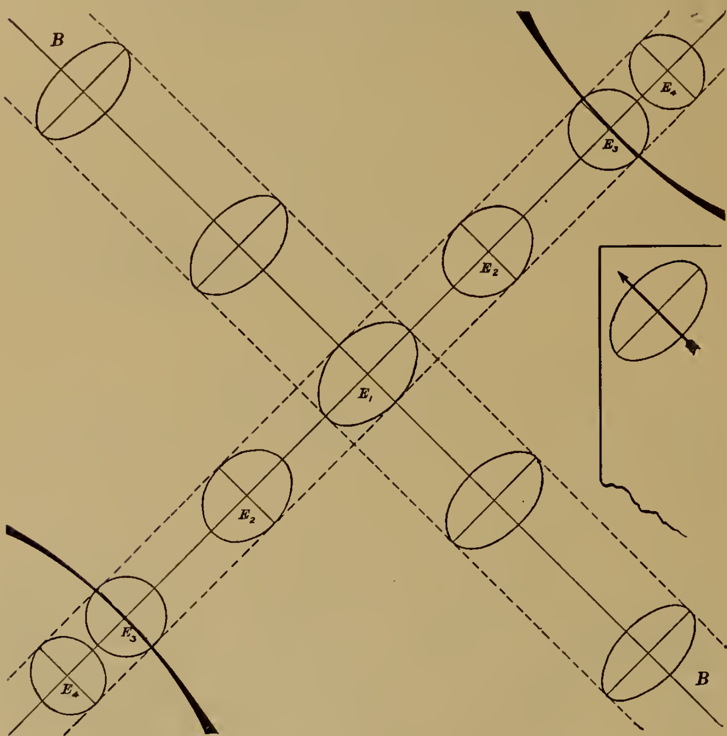
Fig. 1.



Let fig. 1 represent a central section through the convergent cone which traverses a plate cut perpendicular to the acute bisectrix. If the crystal is positive, this acute bisectrix is C, the direction of minimum elasticity. If for each ray direction the ellipsoid is constructed, and the section perpendicular to the ray is cut, the elliptical sections will appear in this figure only as traces marked E_1, E_2, etc. If now a diagrammatic plan be made on the assumption that the above section coincides with the axial plane, and, for brevity, with that plane in "the 45° position", and if the ellipses be diagrammed on this in their full area, that is, if each be tipped into the plane of the diagram before being drawn, we shall obtain something like fig. 2. On this figure lines representing the position of the hyperbola have been drawn to enable it to be referred to the biaxial interference picture, and the ellipses have been numbered to correspond with those shown in fig. 1. The ellipse for the central ray of the cone being drawn perpendicular to the C direction has for its semi-axes *a* and *b*.

If now we consider the series of ellipses belonging to rays in the A–C, or axial, plane, represented in the section above, it will be seen that as we leave the central ray, passing outward to rays making a continually increasing angle with the central one, the axis perpendicular to the A–C plane remains constant

Fig. 2.



and of the value 2*b*, while the axis in the axial plane decreases from its maximum, 2*a*, toward the value 2*c*. Furthermore, when the ray has the direction of the ray axis of the crystal the ellipse obtained for it is a circle. Beyond this ray the axis in the A–C plane is the minor axis of the ellipse. Thus it appears that the ellipses on one side lie with the major axes at right angles to the major axes of those on the other side, the change occurring at the ray axis, which is close to the nose of the hyperbola of the picture.

Proceeding now from the center of the figure at right angles to the axial plane, the ellipses undergo no such change, the major axis now remains constant at $2a$ while the minor axis grows smaller, reducing from $2b$ toward $2c$. The major and minor axes of these ellipses represent the speeds of the two disturbances vibrating respectively in the planes of these axes. If we call the difference of these speeds Δ, as is convenient, it is easily seen that Δ near the nose of the hyperbola is zero, and that from this spot it increases toward the center of the figure, while at right angles to the trace of the axial plane it increases away from the center. Outside of the hyperbola and away from the center it increases in numerical value but is negative.

Suppose now that the quartz wedge is pushed over the plate, thin edge first, with its vibration directions as indicated by the ellipse drawn in its corner. It will readily be seen that this ellipse lies parallel to that for the central ray of the cone, and to all others inside of the hyperbola. The faster ray in the plate will also be the faster in the wedge, and the slower in the plate will be slower in the wedge. The effects of plate and wedge will be added. Now the location of the color bands depends directly on the value of Δ, hence for a given position of the wedge a particular band will be found where the combined Δ of wedge and plate equals the Δ of the plate alone at the original location of the band before the superposition of the quartz wedge. As the wedge is advanced the combined Δ at any point of the plate is increased continuously, while any particular value of the combined Δ necessarily shifts toward that spot in the plate where Δ is least. Therefore, as the wedge is pushed over, the color fringes will travel from the center toward the nose of the hyperbola. Likewise, on the line at right angles to the axial plane they must travel in toward the center.

Outside of the hyperbola, however, the ellipses are in crossed position, and the slower ray in the plate is now the faster in the wedge. A difference of effects results, and a given color fringe will now travel toward a position in the plate where Δ is numerically greater. Therefore, outside of the hyperbola the color fringes will travel away from the nose. Of course, a reversal of the quartz wedge, either by turning it over to reverse the position of its ellipse or pushing it thick end first instead of thin, reverses the travel of the fringes. For a negative crystal, the travel would be in each case in the opposite direction.

There are approximations in the foregoing which have not been pointed out, but which are sufficiently close to avoid the possibility of error in any practical application. I have used this device with many students, and its justification rests in the readiness with which a student who once comprehends the meaning of the ellipsoid becomes independent in his application of this test of the quartz wedge, applying the wedge in either position, and reasoning out his results with an assurance of correctness. If there were no other application I should consider that the results have justified my continued use of the scheme. It applies of course to the uniaxial crystal and the quarter wave-plate, or the first order red, as readily as to the biaxial case.

Michigan College of Mines, Houghton, Michigan,
Jan. 14th, 1911.

Art. XXVIII.—*New Paleozoic Insects from the Vicinity of Mazon Creek, Illinois;* by Anton Handlirsch, Imperial Natural History Museum, Vienna.

The Carboniferous (Pennsylvanic) ironstone nodules found in and around the region of Mazon Creek, Illinois, form an inexhaustible source for our knowledge of the Paleozoic insect world. Each new series of these precious pebbles examined furnishes new and interesting forms of insects, but rarely has one and the same species been represented by more than a single specimen. This fact seems to indicate that the species hitherto discovered are but a small fraction of the whole insect fauna of these far remote times. The more gratefully, then, must we acknowledge the courtesy of Professor Charles Schuchert, who has again supplied for study and description a rich series of fossils, preserved in the geological collections of Yale University. Some years ago he sent me 79 specimens, all from the vicinity of Mazon Creek, Grundy County, Illinois, 11 of which have previously been described. Besides 1, which is a Scorpion, and 17, which I am absolutely unable to determine, I have been able to classify them all. Only 4 of the fossils not hitherto brought to notice belong to known species (*Eucœnus ovalis* Scudder, *E. mazonus* Melander and two Blattoidea); all the others are new to science. It was necessary to establish for these 40 new species, 23 new genera, 9 new families and even a new order. Nevertheless, the whole can be introduced into the scheme established in my "Fossil Insects." All the new forms are evidently heterometabolic. With the exception of some Blattoidea there is not one type of a modern order to be found in the collection. The Palæodictyoptera are well represented by 6 species; many of the other forms belong to the extinct intermediate orders which lead from the Palæodictyoptera to the modern types (1 Protodonata, 2 Megasecoptera, 19 Protorthoptera, 8 Protoblattoidea, 1 Sypharopteroid). Only 3 of the new species belong to the Blattoidea.

The fauna of Mazon Creek seems to have been of a similar character to that of Commentry, Belgium, and Saarbrücken of Europe. It was a fauna of giants in comparison with that of our day.

Order PALÆODICTYOPTERA (Goldenberg).

Family DICTYONEURIDÆ Handlirsch.

This very archaic family, represented by 30 species in the middle productive Carboniferous deposits of Europe (Commentry, Saarbrücken, Hennegau, etc.), seems to be much less frequent in North America. Only 4 species have been recorded from America; a fifth one, contained in the Yale collection, the type of a new genus, is now added to this number.

ATHYMODICTYA, new genus.

Athymodictya parva, new species. Figs. 1, 2.

A small insect, measuring about 26^{mm}. Wings 17^{mm}. Head comparatively small with distinctly vaulted lateral eyes. Pro-

FIG. 1.

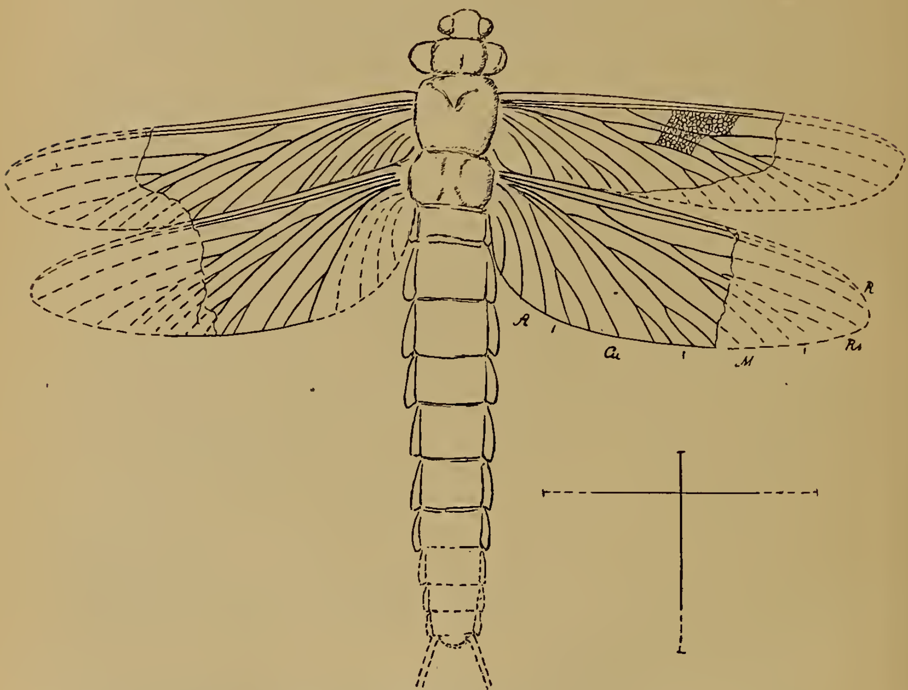


FIG. 1. *Athymodictya parva.* ×3.

thorax much shorter than the mesothorax, its body nearly twice as broad as long, provided with semicircular lateral lobes. Mesothorax robust, almost equal in length and breadth. Metathorax shorter, its breadth one and a half times greater than the length. Abdomen scarcely narrower than the thorax, its first segment shorter than the others, the second, the longest of all, being somewhat broader than long. All the seven segments preserved are provided with narrow lateral lobes.

Wings with very broad base, horizontally expanded. Anterior and posterior wings similar, the latter with distinctly dilated basal half. Costal area very narrow[1]; subcostal vein and radius very close together. Radial sector farther removed from the base in the anterior than in the posterior wing, separated by a rather broad space from the radius and probably provided with a single branch, cleft into about 3 twigs. Medial vein split somewhat before the origin of the radial sector into a forked anterior branch and a posterior branch divided into 3 twigs. Anterior branch of the cubitus rising very near the base, simple in the anterior wing and forked in the posterior; posterior branch of the cubitus split into a simple and a forked twig. Three to four short anal veins. All the spaces between the veins filled with a delicate irregular network, one of the characteristics of the Dictyoneuridæ.

Fig. 2.

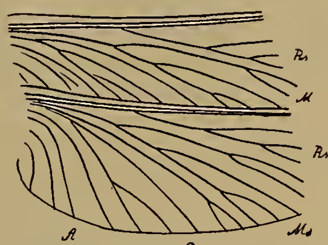


Fig. 2. *Athymodictya parva* (negative of left wing). × 2·5.

Holotype in Peabody Museum, Yale University, Cat. No. 18.

Family SYNTONOPTERIDÆ, new family.

A splendid anterior wing of a more highly specialized Palæodictyopteron induces me to establish a new family, which may be placed near the Mecynopteridæ and Lithomantidæ. The most striking characteristics of the new family are the division of the wing into four nearly equivalent triangular areas, occupied by the sector, the two halves of the media, and the cubitus; the S-shaped origin of most of the twigs; and the comparatively long-vaulted anal veins, provided with a rather great number of short branches.

SYNTONOPTERA, new genus.

Syntonoptera schucherti, new species. Fig. 3.

Negative of a left anterior wing with broad base. Length about 90^{mm}, of which 80^{mm} is preserved. Costal area broad near the base, with pointed apex. Costal and subcostal vein convergent; radius nearly parallel with the subcosta and moderately far removed. Radial sector rising at about one-quarter of the length of the wing, separated from the radius by a distance equal in breadth to the radio-subcostal space, with but (?) 3 slightly vaulted branches, one of which (the proximal) forms a terminal fork. The space occupied by the sector is comparatively small. The medial vein splits near its origin into 2 equivalent branches. Each of these forms a large fork in about the center of the wing. All their main branches run in regular arches to the border of the wing. From the anterior branch of the first fork rise, moreover, 4, from that of the second fork 3, S-shaped twigs, directed backward and outward. The posterior branch of the second fork sends forth 2 short twigs directed forward and outward. The cubital vein splits near the base into 2 main branches; the posterior is split

FIG. 3.

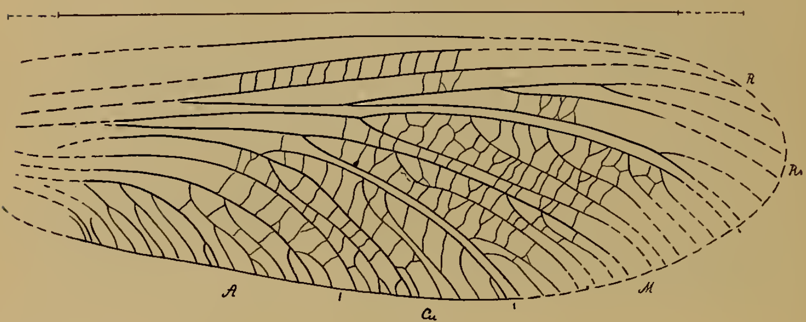


FIG. 3. *Syntonoptera schucherti.*

no further, the anterior giving origin to 3 main twigs, the foremost of these widely diverging and sending forth 4 S-shaped twigs directed backward. Each of the 2 other main twigs forms 3 short apical veinlets. The 2 long-vaulted anal veins, directed like the branches of the cubitus to the posterior margin of the wing, send out 3 or 5 partly simple, partly forked S-shaped branches. Of a third anal vein there is but a fragment to be seen.

By the peculiar distribution of the veins and by the parallel position of the last radial with the first medial branch, of the last medial with the first cubital branch and by the bipartition of the medial vein, the surface of the wing seems to be divided into 4 triangular areas almost equal in value.

It is of great interest to see the manner in which the convex and concave veins alternate in this wing. We find here a proof that the position of the veins above or below merely follows mechanical rules and has nothing to do with the origin of the veins. The costa is convex, the subcosta concave; the radius convex, its sector concave; of the sector branches, the first and the third are concave, the second convex; the first main fork of the media is convex, the second concave and their branches again alternate like those of the sector; the anterior branch of the cubitus is convex, the posterior concave, the twigs like those of the media; first anal vein convex, second concave.

The spaces between all the main branches and veins are traversed by cross veins, sometimes forming a diffuse network.

Many of the twigs or branches of the longitudinal veins have the appearance of intercalary veins like those of Plectoptera and Odonata, but this is only a superficial resemblance caused by their strongly S-shaped curve.

Holotype in Peabody Museum, Yale University, Cat. No. 19.

Family uncertain.

AMOUSUS, new genus.

Amousus mazonus, new species. Fig. 4.

The basal third, 50mm long, of probably a posterior wing. There are to be seen the nearly straight costa, the moderately remote subcosta and the radius, whose sector evidently rose in

FIG. 4.

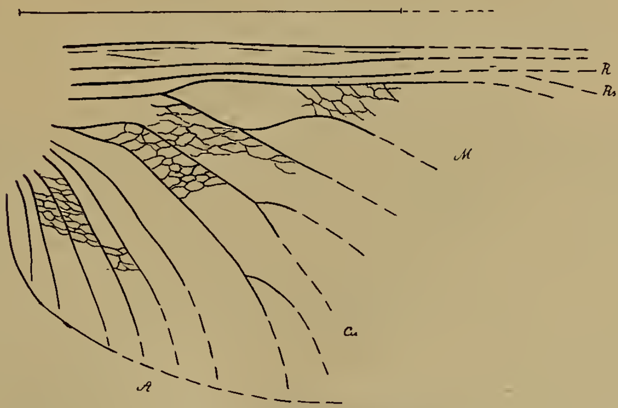


FIG. 4. *Amousus mazonus.*

the second third of the wing. The medialis splits near the base, the anterior branch running for a short distance close together with the radius, the posterior branch soon splitting into 2 twigs. The cubitus is divided immediately after its origin, its 2 forked branches running steeply to the posterior margin. Farther backward follow 6 simple short anal veins, vaulted in the characteristic manner. Interstices filled with irregular network resembling that of the Dictyoneuridæ, to which family this fossil possibly may belong.

Holotype in Peabody Museum, Yale University, Cat. No. 20.

DIEXODUS, new genus.

Diexodus debilis, new species. Fig. 5.

The specimen consists of 21mm of the basal half of a left (? posterior) wing. Costal area moderately broad, pointed. Costa and subcosta nearly straight, radius close to and parallel

FIG. 5.

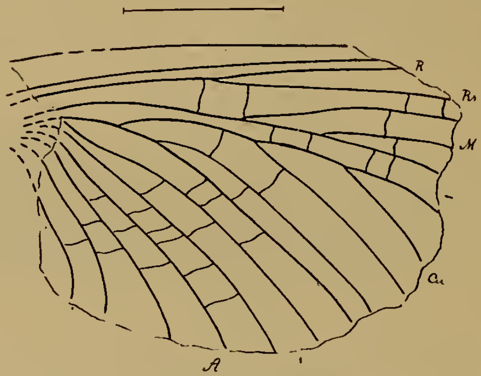


FIG. 5. *Diexodus debilis* (negative). × 2·8.

with the subcosta, sector rising at about a quarter of the length of the wing. The media sends forth its first branch somewhat distally of the origin of the sector and splits soon after into 2 branches. Cubitus forked very near the base, the anterior main branch splitting into 2 branches, the first of which again splits into 3 twigs running in a long vault to the posterior margin, the second forming only a long fork. The second main branch remains undivided. Of the 5 anal veins to be seen, some may have a common stem. Cross veins widely spread.

This species possibly may belong to the Lithomantidæ.

Holotype in Peabody Museum, Yale University, Cat. No. 21.

SCEPASMA, new genus.

Scepasma gigas, new species. Fig. 6.

A fragment, 60mm long, of the anal region of a posterior wing which had probably a length of 180mm and evidently was very broad. There are preserved: a strong vein, split into 3 branches, probably the cubitus; 2 long forked anal veins strongly curved downward; and 10 simple anal veins, joined together by delicate and irregular cross veins, forming a diffuse network.

Though this anal area by the somewhat fan-like arrangement of the numerous anal veins recalls the anal areas of more highly specialized orders, there is no support for the opinion that it could be folded.

I am not able to say to which category this giant species may belong, but it is certainly a Palæodictyopteron.

Holotype in Peabody Museum, Yale University, Cat. No. 22.

Fig. 6.

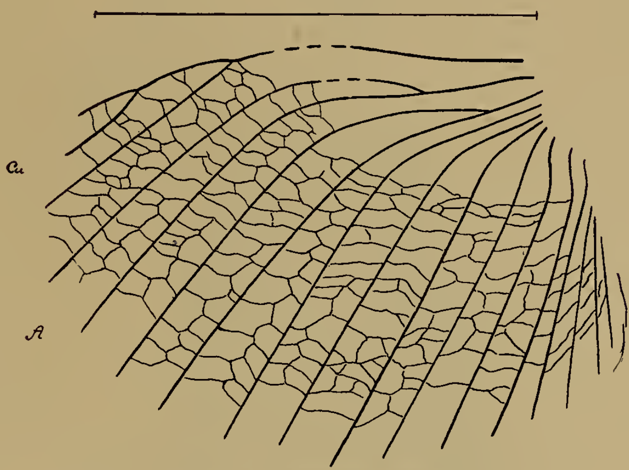


Fig. 6. *Scepasma gigas.*

Ametretus, new genus.

Ametretus lœvis, new species. Fig. 7.

A fragment of 37^{mm} from the base of a ? posterior wing measuring probably about 150^{mm}. Costa slightly vaulted, parallel with and rather remote from the subcosta, which gives off oblique simple or forked veinlets in the costal space. The simple basal pieces of the radius and of the medialis are followed by the cubitus, which is curved downward, splitting into 3 branches. Of the 8 anal veins, which I can distinguish, the first, fourth and sixth are forked, the fifth trichotomous, the others simple. I cannot see cross veins.

This wing seems to belong to one of the more highly specialized Palæodictyoptera, having a narrower base and no network between the veins.

Holotype in Peabody Museum, Yale University, Cat. No. 23.

FIG. 7.

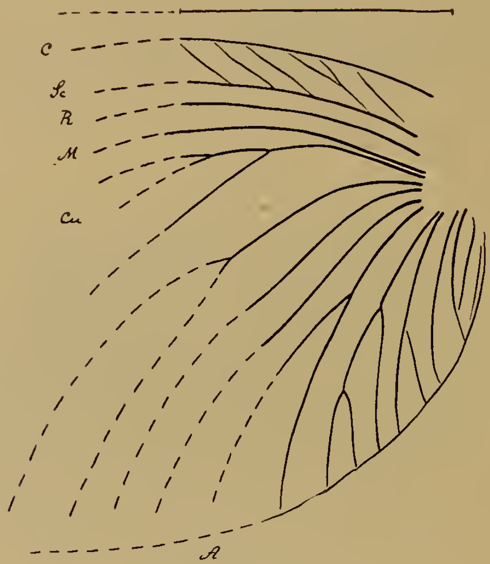


FIG. 7. *Ametretus lævis.*

Order PROTORTHOPTERA Handlirsch.

Family SPANIODERIDÆ Handlirsch.

SPANIODERA Handlirsch.

I have based this genus on a single species. Having now before me 7 other forms, it is possible to make a more exact description of the generic characters.

Anterior wing generally with rounded apex. Costa marginal; subcosta shortened, uniting with the radius; radius simple, not split at its apex; sector rising very near the base but never cleft before the middle of the wing, forming only a small number of branches; medial vein cleft near the base into 2 main branches, remaining either simple or splitting into a few twigs. The medialis is always free and never meets with the sector. Cubitus long, more or less S-shaped, with 3-6 simple or forked branches, bent downward to the posterior margin.

Anal area limited, comparatively slender and filled by a moderate number of sinuate veins. Cross veins oblique in the costal area, stretched and diffuse in the other areas. Posterior wing similar to the anterior, but provided with a large folded anal lobe. Prothorax elongated. Head apparently with prognathous mouth parts. Legs homonomous, moderately long.

FIG. 8.

FIG. 8. *Spaniodera longicollis.* ×1·8.

Spaniodera longicollis, new species. Fig. 8.

Prothorax very slender, 10mm long. Anterior wing 34mm. Very similar to *S. ambulans* Handlirsch, from which it may be distinguished by the longer neck and by some details in the wing venation. Apex of the wings broadly rounded; space between the radius and its sector moderately narrow; sector cleft into 3 branches; media forked very near the base, its anterior branch forming a long fork with, in turn, forked branches in the right wing, a simple shorter fork in the left; posterior main branch of the media simple; cubitus provided with 1 forked and 4 simple branches in the right, with 6 simple branches in the left wing. Anal area containing 6 veins.

Holotype in Peabody Museum, Yale University, Cat. No. 24.

Spaniodera lata, new species. Fig. 9.

Anterior wing 30^{mm} long and comparatively broad. Sector very far removed from the radius, split into only 2 branches. Medial vein branched near the base; in the right wing the

Fig. 9.

Fig. 9. *Spaniodera lata.* × 2·6.

anterior, in the left wing the posterior of these two main branches is forked. Cubitus giving rise to 4 branches, the first of which is forked in the left, the second in the right wing. Costal and subcostal area filled by numerous oblique cross veins; the other cross veins far removed. Anal area showing about 7 veins of a peculiar specialization.

Holotype in Peabody Museum, Yale University, Cat. No. 25.

Spaniodera elatior, new species. Fig. 10.

Prothorax slender, measuring 8mm. Anterior wings 38mm. Subcosta strongly shortened, scarcely reaching the outer half of the wing. Cross veins in the costal and subcostal area much

Fig. 10.

Fig. 10. *Spaniodera elatior.* ×2.

less numerous. Sector far removed from the radius, split into 3 twigs. Media cleft near the base into an anterior forked and a posterior simple branch. Cubitus with 4 branches, the third of which is forked in the right wing. Anal area filled by 7–8 simple veins.

Holotype in Peabody Museum, Yale University, Cat. No. 26.

Spaniodera schucherti, new species. Fig. 11.

Anterior wing quite elliptical, not so distinctly enlarged in the apical half as in the other species, 30mm long. Sector twice forked. Medial vein cleft at a greater distance from the base, much nearer the middle of the wing, its twigs bent distinctly downward to the posterior margin of the wing, the anterior

Fig. 11.

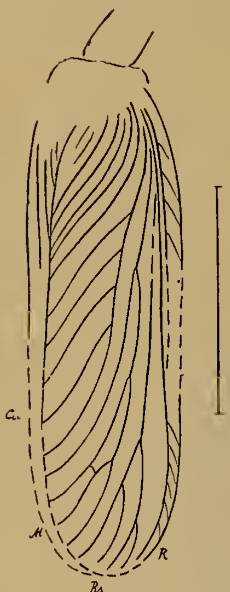


Fig. 12.

Fig. 11. *Spaniodera schucherti.* ×2. Fig. 12. *S. acutipennis.* ×2·5.

one split into 3 twigs, the posterior simple. Cubitus somewhat shortened, with but 4 simple branches. Anal area less slender, provided with 7 simple veins.

Holotype in Peabody Museum, Yale University, Cat. No. 27.

Spaniodera acutipennis, new species. Fig. 12.

Length of the anterior wing 33mm. Apex distinctly pointed. Sector twice forked. Media cleft near the base, its anterior branch with a terminal fork, its posterior branch simple. Cubitus shortened, with but 3 branches. Only a few anal veins.

Holotype in Peabody Museum, Yale University, Cat. No. 28.

Spaniodera parvula, new species. Fig. 13.

The smallest of all known species; the wings are only 22^{mm} in length. Prothorax 5^{mm}. Sector forming only a simple fork. Anterior branch of the media trichotomous, posterior branch simple. Cubitus long, with 5 branches. Posterior leg very slender and comparatively long.

Holotype in Peabody Mnseum, Yale University, Cat. No. 29.

FIG. 13.

FIG. 13. *Spaniodera parvula.* ×3.

FIG. 14.

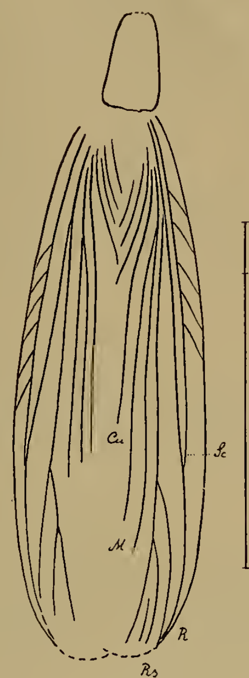


FIG. 14. *S. angusta.* ×1·9.

Spaniodera angusta, new species. Fig. 14.

Of a very slender shape. Length of the anterior wing 38^{mm}, of the pronotum 7^{mm}. Radial sector split into 3 or 4 twigs. Media cleft very near the base.

Holotype in Peabody Museum, Yale University, Cat. No. 30.

Note.—Some of the species described by Scudder and Melander may possibly belong to the genus *Spaniodera*. This would be the case with *Propteticus infernus* Scudder, if the drawing of the subcosta should prove to be wrong. The same thing is true of *Camptophlebia clarinervis* Melander and *Paracheliphlebia extensa* Melander, perhaps also of *Miamia bronsoni* and *Dieconeurites rigidus* Scudder. All these forms need careful reëxamination.

Dieconeura Scudder.

Dieconeura mazona, new species. Fig. 15.

Body conspicuously long and slender. The 3 segments of the thorax nearly equal in length; prothorax narrow, about

Fig. 15.

Fig. 15. *Dieconeura mazona.* ×2·5.

one and a half times as long as broad, 3·5^{mm} long. The head seems to have been short, with strongly vaulted lateral eyes. Abdomen narrower than the thorax, the segments becoming shorter from the first to the fourth, then increasing to the eighth and ninth. Apex of abdomen extending beyond the wings.

Anterior wing slender, 25mm in length, its apical border obliquely rounded. Subcosta shortened, united at its apex with the radius and with the costa. Radius reaching to the apex of the wing, not split; its sector rising at one-fourth of the wing length, giving off 3 simple and arched branches. Media cleft about in the middle of the wing, its anterior main branch uniting for a short distance with the sector, then removing again and forming a terminal fork. The posterior main branch of the media simple. Cubitus strongly S-shaped, with 3 or ?4 simple branches, bent to the posterior margin. Anal area long.

In the posterior wing the sector has 4 simple branches. The media is a long fork, quite independent of the sector.

Holotype in Peabody Museum, Yale University, Cat. No. 31.

Family SCHUCHERTIELLIDÆ, new family.

This family is based on a rather incomplete anterior wing, undoubtedly belonging to the Protorthoptera, but differing essentially from all the other types of this order. *Protokollaria* alone affords a comparison.

Schuchertiella, new genus.

Schuchertiella gracilis, new species. Fig. 16.

A right anterior wing, reaching about 30mm in length, only 19mm of which is preserved. The form of the wing seems to

Fig. 16.

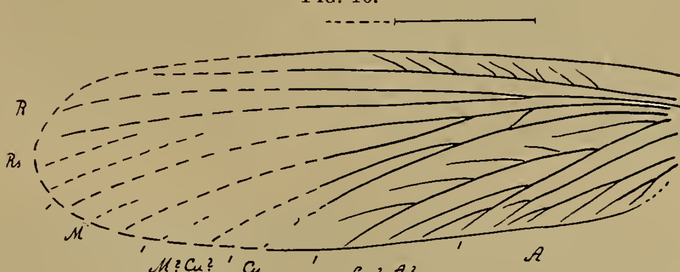


Fig. 16. *Schuchertiella gracilis* (negative of right wing). × 3.

have been an elliptical one, with slightly arched anterior margin. Costal area moderately broad, the subcosta very well developed, united with the marginal costa by oblique cross veins and certainly not very much shortened. Radius nearly parallel to the subcosta and no farther removed than the subcosta from the costa. Radial sector rising at about a quarter of the length, splitting about the middle of the wing, probably into a few branches only. Medial vein cleft somewhat after the origin of the sector into 2 main branches, which probably were forked again in the apical half of the wing. The media is followed by a long vein, slightly curved down toward the posterior margin and forked somewhat before the middle of the wing. This vein may be either the whole cubitus or the anterior branch of it and is attached to the media by an oblique bridge which we must suppose to be a proximal branch of the media, uniting for but a short space with the cubitus. This interpretation being correct, it would tend to reclaim the following richly ramified vein for the cubitus, for it is not to be assumed that the cubitus could be reduced to a simple vein. In the other case it would be possible to designate the above mentioned richly ramified vein as the first anal vein. As undoubted anal veins we must acknowledge the 3 oblique veins provided with terminal forks, which close the venation at the posterior angle of the wing. I see no cross veins but many small folds, which induces me to suppose that this wing was a delicate and membranous one.

Holotype in Peabody Museum, Yale University, Cat. No. 32.

Family GERARIDÆ Handlirsch.

The Yale collection contains several new forms evidently belonging to this family. The examination of these leads me to make some corrections in my first description.

The prothorax is not, as I supposed, short and stout, but on the contrary forms a long neck, which I previously had held for a part of the head. The new material shows that this family has no close relationship to the Œdischiidæ, approaching rather to the Spanioderidæ, from which it principally differs by the much more expanded radial sector and the much more reduced cubitus. The subcosta shortened, but discharging into the costa, not into the radius. Costa marginal.

Gerarus Scudder.

Prothorax with a broad base, either provided with tubercles or smooth, but in every case produced into a long, neck-like part bearing the head.

Gerarus latus, new species. Fig. 17.

Anterior wing elliptical, nearly three times longer than broad, measuring 44^{mm}. Subcosta not conspicuously shortened, with numerous oblique cross veins, and equally far removed from the costa and from the radius, the latter nearly reaching the apex of the wing. Sector rising very near the base, moving far away from the radius and sending obliquely toward the apical border 6 partly simple, partly forked branches, the first of which rises quite in the basal half of the wing. Medial vein independent, not meeting with the sector and branched in a singular manner: beginning from the base, we first find 2

Fig. 17.

Fig. 17. *Gerarus latus.* × 1·8.

Fig. 18.

Fig. 18. *G. collaris.* × 1·4.

short branches directed backward and not reaching the margin; the stem then bends obliquely to the posterior margin, emitting obliquely forward 4 branches which retain the primitive direction of the media. Cubitus comparatively little expanded, scarcely reaching the apical half of the wing and giving rise to but 3 short branches which are directed backward. The long and pointed anal area may have been provided with about 5 veins. Traces of the long neck are to be seen.

Holotype in Peabody Museum, Yale University, Cat. No. 33.

Gerarus collaris, new species. Fig. 18.

This form seems to be very nearly related to *G. longus* Handlirsch and may possibly be but a variety of this species. The anterior wings have a length of 52^{mm}. Subcosta strongly shortened, extending only a little distance in the apical half of the wing and provided with numerous oblique veinlets very regularly arranged. Radial sector differing somewhat in both fore wings; with 5 branches in the right, the first of which forms a short apical fork, the second and third trichotomous, the fourth and fifth dichotomous; and with 6 branches in the left wing, the third of these being trichotomous, the fourth and fifth simple, the sixth forked. Media cleft into a long fork, the branches of which fork again. Cubitus strongly reduced, probably with not more than 1 or 2 branches. Sector, media and cubitus very close together near the base. Prothorax bottle-shaped, without tubercles, more than twice as long as broad at the base.

Holotype in Peabody Museum, Yale University, Cat. No. 34.

Gerarus (?) reductus, new species. Figs. 19, 20.

As only fragments of the positive and negative of the right anterior wing and of the left anterior and posterior wing are preserved, I cannot be positive on the point of the generic

FIG. 19.

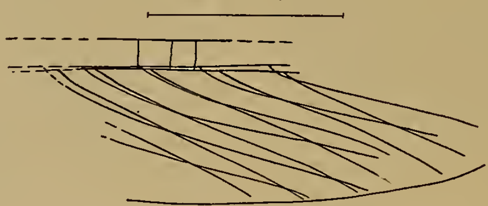


FIG. 19. *Gerarus reductus* (negative of two left wings). ×2·2.

determination of this fossil. The total length of the wing may have surpassed 40^{mm}, the breadth about 12^{mm}. Costal margin gently curved, subcosta shortened, cross veins of the costal area forming a network near the base, elsewhere far remote, simple and oblique. Radial sector rising very near the base, not very far removed from the radius and provided with about 6 very regular simple branches directed obliquely backward and outward. The media is cleft near the origin of the sector into 2 main branches, the anterior of these forming a large fork, the posterior cleft no farther. There are to be seen but two branches of the cubitus, the anterior of which is

FIG. 20.

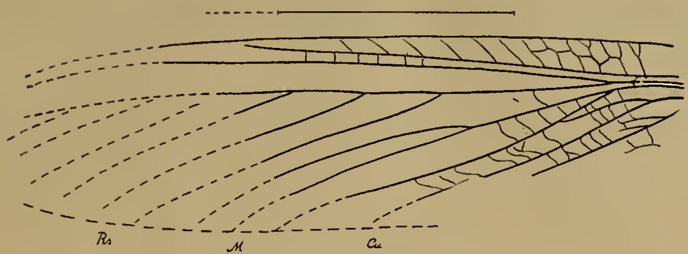


FIG. 20. *Gerarus reductus* (negative of right fore wing). ×2·2.

united to the media by an S-shaped twig. The cross veins are straight between subcosta, radius and sector, waved and sometimes ramified in the medial and cubital region.

Holotype in Peabody Museum, Yale University, Cat. No. 35.

Gerarus longicollis, new species. Fig. 21.

Prothorax 14^{mm} in length, provided in the basal part with 2 lateral tubercles and with another situated in the middle of the hind margin; the neck-like slender anterior portion of the prothorax conspicuously thin and long. Head evidently broader than the neck. Anterior wing 36^{mm} long. Costal area broad, subcosta extending about two-thirds of the wing. Radius conspicuously far removed from the costa in the apical third. Sector rising at a quarter of the length, first diverging from and then converging with the radius; of its 4 branches the first is forked. Media cleft somewhat below the origin of the sector, its posterior main branch simple, the anterior forked into 2 twigs, the anterior of these uniting for a short distance with the radial sector. Cubitus free, giving rise to probably but 2 branches directed backward.

The posterior wing being very fragmentary, it is difficult to distinguish media and cubitus, but it is possible to see by the different arrangement of these veins that there was present a large anal lobe.

Holotype in Peabody Museum, Yale University, Cat. No. 36.

GERARULUS, new genus.

Evidently related to *Gerarus* but distinguished by the strongly expanded apical half of the anterior wing and by the radius being branched before the end. Costa marginal; subcosta shortened, united with the costa. The space between the sector and the radius conspicuously enlarged, sector with numerous branches, media cleft into 2 ramified main branches. Cubitus of the anterior wing cleft near the base into 2 forked main branches, the anterior of which unites for a short dis-

Fig. 21.

Fig. 21. *Gerarus longicollis.* ×1·8.

tance with the posterior branch of the media. Anal area of the anterior wing not distinctly limited, with but few partly ramified veins. Posterior wing with an anal fan.

Gerarulus radialis, new species. Fig. 22.

Length of the anterior wing about 30^{mm} (24^{mm} only being preserved). Costal area comparatively narrow, extending about two-thirds of the wing and filled by simple and very regularly distributed oblique cross veins. Radius very near the subcosta, provided in the apical third with branches directed toward the costa. Sector rising at about a quarter of the length, widely diverging and giving off about 9 very regular branches, the first of which is forked. Media cleft into 2 main branches, the anterior of which closely approaches the sector. Each of these main branches splits into 3 twigs. Cubitus cleft immediately after the origin, its long anterior branch touching for a moment the media and then splitting

FIG. 22.

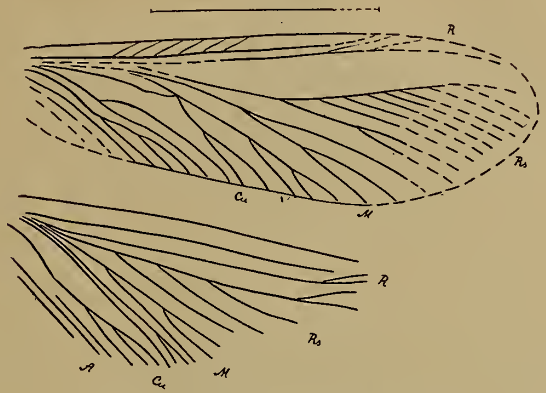


FIG. 22. *Gerarulus radialis.* ×2·2.

into 2 twigs, the posterior branch forming a long fork. First anal vein sinuated, with 2 twigs directed backward. In addition, there are ? 3 short and simple anal veins to be seen.

In the posterior wing the radius is ramified in a similar manner to that in the front wing. The sector rises very near the base, does not diverge so far and gives off its branches much nearer the base. Media cleft very near the base into 2 ramified branches. Cubitus with a simple anterior branch approaching the media and with a waved posterior branch splitting into a few twigs. Anal veins simple and straight.

Holotype in Peabody Museum, Yale University, Cat. No. 37.

ANEPITEDIUS, new genus.

The following species, which I consider the type of this new genus, is likewise very closely related to *Gerarus* and shows a slender pear-shaped prothorax, forming a long neck. The long wings, with a strongly shortened subcosta, meeting with the costa. The radius in its apical portion sends forth some ramified S-shaped branches, directed forward. The sector rises near the base and apparently gives off but a few branches.

The media likewise forms only few branches and unites in the anterior wing with the sector by a short cross vein but remains quite independent in the posterior wing. Anal area of the posterior wing enlarged and evidently fan-like.

FIG. 23.

FIG. 23. *Anepitedius giraffa* (negative). ×2·2.

Anepitedius giraffa, new species. Figs. 23-25.

Prothorax 14mm long, somewhat more than twice as long as broad at the base, produced into a neck-like form, traversed by a ridge and evidently depressed on the sides of the basal half.

Wings long and slender, measuring about 40mm, 33mm of which is preserved. By the superposition of all the four wings, the venation becomes very confused and difficult to decipher. Subcosta scarcely extending below the middle of the wing. Costal area comparatively narrow, traversed by about 8-10 regular oblique cross veins. Radius at the same distance from the subcosta as the latter is from the costa and giving rise to 2 S-shaped forked branches, directed toward the

Fig. 24.

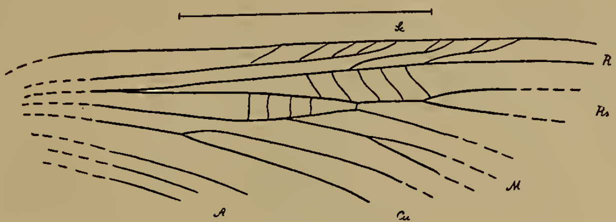


Fig. 24. *Anepitedius giraffa* (anterior wing). ×2·2.

costal margin. Sector rising near the base and separated from the radius by a broad interstice, traversed in the anterior wing by oblique, in the posterior by straight cross veins. The sector seems to have had but few branches. Media cleft in the anterior wing not far above the middle, its anterior branch

Fig. 25.

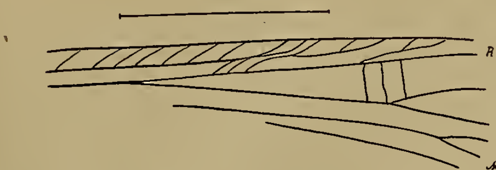


Fig. 25. *Anepitedius giraffa* (posterior wing). ×2·2.

advancing in a blunt angle until near the sector, uniting with it by a short and strong cross vein; the posterior branch is forked. In the posterior wing the bifurcation of the media seems to take place quite near the base, the anterior branch being independent of the sector and forking again near the end, the posterior apparently remaining undivided. Cubitus forming in the anterior wing a quite free vein cleft into 2 long branches. Of the anal veins I cannot see more than 3, which are almost parallel.

Holotype in Peabody Museum, Yale University, Cat. No. 38.

Family APITHANIDÆ, new family.

A very singular slender insect, differing from all other groups of the Protorthoptera, induces me to establish a new family.

The pear-shaped prothorax is of a moderate length; the mesothorax somewhat enlarged, bearing the comparatively broad anterior wings, which show a singularly specialized venation and could be laid backward over the abdomen. The metathorax conspicuously shorter. Abdomen slender, its first segment being the shortest of all, nearly twice as broad as long, the second about quadrate, the following to the seventh much longer than broad. The end of the abdomen and the posterior wing not being preserved, I am not able to say anything regarding the appendages and the anal lobe. The (? anterior) legs were short and delicate.

The venation of the anterior wing is a characteristic one: the costa marginal; subcosta shortened, united with the costa; radius with a short sector, rising outward from the middle of the wing and forming a simple fork. Media independent, cleft near the middle of the wing into 2 branches. Cubitus divided near the base into 2 main branches, the anterior strongly waved and making a short terminal fork, the posterior trichotomous. Anal area slender, reaching half the length of the wing and containing few veins. Cross veins simple and oblique in the costal and subcostal area, elsewhere evidently very rare.

Apithanus, new genus.

Apithanus jocularis, new species. Figs. 26, 27.

Prothorax 5^{mm} long, one and a half times longer than broad. Mesothorax nearly quadrate. Metathorax one and a half times broader than long. First segment twice as broad as long, shorter than the metathorax; second segment quadrate; the third to the seventh each longer than broad. The middle line of the abdomen showing tubercles on the base and apex of each segment. The femora of probably the fore legs short and delicate, doubtless not exceeding the length of the prothorax. Anterior wings 30^{mm}, three and a fourth times longer than broad, dilated in the apical half. Apical margin obliquely rounded. Costa marginal, slightly waved. Subcosta extending nearly two-thirds the length of the wing, uniting with the costa and giving off about 7 oblique veinlets. Radius very close to the subcosta in the basal third, farther outward more remote, the interstice being traversed by 5 oblique cross veins. Sector not rising before the middle of the radius, from which it is separated by a broad interstice, and forming only one broad fork. Media quite free, cleft somewhat before the middle into 2 branches converging toward the margin, the anterior of these branches being attached to the posterior branch of the sector by a long, oblique cross vein. The cubitus running nearly parallel with the posterior branch and with the stem of the media, splitting quite near the base into an anterior branch forming a short apical fork and into a posterior branch cleft into 3 long branches which descend to the posterior margin. Anal area long and lancet-shaped, showing dis-

FIG. 26.

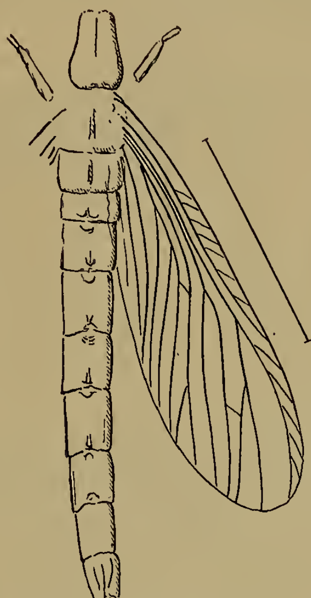


FIG. 26. *Apithanus jocularis.* × 2.

tinctly only 2 veins, but probably there were 2 more which are not preserved.

Holotype in Peabody Museum, Yale University, Cat. No. 39.

Family NARKEMIDÆ, new family.

Anterior wings laid backward over the abdomen, broad, elliptical, with a broad costal area; much shortened subcosta uniting with the radius and giving rise like the free end of the radius to very regular oblique veinlets reaching the costa and being themselves united by cross veins. Sector rising at about a quarter of the wing length, giving off a small number of branches which are directed toward the apical border. Media independent of the radius, simple and only provided with a short apical fork. Cubitus very well developed, cleft near the base, the anterior main branch splitting by repeated forking into a greater number of twigs, one of which reaches the media, the others going parallel with the branches of the

FIG. 27.

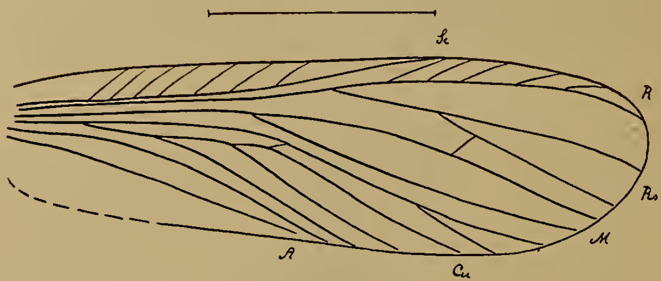


FIG. 27. *Apithanus jocularis.* ×2·9.

sector and with the media to the margin; the posterior main branch splits into a bundle of divergent twigs, falling obliquely to the posterior margin. Anal area broadly lancet-shaped, separated from the wing by an S-shaped waved vein. All the interstices between the main veins are bridged over by vertically arranged simple cross veins.

It is a curious fact that original color patterns, consisting of a number of broad and very regular transverse bands, have resisted destruction through petrifaction. Similar patterns have been found in some fossils of Commentry, as in *Cnemidolestes* and *Protophasma.* Unfortunately the venation of the Cnemidolestidæ not being sufficiently known, it is at present impossible to suppose that any relation exists between the two groups because of their similar color patterns.

NARKEMA, new genus.

Narkema tæniatum, new species. Fig. 28.

Front wing elliptical, scarcely two and a half times as long as broad, about 43^{mm} in length, 37^{mm} of which is preserved. Costal area very broad, subcosta extending but little beyond the middle of the wing, uniting with the radius. Radius not far removed from the subcosta, not reaching quite to the tip of the wing and sending forth, like the subcosta, a number of very regular oblique and straight veinlets, directed forward and bridged over by delicate cross veins.

The sector rises at a quarter of the length, runs parallel to and not far from the radius and sends off 2 simple and 1 forked branch, directed toward the margin. The media passes near the radius and sector without meeting with them and forms a great and wide bow, only forking near the end. A great deal of the wing is occupied by the cubitus, cleft near the base, the anterior main branch splitting into 2 twigs, the posterior end of which is not divided and attains the posterior margin, while the anterior approaches the media, sending a small branch to this vein, and then regaining the original direc-

FIG. 28.

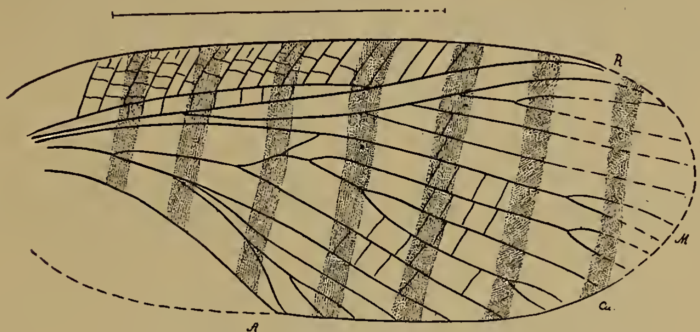


FIG. 28. *Narkema tæniatum.* ×2.

tion splits into 3 twigs, the first and third of these forming apical forks. The posterior main branch splits into 3 divergent twigs, the hindmost of which again splits into 3 twigs. The first anal vein being gently S-shaped, allows us to suppose that there was a lancet-shaped anal area, provided with a small number of veins. Cross veins have been present in a rather great number; they are vertically situated on the main veins.

Both wings are equally decorated by 7 transverse bands extending across the whole wing without regard to the venation.

Holotype in Peabody Museum, Yale University, Cat. No. 40.

Family CACURGIDÆ, new family.

In this family, which I propose provisionally, are placed forms regarding which I cannot with certainty discern whether they are Protorthoptera or Protoblattoidea. They all agree in the sector rising at a greater distance from the base and in the presence of a short oblique vein, going from the stem of the media to the cubitus and forming a sort of basal cell. This vein evidently is a branch of the media, which unites with the cubitus for the entire distance or for a certain space only. The cubitus being separated from the anal area by a comparatively large space occupies a great part of the wing. Costa marginal. Cross veins irregular, oblique and often ramified, the ramifications of the main veins never being very rich.

I consider as the type of this family a new genus, *Cacurgus*, which is the best preserved of all. Besides this another new genus, *Spilomastax*, is placed here, and of the previously described forms, *Palæomastax* Handlirsch from the Westphalian of Belgium, *Archimastax* Handlirsch from Fayetteville, Arkansas, and *Archæologus* Handlirsch from Mazon Creek. These latter I had described as genera of doubtful position. It is not impossible that *Axiologus thoracicus* Handlirsch may also belong in this family.

CACURGUS, new genus.

Cacurgus spilopterus, new species. Figs. 29, 30.

Both anterior wings are preserved, partly crossed over the abdomen in a quite natural position, so that there can be no

FIG. 29.

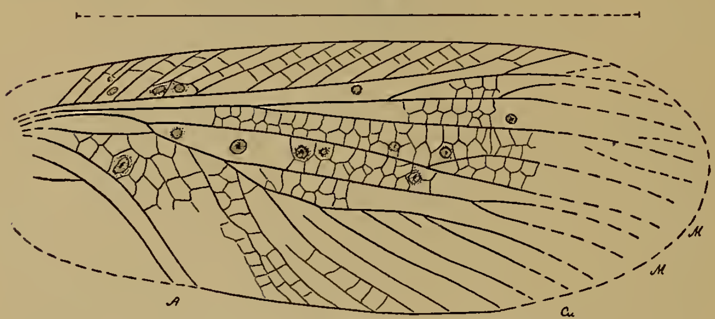


FIG. 29. *Cacurgus spilopterus* (right fore wing). ×1·25.

doubt that they belong to the same individual. Nevertheless the venation seems to be rather different in both wings.

The form of the wing probably has been an elliptical one, two and a half times longer than broad, measuring about 75mm in length. Costa marginal. Costal area broad, with numerous oblique branches from the subcosta, bridged over by cross veins. Subcosta attaining three-quarters the length of the wing and uniting with the costa. Radial sector rising somewhat before the middle and splitting into but 3 branches. The radius itself gives off 2 strongly ramified branches, directed toward the costal margin. The media in its basal part bends closely toward the radius and is cleft before attaining the end of the first quarter of its length. Its anterior main branch continues in a normal way and splits in the apical half; the posterior has the aspect of an oblique cross vein uniting the media with the cubitus. At a certain distance from this point of fusion we see that in the right wing a new separation of the two veins takes place, the branch of the media forming a large terminal fork. In the left wing there is but a temporary separation of the fused veins, which then unite again and remain so to the end. Nevertheless it is possible, but not determinable, that the last fork of the cubitus may take rise from this second medial branch. In this case we would be forced to assume a strong reduction of the cubitus in the left wing in comparison to the right, where this vein

FIG. 30.

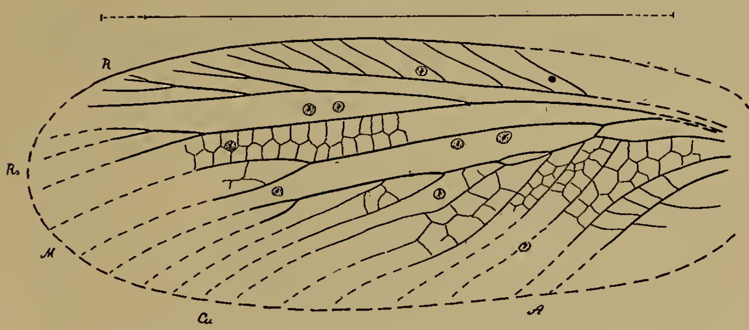


FIG. 30. *Cacurgus spilopterus* (left fore wing). × 1·25.

with its 8 or 9 partly forked branches occupies the whole hind margin. There being only 8 branches in the left wing, their number would be reduced to 6 by counting the apical fork as belonging to the medial vein.

The anal area is broadly lancet-shaped, limited by an S-shaped vein and seems to have been filled by only a few veins of a similar curve. In all the broader interstices the cross veins are twisted into a moderately regular and polygonal network. Irregularly spread about there are to be found in both wings shallow, more or less regular, round bodies of different sizes, situated in darker patches of the wing membrane and showing a small groove in the middle. These structures give the impression of membrane thickenings. I probably should have regarded them as extraneous and not pertaining to the insect if they had been observed only in this case, but as they are also present in the wings of the related form *Spilomastax*, I think they will prove to be organic structures of these insects. Dr. Reis has found similar but smaller structures on the wings of one of the Protodonata of Triassic age. Tubercles on the membrane have also been found in one of the Palæodictyoptera.

Holotype in Peabody Museum, Yale University, Cat. No. 41.

SPILOMASTAX, new genus.

Spilomastax oligoneurus, new species. Fig. 31.

Two fragments evidently appertaining to the left and right anterior wing of a comparatively small insect, whose wings can be estimated at 30–35^{mm}. Subcosta far removed from the marginal costa and provided with regular oblique branches. Radius giving off its sector at about the middle. Media sending the typical short and oblique branch to the cubitus at about a quarter of its length and split into a large fork before attaining the middle of the wing. Cubitus cleft immediately after its

FIG. 31.

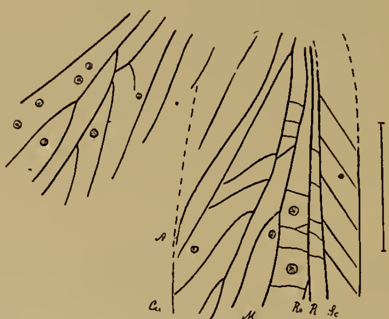


FIG. 31. *Spilomastax oligoneurus*. ×2.

origin, the anterior branch waved, sending 4 branches obliquely outward and backward, the first 2 of them not reaching the margin; but the posterior main branch running straight and undivided to the end. First anal vein gently curved, second swung forward toward the first. Cross veins irregular, here and there ramified but not twisted into a polygonal network.

Both wings show numerous quite irregularly distributed shallow round bodies similar to those in *Cacurgus*.

Holotype in Peabody Museum, Yale University, Cat. No. 42.

[To be continued.]

Art. XXIX.—*Results of a Preliminary Study of the so-called Kenai Flora of Alaska*; by Arthur Hollick.*

Introduction.

During a recent preliminary study of a series of collections of fossil plants from Alaska Peninsula, especially from the vicinity of Herendeen Bay and Chignik Bay, tentatively assumed, for the most part, to represent the flora of deposits to which the name Kenai formation has been applied, a number of facts were brought to light which are of considerable biological interest and which may prove, after critical analysis, to be of value from the standpoint of stratigraphy.

The name Kenai was originally applied to a series of beds exposed in southeastern Alaska, particularly on the shores of Kachemak Bay, Kenai Peninsula,† which at that time were regarded as Miocene or Oligocene in age but are now generally recognized as Eocene. The results attained from the recent studies indicate that, if the use of the name is to be restricted to the beds of the type locality and their equivalents elsewhere, there is also a series of beds, more or less closely associated with them stratigraphically, which may or may not be included in the formation. The ultimate inclusion or exclusion of these latter, either in whole or in part, cannot be determined, however, until all of the paleobotanical evidence has been carefully weighed and compared with whatever stratigraphic observations may be available.

For example, some of the collections contain only Tertiary species. In others, often from the same localities, there is a preponderance of Tertiary species and a minority of Cretaceous. In others the majority are Cretaceous, with certain genera which are identical with those of the Jurassic. The several collections appear to merge into each other without any abrupt break in the paleobotanical sequence, and further careful investigation will be necessary before attempting to draw any stratigraphic line intended to indicate a differentiation of the flora into one undoubtedly of Tertiary and another of Cretaceous age; but the facts may, at least, be described and their biological significance discussed.

Description of the Flora.

The flora represented in the collections thus far studied, if regarded as a unit, is unique so far as North America is concerned. There is none other described from either the United

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

† Dall and Harris, Bull. U. S. Geol. Surv., No. 84 (Correlation Papers, Neocene), p. 233, 1892.

States or Canada with which it may be satisfactorily correlated. It contains many species which are identical with those of certain well-defined Tertiary horizons in the United States and, if these species were the only ones represented, the Tertiary age of the beds in which they occur would not be questioned: such species, for example, as *Taxodium distichum miocenum* Heer, *Populus arctica* Heer, *P. Richardsoni* Heer, *Corylus McQuarrii* (Forbes) Heer, *Carpinus grandis* Ung., *Betula Brongniartii* Heer, *Paliurus Colombi* Heer, etc.

Associated with these, however, not only in collections from a single locality but frequently in the same pieces of matrix, are species which elsewhere occur in strata of recognized Cretaceous age, such as *Adiantum formosum* Heer, *Sequoia rigida* Heer, *Sagenopteris elliptica* Font., etc., and others which, if found by themselves, would almost certainly be considered as closely allied to certain Jurassic species, such as *Pterophyllum concinnum* Heer, *Anomozamites Schmidtii* Heer, *Nilssonia comtula* Heer, etc.!

When first examined, it was thought that this association of undoubted Tertiary angiosperm species with apparently Mesozoic types of gymnosperms was impossible, and that collections from different geologic horizons must have somehow become mixed; but the fact that some of these diverse floral elements were often included in the same piece of matrix proved that they must have been synchronous.

Discussion of the Flora.

Unless all of our previous knowledge and experience in relation to the beginning and subsequent evolution of the angiosperms is at fault, it is evident that the presence of highly developed angiosperm species in any flora at once precludes the possibility of regarding it as Jurassic in age. Furthermore, the fact that certain of the angiosperms in the flora under consideration are undoubted Tertiary species makes it imperative to regard the apparent identity of certain of the associated cycads with Jurassic species as untenable and to regard such apparent identity as due to superficial resemblances only. The theory that a specific type could persist throughout such a great length of time as that implied could hardly be accepted on evidence based entirely upon such inconclusive factors. The genera in which the species belong, however, are unquestionably identical with Jurassic generic types; but it is more logical to assume that such types could have continued into Tertiary times than to imagine that highly developed angiosperms could have been in existence in the Jurassic period.

While searching through paleobotanical literature for any possible description of, or reference to, a flora similar to ours, three papers were noted which have a bearing on the subject. Saporta* describes the discovery of a single species of a cycad, *Zamites epibius* Sap. (*l. c.* p. 322), in the middle Tertiary of Provence, France, associated with many of the same angiosperm genera as those represented in the Alaskan flora. He describes and figures it again in his "Études sur la Végétation du Sud-Est de la France a l'Époque Tertiare, Part III,"† compares it with *Z. formosus* Heer from the Jurassic of Switzerland, and says (*l. c.* p. 11): "....*Zamites epibius*, despite its analogy with the Jurassic genus, must necessarily be specifically distinct, especially when one realizes the vast time interval which separates them." The interest and importance which Saporta attached to this single specimen may be inferred from the lengthy discussion which he gives to it in each paper. It is possible that a small fragment in one of our collections, evidently a *Zamites*, may belong to Saporta's species.

The third paper is by Heer,‡ in which he describes and illustrates a Tertiary flora almost identical with ours, from the island of Saghalien, in northeastern Asia, where the same association of angiosperms and cycads occur and in regard to which he remarks (*l. c.* p. 9): "The most striking....is the family of the Cycads..... There are two species, which differ widely from all living ones, but which show a striking and unmistakable identity with Jurassic and Rhaetic forms." Two species of *Nilssonia* are described and figured (*N. serotina* and *N. pygmæa*). The former species is undoubtedly represented in our collections by a number of specimens, and it is interesting to note that one of his figures (*l. c.* fig. 1, pl. II) depicts this species associated with a leaf of *Populus arctica* Heer on one and the same piece of matrix: an association of species which is duplicated in several of the fragments of matrix in the Alaskan collections.

Significance of the Facts.

To those who are familiar with the factors which influence the distribution of our living flora, the presence of cycads, representing a tropical type of vegetation, associated with species of *Populus*, *Corylus*, *Carpinus*, *Betula*, *Juglans*, etc., in far northern latitudes, will appear incongruous; but the fact that such an association existed in those regions in the Tertiary period cannot be questioned. It is evident, of course, that cycads must have continued their existence somewhere throughout both Tertiary and Quaternary times, otherwise they would

* Bull. Soc. Géol. France, Ser. II, xxi, 314–328, pl. 5, f. 1–3, 1864.
† Annales Sci. Nat., Ser. V (Bot.), viii, pl. 1, f. 1, 1867.
‡ Fl. Foss. Arct., v (Mioc. Fl. Sachalin), 1878.

not be represented in our living flora. Nevertheless, so far as the paleontologic record indicates, they apparently disappeared from the southern and central parts of the North American continent in the Tertiary period and were almost exterminated in similar European latitudes at the same time, but continued to exist in northwestern America and northeastern Asia, until their descendants were in part exterminated and the remainder driven southward by the advancing cold of the Quaternary period to where they are now growing.

Their present range of distribution in the New World is between northern Mexico and Bolivia, which affords an approximate indication of the possible extremes of climatic conditions which might have prevailed in Alaska at the time when this flora was growing there. The climate could not have been colder than that of northern Mexico or southern California at the present time, if the cycads are to be regarded as adequate climatic indicators; nor could it have been much warmer, if the associated angiosperm genera are to be regarded in the same light. The logical inference is, therefore, that the climate which was synchronous with this Alaskan flora was about the same as that of southern California and Florida at the present day. We may also be warranted, apparently, in assuming that, at the time when this flora flourished, either the climate of the northern Pacific region was warmer than that which prevailed in the mid-continental areas farther to the south, or else that their meteorological conditions were not identical, thus giving rise to floral differences similar to those which prevail at the present day in the coastal and interior regions of the West.

Finally, the identity of the Tertiary floras of northwestern America and northeastern Asia is confirmatory evidence of a former land connection between the two continents in recent geologic times, which is so strongly indicated by the well recognized physiographic and topographic features.*

* See "The Probable Tertiary Land Connection between Asia and North America," Adolph Knopf. Univ. Calif. Pub., Bull. Dept. Geol., v, 413–420, 1910.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Use of Calcium Carbide for the Determination of Moisture.*—This application of calcium carbide has been discussed by Masson. Difficulties occur in the ordinary methods of determining moisture from the fact that other vapors besides water may be given off by the substance, or that the substance is oxidized and gains weight when heated in the air to expel its moisture. Calcium carbide has the advantage that water is the only ordinary substance that will react with it, and the acetylene produced by the reaction can be readily measured. Hygroscopic organic substances are mixed with an excess of finely powdered carbide, when the reaction takes place quickly without artificial heating, and the gas evolved may be measured or its pressure determined by means of a manometer. The method has been applied for the determination of moisture in wool, explosives, petroleum, etc. The author has studied the application of the method to the determination of water of crystallization in salts, and finds that salts may be roughly divided into four classes in respect to their behavior with calcium carbide. In the first are those, such as sodium carbonate and sodium sulphate, which react at once and completely. In the second class are those that react rapidly and completely only on heating, such as barium chloride. The third class, which includes such salts as copper sulphate and the alums, react, either in the cold or on heating, in such a way as to lose only a part of their water, leaving a hydrated residue which belongs to the fourth class, characterized by being quite stable towards carbide even at 170° C. It is a noteworthy fact that ammonium salts do not lose ammonia, nor do crystalline acids react as such, when these are heated with the carbide and calcium hydroxide present as a result of the acetylene production. This is to be attributed to the complete absence of free water. It is interesting to notice that various observers have found that 18^{mg} of water corresponds to $10{\cdot}5^{cc}$ of acetylene at standard conditions, while the theoretical volume is, of course, $11{\cdot}2^{cc}$.—*Chem. News*, ciii, 37. H. L. W.

2. *Action of Water upon Phosphorus Pentoxide.*—Various statements are found in the literature concerning the products of this reaction, that is, whether metaphosphoric acid, HPO_3, the pyro- acid, $H_4P_2O_7$, the ortho- acid, H_3PO_4, or mixtures of these are first formed. Balareff has now investigated this matter by allowing pure sublimed P_2O_5 to deliquesce very slowly, and more rapidly in more or less moist air, and also by throwing it directly into water. In every case where the product was examined immediately after deliquescence, only metaphosphoric acid, HPO_3, could be detected. In about 18 hours some of these products

were found to be completely converted into H_3PO_4, and the remarkable fact was noticed that HPO_3, produced from P_2O_5 as described, becomes hydrated to H_3PO_4 much more rapidly than the same compound which has been produced by the dehydration of H_3PO_4 by heating.—*Zeitschr. anorgan. Chem.*, lxix, 215.
H. L. W.

3. *The Fractional Crystallization of Argon.*—According to its position in the periodic system of the elements, argon should have an atomic weight of less than that of potassium, 39·10, instead of 39·88, the atomic weight now attributed to it. FRANZ FISCHER and VICTOR FROBOESE have attempted to fractionate it by freezing the liquid. Since argon has been purified previously by fractional distillation, they reasoned that it might form a constant boiling mixture with some unknown impurity, as is the case, for instance, with hydrochloric acid and water. However, the results of fractional crystallization were negative, so that no evidence was found that the atomic weight is not exceptional, like that of tellurium, in the periodic system.—*Berichte*, xliv, 92.
H. L. W.

4. *Qualitative Chemical Analysis;* by BASKERVILLE and CURTMAN. 8vo, pp. 200. New York, 1910 (The Macmillan Company).—Nearly every teacher of qualitative analysis writes a book on the subject, because there are many variations in the course of analysis and also many ways of presenting the subject. The book under consideration appears to be a very good one. There is a suitable amount of description and theoretical matter, and equations are very fully supplied. The analytical processes, which are given in tabular form, with numerous notes, are in general well selected. An attempt is made to have the student distinguish qualitative reactions in a somewhat quantitative way by comparing his tests with tests of measured solutions of known strength. The authors say in regard to this plan, "The value of such training cannot be overestimated. Our students rarely find any difficulty in differentiating between a trace and a significant amount." The last sentence is somewhat disappointing when compared with the preceding one, for as much might be expected of the student even without the special method of comparison.
H. L. W.

5. *Die Verwertung des Luftstickstoffs;* von Prof. Dr. J. ZENNECK. 8vo, pp. 29. Leipzig, 1911 (Verlag von S. Hirzel).—This pamphlet gives a recent lecture on the production of air-saltpeter by the aid of the electric arc. The principles of the method and a description of the apparatus are described in a very interesting way, with the aid of many excellent illustrations. The development of this new industry in connection with Norwegian water-power is of the greatest significance for the advancement of agriculture and other industries. It will be recalled that attempts to produce nitric acid commercially from the air were made in the United States a number of years ago, apparently without complete success.
H. L. W.

6. *Allen's Commercial Organic Analysis.* Volume IV. 8vo, pp. 466. Philadelphia, 1911 (P. Blakiston's Son & Co.).—This, the fourth volume, of the entirely rewritten fourth edition of "Allen," treats of Resins, India Rubber, Rubber Substitutes and Gutta-Percha, Hydrocarbons of Essential Oils, and Volatile or Essential Oils. The importance and excellence of the work are so well known that no comments in regard to details seem to be necessary, except the statement that the present volume appears to maintain the high standard of the preceding ones. H. L. W.

7. *The Absorption Spectra of Solutions;* by HARRY C. JONES and W. W. STRONG. Pp. 159 with 98 plates. Publication No. 130, Carnegie Institution of Washington, 1910.—This investigation is a continuation of the work of Jones and Uhler which was begun in 1905 and subsequently greatly extended by Jones and Anderson. (See Carnegie Publications Nos. 60 and 110; also this Journal, vol. xxviii, page 78.)

The first chapter of this monograph is devoted to a brief but excellent classification of the various types of spectra, to some of the theories of spectra, and to the methods best suited for studying specific spectroscopic problems. Chapter II deals with the apparatus used in the present investigation. The remaining ten chapters give in detail the variations in the absorption spectra of solutions of certain salts of potassium, cobalt, nickel, copper, chromium, erbium, praseodymium, neodymium, and uranium which are caused by chemical agents and by changes of temperature.

The quantity of work done is very great, since about 3000 solutions were investigated. The quality of the work is of the first class, as can be readily seen both from the text and from the 98 plates. The results obtained are too numerous to be recorded in a brief review. Suffice it to say that well-defined "solvent-bands" have been discovered for water, the alcohols, acetone and glycerol, and that all of the results seem to confirm the hypothesis of solvation as developed and emphasized by Jones.

H. S. U.

II. GEOLOGY AND MINERALOGY.

1. *Indiana. Department of Geology and Natural Resources. Thirty-fourth Annual Report.* W. S. BLATCHLEY, State Geologist. 1909. Pp. 392, with numerous maps, photographs, tables, etc. Indianapolis, 1910.—The soil survey of Indiana, begun in 1907, was continued during 1909 by A. E. Taylor and C. W. Shannon, and the statement of the important results of their work fills the larger part of the present volume. During the three seasons in which the work has been carried on, thirty-three counties in the southern part of the state have had their soils classified, mapped, and treated in detail. It is proposed to go on until the entire State has been similarly treated. The Survey

during 1909 also gathered detailed data in regard to undeveloped water-power sites of the larger streams ; this work has been under the charge of W. M. Tucker. The volume contains, further, a report in regard to the natural gas, by B. A. Kinney, and another by the State Inspector of Mines, J. Epperson.

2. *West Virginia Geological Survey. Volume Five, Forestry and Wood Industries ;* by A. B. Brooks. I. C. White, State Geologist. Pp. xiv, 481, with an envelope map of West Virginia and numerous illustrations. Morgantown, 1910.—This fifth volume of the West Virginia Geological Survey, carried on under the guidance of Professor I. C. White, is devoted to a discussion of forestry by A. B. Brooks. This is a subject of vital interest at the present time, and one which fortunately is attracting the attention of those whose political position is such as to enable them to improve the existing situation. In the early days, the State was covered by an almost unbroken forest of more than fifteen and a-half million acres in extent. Now the virgin forest has been reduced to one and a-half million acres. It is estimated that if the large number of saw mills engaged in the State were to continue in active operation as at present, they would cut all the timber in a little over sixteen years. This outlook is sufficiently serious ; but it is aggravated by the very large waste that comes in in various ways, particularly through loss by fire. The volume by Mr. Brooks discusses the subject thoroughly from various standpoints, showing the great importance of the forests in their indirect relations, as well as a source of usable timber. An interesting chapter is devoted to the agents destructive to trees, including a great variety of destructive fungi and insects. A summary is given of the forestry work now being carried forward in some twenty States ; an exhaustive list of the native trees is also added. The volume is made attractive by a large number of excellent reproductions of photographs.

The Survey has also recently issued a map of oil and gas fields, and the structural contour of Wood, Ritchie and Pleasants Counties.

3. *Geological Survey of Tennessee ;* George H. Ashley, State Geologist.—The State Geological Survey of Tennessee was established in 1909. The special purpose, scope and methods of the work planned are detailed by the State Geologist in a pamphlet, 1–A, of 33 pages, extracted from Bulletin No. 1, on Geological work in Tennessee. Other pamphlets, recently issued, are 2–A, giving an outline introduction to the Mineral Resources of Tennessee, and 3–A, on drainage problems ; these are taken from Bulletins No. 2 and No. 3, respectively.

4. *Atlas Phographique des Formes du Relief Terrestre.*—At the ninth Geographical Congress, held in Geneva in 1908, it was voted to adopt the plan proposed by MM. J. Brunhes and E. Chaix for the preparation of a collection of views, showing the different forms of terrestrial relief. A commission of eleven was appointed to report a complete plan for this enterprise at the

next Congress and to take steps to inaugurate the work. A preliminary circular has been issued, giving the plan as thus far developed. The photographs are to be published in quarto form, as separate plates, with one to two views on each ; a leaf of the same form will accompany each plate, giving a brief explanation, a chart showing the point of view, etc. It is estimated that some 500 to 600 plates will be needed to print all the types of relief as classified according to the provisional scheme adopted. If, in addition to these, regional series are arranged for, the number may be increased two or three times. The price proposed is one franc for a single plate or half that sum when a series of 100 are subscribed for. Of the various series planned the Committee wishes to go forward first with those dealing with the forms determined by tectonic conditions (faults, folds, etc.) and those connected with glacial action. Photographs relating to these two subjects are solicited and at the same time subscriptions are asked for parts of the work. Communications may be sent to one of the Executive Committee : Prof. J. Brunhes, Fribourg, Switzerland ; Prof. E. Chaix, 25 Avenue du Mail, Geneva ; Prof. Em. de Martonne, 248 Boulevard Raspail, Paris.

5. *The Illinois Oil Fields in 1910.*—R. S. Blatchley, of the Illinois Geological Survey, has issued a circular giving an account of the production of oil in the state during 1910. The estimated amount produced for the year is 35,000,000 barrels, while that of 1909 was not quite 31,000,000 barrels. Extensive explorations by drilling have been conducted at numerous points.

6. *Physical Notes on Meteor Crater, Arizona.*—The interesting but as yet unsolved problems connected with Meteor Crater in Arizona (see vol. xxx, 427) have been discussed in a paper by W. F. Magie in the Proceedings of the American Philosophical Society (vol. xlix, pp. 41–48). After describing the locality and the general character of the specimens found, he goes on to give the results obtained from some magnetic experiments with a cylinder of the Canyon Diablo iron. Briefly stated, these showed it to have a magnetic permeability about one-half that of a cylinder of Norway iron. Experiments were also made with the shale balls : one of these, nine inches in diameter and entirely oxidized, was examined as it lay in the pulverized sandstone of the outer rim of the crater. It showed strong local poles over the surface, with, in general, south polarity on top and north at bottom. Another piece of a shale ball, which at the crater showed distinct polarity somewhat irregularly distributed, after arriving at Princeton in a box with other specimens, had lost its polarity and behaved like soft iron. Much of the shale is so feebly magnetic as hardly to affect a needle even close to it. The observations of Baker in 1891 showed no evidence of a local magnetic field within the crater, while the whole variation in the dip of a vertical needle was such as might have been due to errors of observation or perhaps to local conditions, such as the presence of iron pipes in the drill holes. Whether the size of the

meteor, to which it is assumed that the crater is due, was 750 ft., or 250 ft., in diameter, it should, at a reasonable depth, seriously affect the magnetic field, and a difference of dip between extreme stations of 30′ should exist even for the smaller sized sphere. "That no such difference was found argues that the meteor was broken and scattered by the impact, or more probably, as Mr. Barringer strongly argues in his latest paper, was a cluster or swarm of small masses of iron, mostly of the shale ball variety. The possible intrinsic magnetism of these masses, coupled with the possibility that they have gradually oxidized in the depths of the crater, would account for the absence of any observed magnetic field."

The symmetry exhibited by the crater, both in the tilting of the strata of the rim and the distribution of ejected material, is such as can plausibly be referred to the impact of a body rather sharply inclined to the vertical. Some experiments were tried with a lead ball shot from a high-power rifle at an angle of 30° from the vertical into a level floor of smooth, densely packed silica. The distribution of ejected matter on either side of the surface was distinctly like that observed in the crater.

An approximate estimate is made as follows of the energy with which the meteor may have struck the earth. The work done in the excavation of the crater involves the probable ejection of some 330 million short tons. To lift the mass up and clear of the hole would have required about 16×10^{10} foot-tons; while if allowance is made also for the work of tilting back the strata and lifting the unbroken rock masses around the rim, some 20×10^{10} foot-tons in all may have been required. The larger part of the energy, however, was spent in breaking up the rock and reducing the sandstone grains to the condition of finely pulverized silica. It is estimated that over 500 million tons of rock were broken up, and one-fifth of this converted into the pulverized form. The work done against friction resulted in heat, but in general the temperature did not rise to a point sufficient to melt the quartz, as only a small amount of melted material is found. Taking 2500° C. as the outside limit of temperature, and supposing all the silica heated to that extent, the heat developed would be equivalent to $9{\cdot}25 \times 10^{13}$ foot-tons. If, however, a general temperature of 625° is assumed, that is, below the point at which the Widmanstätten figures would disappear, the heat developed would be equivalent to $2{\cdot}3 \times 10^{13}$ foot-tons. In addition to the work on the silica, a layer of hard limestone, 300 feet thick, was also broken up, and much of it pulverized. It is estimated finally that the total amount of energy expended may easily have been 60×10^{12} foot-tons. The velocity of the meteor may be put somewhere between the outside limits of 3 and 48 miles per second. If 18 to 20 miles per second be assumed as the most probable velocity, it is found that a mass of 400,000 tons would have had the amount of energy estimated as necessary for the work done in connection with the formation of the crater.

7. *Minéralogie de la France et de ses Colonies. Description Physique et Chimique des Minéraux; Étude des Conditions Géologiques de leurs Gisements;* by A. LACROIX. Vol. IV. Part I, pp. iii, 1–360; Part II, pp. 361–924. Paris, 1910 (Ch. Béranger).—The author is to be congratulated as well as the mineralogical public, in that the great work which he undertook some seventeen years since has now been brought to a successful conclusion. The four volumes which have been published give an admirable account of the minerals of France and the French Colonies. The work of the author is always thorough and original, and the description of species contains much that is important and new. Volume four, which has recently been issued in two parts, is devoted for the most part to the sulphates, phosphates, and related compounds. There is also a Supplement of more than two hundred pages, made necessary by the discoveries of recent years. The work is well printed and fully illustrated.

8. *Practical Mineralogy Simplified for Mining Students, Miners and Prospectors;* by JESSE PERRY ROWE. First Edition. Pp. 162. New York, 1911 (John Wiley & Sons).—This little book has been prepared with the object of putting before practical miners a simple and elementary description of the commonly occurring minerals and ores, with a means for their investigation. The species are grouped according to the prominent metals present, and two large tables give a summary of the characters for non-metallic and metallic minerals respectively.

9. *Calcites of New York;* by HERBERT P. WHITLOCK, Pp. 190, 27 plates. New York State Museum, John M. Clarke. Director. Memoir 13. Albany, 1910.—The species calcite is an almost inexhaustible subject from the standpoint of the crystallographer, and many important monographs have been published describing the forms from different localities. The author has now taken up the calcites of New York, which have been obtained from a wide range of different localities, among which that of Rossie has been famous for nearly 100 years. The thoroughness of this investigation will be appreciated from the fact that some twenty-five plates are needed to show the different types of crystals with their wide range of forms; among these a considerable number of new ones are noted.

10. *Les Minéraux des Pegmatites des Environs d'Antsirabé a Madagascar;* par L. DUPARC. Mem. Soc. Phys. et d'Hist. Nat. de Genève, xxxvi, fasc. 3, pp. 283–410, 1910.—In this work the author gives an account of his investigations of the pegmatite dikes of a part of Madagascar, which in recent years have furnished the markets of the world with beautiful gem-stones and fine crystals for mineral collections. In the laboratory study of the material collected the author was aided by his assistants, MM. Wunder and Sabot. A short sketch is given of the geology of the island; there follows a general description of the occurrence of the dikes, accompanied by a detailed account of the separate localities visited, where work of exploitation is going

on; the memoir closes with a chemical and physical study of the minerals collected. Some attention is also devoted to the occurrence and petrography of a number of basaltic cones and extrusions of lava encountered in his journey.

The pegmatites occur as a series of seams, dikes, stringers, and lenses, penetrating granites, gneisses, and schists, and their general character appears to be quite similar to what has been observed elsewhere in such cases. Here also they often attain gigantic dimensions in the size of the individual crystals.

The surface of the country, the hill slopes and ridges, as well as the valleys, is nearly everywhere covered by a thick deposit of laterite, resulting from decay of the rocks in place. The pegmatites are likewise changed on the surface, but their presence beneath is revealed by the large unaltered masses of quartz, which form lines of bowlders in the soil. Some of the gem material is found in the soil, but the best occurs in pockets, etc., in the yet unaltered dikes. The chief minerals accessory to the pegmatitic quartz, feldspar and mica which furnish the gems are tourmaline, beryl, and garnet with some spodumene. The tourmalines are mostly black, but splendid rubellites and green, yellow, and brown varieties occur, and, as in other localities, the same crystal often shows zones and bands of several colors. The beryls are sometimes of enormous size and furnish aquamarines as gems; sometimes they are of a sky-blue color; there occurs also more rarely a beryl of a peach-blossom color, with a different crystalline form, which makes fine gems (see this Journal, xxxi, 81). The garnet is a yellow variety of spessartite and has yielded some small gems. The spodumene is sometimes lilac (kunzite), sometimes yellowish green, or white. A large number of chemical analyses and determinations of the optical and physical properties of these minerals have been made and the results are given. The whole is a valuable and extensive contribution to our knowledge of the mineralogy of Madagascar. L. V. P.

11. *Production of Phosphate Rock in Florida during 1910.*—E. H. Sellards, State Geologist, states in a preliminary circular that the production of phosphate rock in Florida during 1910 exceeded that of any preceding year, the output having for the first time exceeded 2,000,000 tons. The total production for 1909 was 1,862,151 tons, while for 1910 the production was approximately 2,029,797 tons. This amount includes a production of 392,088 tons of hard phosphate rock and 1,637,709 of pebble rock; the increase noted, therefore, is in the latter variety, the former having diminished from a total of 527,582 tons in 1909.

12. *North Carolina Geological and Economic Survey;* Joseph Hyde Pratt, State Geologist.—The following publications have been recently issued:

Economic Paper No. 19. Forest Fires in North Carolina during 1909; by J. S. Holmes, Forester. Pp. 52, with 9 plates.

No. 20. Wood-Using Industries of North Carolina; by Roger E. Simmons, under the direction of J. S. Holmes and H. S. Sackett. Pp. 74, with 6 plates.

13. *Note on the parietal crest of Centrosaurus apertus and a proposed new name for Stereocephalus tutus;* by LAWRENCE M. LAMBE. The Ottawa Naturalist, vol. xxiv, pp. 149–151 with plate III, Dec. 1910.—Centrosaurus is one of the Ceratopsia from the Judith river (Belly river) formation of Alberta and was first described by Lambe in 1902 as *Monoclonius dawsoni* and in 1904 made the type of a new genus and species. The remains consisted of a parietal frill and a supposed nasal horn core, but now the latter is discovered to be in reality a portion of the crest itself, being a curious projecting process of the parietal bar which forms the rear margin of the fontanelle on the right-hand side, extending obliquely forward and slightly upward over the fontanelle itself though not in contact with any of its forward border. Lambe supposes the entire structure to have been covered with a common integument. It seems from the drawing, however, to be a process similar to the curious hook-like projections from the rear of the frill and is probably an instance of the development of spinescence accompanying racial old age. So far as one may judge from such fragmentary remains, Centrosaurus does not seem to the reviewer to be antecedent to either of the Laramie ceratopsian genera, Triceratops or Torosaurus, but to represent the terminal member of a side branch of the Monoclonius-Triceratops phylum, occupying a place among the Ceratopsia similar to that of Stegosaurus among the armored dinosaurs.

The proposal of the new name Euoplocephalus to replace Stereocephalus (preoccupied), which was also described by Lambe, is but natural, although, in view of the necessary revision of all of these genera in the Stegosauria monograph now under preparation by the reviewer, it may perhaps only add to the burden of an already great synonymy. R. S. L.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The Carnegie Foundation for the Advancement of Teaching. Fifth Annual Report of the President,* H. S. PRITCHETT, and of the Treasurer, R. A. FRANKS. Pp. vi, 113. New York City, October, 1910.—The Carnegie Foundation completed its fifth year on September 30th, 1910. At that time, the original gift of $10,000,000 had been increased by something more than $1,100,000, from the accumulated surplus. This increase obviously adds much to the extent of the work which can be accomplished ; the fact, however, that of the total income for the last year, $543,880, all but $5,700 was expended, seems to indicate that an increase of capital from this source is hardly to be looked for in the future. The list of accepted institutions is now seventy-one, having been increased the past year by the addition of the University of California, Indiana University, Purdue University, and Wesleyan University. Retiring allowances were given to sixty-four teachers, forty-six of whom were in accepted institutions and eighteen in institutions not on the accepted list. Twenty-

three pensioners died during the year. It is interesting to note that two institutions not included in the Carnegie list have undertaken to provide a pension fund for themselves.

The Second Part of the Report is devoted to an interesting discussion of the relations of colleges to the secondary schools. The difficulty of bringing the high school and the college into close relations is one that has been felt for many years, and the importance of it is especially recognized at the present time. Dr. Pritchett takes up the various points involved, and indicates what he would regard as a promising method of removing the difficulty. The closing pages of the Report are devoted to brief obituary notices of the teachers who have died during the past year.

2. *A Text-Book of General Bacteriology;* by EDWIN O. JORDAN, Ph.D. Second revised edition, pp. 594, illustrated. Philadelphia and London, 1910 (W. B. Saunders Company).—While the book is adapted primarily to the needs of students of medicine, it is general in its scope, as indicated by the following subjects treated: Methods of studying bacteria, their structure and development; effects of physical and chemical agents, effects produced by bacterial growth, the relations of bacteria to diseases of animals and plants, bacteria in milk, air, soil, water, etc., their importance in the arts and industries, and other topics. A good bibliography is given.

The subject matter is presented clearly, the illustrations are good, and the book should be of much value to students of general bacteriology. L. F. R.

3. *Catalogue of the Lepidoptera Phalænæ in the British Museum*, by SIR GEORGE F. HAMPSON. Volume X. *The Noctuidæ.* Pp. xix, 829, 214 figures.—The tenth volume of the British Museum Catalogue of Moths, earlier parts of which have been repeatedly noticed in this Journal, has recently appeared. It is devoted to the Noctuid subfamily Erastrianæ. This is represented here by 1222 species belonging to 136 genera. This sub-family is largely confined to the more arid districts of tropical and warm temperate regions, and has few species in the colder zones. The plates belonging to this volume are promised at an early date.

Mécanique Sociale; par SPIRU C. HARET. Pp. 256. Paris (Gauthier-Villars); Bucarest (Ch. Göbl), 1910.

OBITUARY.

Dr. HENRY PICKERING BOWDITCH, Professor of Physiology in Harvard University, died on March 13 at the age of seventy-one years.

Professor J. H. VAN'T HOFF, the distinguished Professor of Physical Chemistry at the University of Berlin, died on February 1 in his fifth-ninth year.

Professor JULIUS WILHELM BRÜHL, the German chemist, died at Heidelberg on February 5 at the age of sixty years.

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[FOURTH SERIES.]

Art. XXX.—*The Melting Points of Minerals in the Light of Recent Investigations on the Gas Thermometer*; by Arthur L. Day and Robert B. Sosman.

When the work of the Geophysical Laboratory was begun, no temperatures above 1150° C. had ever been accurately measured with the nitrogen thermometer. It had been the custom of the Reichsanstalt to interpret the readings of a thermoelement above 1150° by first calculating the curve of temperature and thermal electromotive force of the element for the region between 400° and 1150°, and then extrapolating this curve. The fixed temperatures commonly printed on high-temperature measuring devices, like the Siemens and Halske direct-reading galvanometers, are based on this extrapolation.

The absolute accuracy of the Reichsanstalt scale (400° to 1150°) was estimated to be about 3° at 1150°, and the extrapolation above 1150° with the thermoelement is certainly in error by more than ten times this amount at the melting point of platinum. It was therefore deemed necessary to undertake a new investigation of the high temperature region with the gas thermometer, and in particular to extend its range for a considerable interval above 1150°, in order that a sound basis might be established for the mineral work of this laboratory.

Accordingly, such an investigation was begun in 1904, and the final results were published within the past year.* It proved possible not only to attain higher accuracy in the region between 400° and 1150°, but to extend the fundamental measurements to 1550° with an accuracy estimated at 2° at the latter temperature.

In the meantime, the temperature measurements made in this laboratory with thermoelements had been interpreted in

* Preliminary publication: Day and Clement, this Journal, xxvi, 405–463, 1908. Final publications: Day and Sosman, this Journal, xxix, 93–161, 1910; R. B. Sosman, ibid., xxx, 1–15, 1910.

the old way, by extrapolating the curve of temperature and thermal electromotive force. These results now require to be corrected by the amount of the difference between the old temperature scale and the new, which makes it necessary to recalculate the existing temperature data of this laboratory in terms of the new scale. This paper will present a summary of the values resulting from this recalculation.

1. *Melting and Inversion Points.*

The "melting point" of a pure substance may be defined as the temperature at which the crystalline and liquid substance can remain side by side *in equilibrium*; an "inversion point," as a temperature at which two different crystalline forms of the substance can remain side by side *in equilibrium*. Only the addition or withdrawal of a quantity of heat will cause the disappearance of one of the two forms in contact. Both melting and inversion are therefore characterized by two concurrent phenomena, the appearance or disappearance of a particular crystal structure and the appearance or disappearance of a quantity of heat.

2. *Melting Intervals.*

The above definition applies to *pure compounds*. If the material is a mixture or a solid solution, it will have, not a melting *point*, but a melting *interval*, with (theoretically) definite temperature limits.

The so-called melting interval of slow melting compounds is of entirely different character. Tammann,* and more recently Dittler,† have criticized certain of the melting-point determinations made in this laboratory, more particularly those of anorthite and diopside, as being too high because of inadequate furnace control and superheating. This is plainly due to oversight in the consideration (1) of the phenomenon of melting in silicates, and (2) of the records of our measurements. If a substance always undercools before crystallizing, the temperature of crystallization will vary with the rate of cooling, i. e., will be a random temperature depending upon the conditions of experiment and not a physical constant characteristic of the substance. If the same substance melts so slowly that it readily becomes superheated while melting, the temperature of complete liquefaction will vary with the rate of heating and is also a random temperature dependent solely upon the conditions of experiment. Pure quartz, albite and orthoclase are such substances, and no doubt others will be found. The temperature-time curve is not a competent method with which to determine the temperature of change of state of such substances.

* Zts. physikal. Chem., lxviii, 257–269, 1909.
† Zts. anorg Chem., lxix, 273–304, 1911.

If, on the other hand, the substance yields the *same constant melting temperature with widely different rates of heating*, the melting temperature is a physical constant which is characteristic of the substance and does not depend upon the conditions of experiment. Diopside and anorthite are such substances, and the published melting points of pure anorthite and diopside to which criticism has been directed, were obtained in this way. (See references 1, 4, 32, 44, 46.)

If it be contended (as has recently been done by Dittler) that the thermoelement does not give the true temperature of the mineral at any time during the heating, or that the energy change in the system is not contemporaneous with the disappearance of crystal structure, experimental proof is readily obtainable with the "quenching" furnace, which fixes the matter beyond all doubt.

Suppose the melting point of diopside, for example, to have been observed, in the manner described above, at 1391°. Place a portion (2 grams) of this crystalline charge in a quenching furnace, heat it slowly to 1388° and hold the temperature constant at that point for an hour, or until there can be no further question that the thermoelement and all parts of the charge have the same temperature; then remove the bottom of the furnace and drop the crucible with the diopside suddenly into a basin of mercury, which has the effect of cooling it almost instantly without giving the slightest opportunity for any further change within the substance. If the crystalline structure of the diopside, upon examination, is found to be unchanged, 1388° is below the melting temperature. Place the same material in the furnace once more, heat to 1396°, hold this temperature constant for some time and drop the charge quickly into mercury as before. If the diopside now appears as a clear glass, the change of state and all its attendant phenomena must have occurred between 1388° and 1396°.

By way of offering a visible record of this particular case, this experiment has been performed in this laboratory with both diopside and anorthite (chemically pure), and photographs of the substances as they appeared after removal from the furnace are reproduced in figs. 1 to 4. These photographs with their accompanying data give absolute proof that the melting point of the diopside was between 1388° and 1396°, and the melting point of the anorthite between 1547° and 1561° (new nitrogen-thermometer scale).

The so-called melting interval of slow-melting compounds (quartz, albite, orthoclase) should be carefully distinguished from the "melting interval" of mixtures (lime-soda feldspars, impure natural minerals). The former melt and become amorphous very slowly, but their melting interval is an interval of *time*, whereas the melting interval of mixtures is an interval of

FIG. 1.

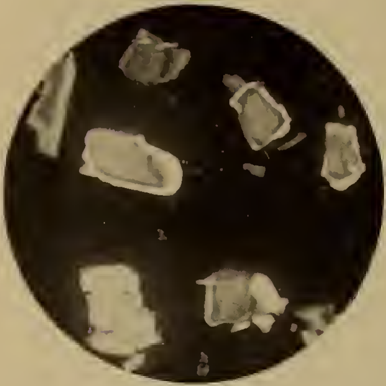

FIG. 2.

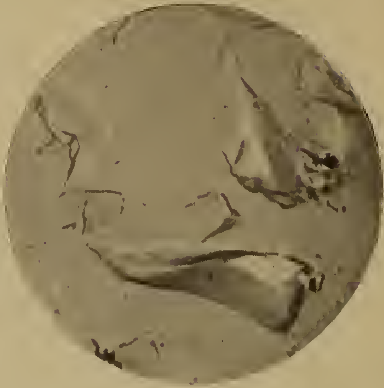

FIG. 3.

FIG. 4.

FIG. 1. Chemically pure diopside. Element R, 14100 microvolts = 1388°. Time, 1 hour. Crossed nicols. 200 diameters. *Crystalline.* The interference colors show in bands around the edges of the crystal fragments.

FIG. 2. Chemically pure diopside. Element R, 14200 microvolts = 1396°. Time, ¼ hour. Photo with crossed nicols. Magnified 32 diameters. *Glass.*

FIG. 3. Chemically pure anorthite. Element R, 15950 microvolts = 1547°. Time, ¼ hour. Crossed nicols. 200 diameters. *Crystalline.* The twinning shows distinctly.

FIG. 4. Chemically pure anorthite. Element R, 16100 microvolts = 1561°. Time, ¼ hour. Crossed nicols. 100 diameters. *Glass.*

temperature. The pure soda feldspar (albite), if held at a temperature slightly above its melting point for a sufficient length of time, will melt completely; the mixture, on the other hand, if held at a temperature within its melting interval, will melt in part, come to equilibrium, and remain indefinitely part crystalline and part liquid.

The *solidifying* points and intervals of silicates, unlike those of most metals, are not as accurately determinable as the *melting* points and intervals, because of the tendency to undercooling. The extent of the undercooling varies widely, and is affected by numerous incidental conditions. It may amount to only one or two degrees under one set of conditions; and for the same substance may become so great under other conditions that the material is obtained at ordinary temperatures in the form of glass, which will remain amorphous indefinitely.

3. *Principal Temperature Determinations at the Geophysical Laboratory, 1905–1910.*

In Table I the principal fixed temperatures that have been determined during the past five years in this laboratory are summarized, and restated in terms of the revised temperature scale. *These are not new determinations.* The original thermoelement or optical data have simply been interpreted in terms of the Day and Sosman scale of 1910.

All of the early thermoelectric measurements of this laboratory were interpreted by calculating a curve of the form: $e = a + bt + ct^2$ from the melting points of zinc, silver, and copper, and using this curve for extrapolation, as has been the general custom since the publication of the work of Holborn and Day in 1899. Occasionally a function of the form $t = a + be + ce^2$ has also been employed.

The curve $e = f(t)$ gives temperature values that are about 16° low at 1500°, and the curve $t = f(e)$ gives values that are about 33° low at 1500°. At 1100° the correction is only 1·5°, so that temperatures up to 1100° remain practically unchanged.

The data of Shepherd and Rankin on Binary Systems of Alumina with Silica, Lime, and Magnesia, have already been revised and published in the German translation of that article.* The revision of the other data is here published for the first time.

The melting points which form the basis of reproduction of the present scale are as follows: †

Zinc	418·2
Antimony	629·2
Silver	960·0
Gold	1062·4
Copper	1082·6
Diopside	1391·
Palladium	1549·
Anorthite	1550·
Platinum	1755·

* Zts. anorg. Chem., lxviii, 370–420, 1910.
† Day and Sosman, loc. cit., p. 161.

TABLE 1.—*Principal Temperature Determinations at the Geophysical Laboratory*, 1905–1910.

Substance	Formula	Transformation	Temperature	Observer	Reference
Quartz	SiO_2	α to β, and reverse	575°	Wright & Larsen	39, 64 (1909–10)
Aluminum Silicate, (Sillimanite)	Al_2SiO_5	Melting	1816	Shepherd & Rankin	41, 65 (1909–10)
α-Magnesium metasilicate	$MgSiO_3$	"	1554	Allen, Wright & Clement	13 (1906)
"	"	"	1557	Allen & White	32 (1909)
α-Calcium metasilicate (Pseudo-wollastonite)	$CaSiO_3$	"	1540	Allen & White	6 (1906)
α-Calcium orthosilicate	Ca_2SiO_4	"	2130	Day & Shepherd	8, 11, 19 (1906–7)
Eutectic between α-calcium metasilicate and cristobalite	$CaSiO_3$ 77 %** SiO_2 23 %	"	1426	"	"
Eutectic between α-calcium metasilicate and α-calcium orthosilicate	$CaSiO_3$ 66 % Ca_2SiO_4 34 %	"	1440	"	"
Eutectic between α-calcium orthosilicate and lime	Ca_2SiO_4 93 % CaO 7 %	"	2065	"	"
Tricalcium aluminate	$3CaO.Al_2O_3$	Dissociation into CaO and liquid	1537	Shepherd & Rankin	41, 65 (1909–10)
5:3 compound of lime and alumina	$5CaO.3Al_2O_3$	Melting	1382	"	"
Calcium aluminate	$CaO.Al_2O_3$	"	1592	"	"
3:5 compound of lime and alumina	$3CaO.5Al_2O_3$	Dissociation into Al_2O_3 and liquid	1700	"	"
Eutectic	$3CaO.Al_2O_3$ 9 % $5CaO.3Al_2O_3$ 91 %	Melting	1378	"	"
Eutectic	$5CaO.3Al_2O_3$ 94 % $CaO.Al_2O_3$ 6 %	"	1378	"	"
Eutectic	$CaO.Al_2O_3$ 73 % $3CaO.5Al_2O_3$ 27 %	"	1585	"	"
Magnesium-calcium metasilicate, (Diopside)	$MgSiO_3.CaSiO_3$	"	1391*	Day & Sosman	46 (1910)
"	"	"	1391	Allen & White	32 (1909)

** Percentages by weight.

TABLE I.—*Continued.*

Substance	Formula	Transformation	Temperature	Observer	Reference
Eutectic between 2 solid solutions of diopside and α-$MgSiO_3$ in each other	95·5% sol. {62% diops. 38% $MgSiO_3$}; 4·5% sol. {4% diops. 96% $MgSiO_3$}	Melting	1385°	Allen & White	32 (1909)
Eutectic between diopside and α-$CaSiO_3$	$MgSiO_3.CaSiO_3$ 60 % $CaSiO_3$ 40 %	"	1357	"	"
Calcium aluminum silicate. (Anorthite)	$CaAl_2Si_2O_8$ or $CaSiO_3.Al_2SiO_5$	"	1552	Day & Allen	1, 4 (1905)
"	"	"	1550*	Day & Sosman	46 (1910)
Bytownite	$Albite_1$ $Anorthite_5$	"	1516†	Day & Allen	1, 4 (1905)
Labradorite	$Albite_1$ $Anorthite_2$	"	1477†	"	"
Andesine-Labradorite	$Albite_1$ $Anorthite_1$	"	1430†	"	"
Andesine	$Albite_2$ $Anorthite_1$	"	1375†	"	"
Calcium carbonate	$CaCO_3$	Dissociation pressure = 1 atm.	898	Johnston	56 (1910)
Borax	$Na_2B_4O_7$	Melting	741	Day & Allen	1, 4 (1905)
Sodium chloride	NaCl	"	800	White	44 (1909)
Sodium sulphate	Na_2SO_4	"	884	"	"

In the first column of Table I is the name of the compound or mineral; in the second, its molecular formula; in the third, the transformation or reaction which takes place at the temperature given in the fourth column. The last two columns contain the names of the observers, and the references. The numbers are those in the published list of papers of this laboratory, and the references are given at the end of this article.

A number of melting and transition temperatures were only approximately determined, on account of the sluggishness or slow rate of the change. These are summarized in Table II.

* Direct comparison with the nitrogen thermometer.

† Being isomorphous mixtures of two compounds, these substances have no melting *point*, but a melting *interval*. The temperature limits of this interval are probably narrow, and its existence is entirely covered up by the slowness with which these silicates reach equilibrium. See full discussion in paper 1 (pp. 60–69), or 4 (pp. 40–50).

TABLE II.—*Approximate Temperature Determinations.*

Substance	Formula	Transformation	Temperature	Observer	Reference
Cristobalite (from quartz)	SiO_2	Melting	About 1600	Day & Shepherd	8, 11, 19 (1906–7)
Quartz	SiO_2	Inversion to cristobalite	Above 800	Day & Shepherd Wright & Larsen	8, 11, 19 (1906–7) 39, 64 (1909–10)
Eutectic* between cristobalite and sillimanite	SiO_2 80% Al_2SiO_5 20%	Melting	A little below 1600	Shepherd & Rankin	41, 65 (1909–10)
Eutectic between corundum and sillimanite	Al_2O_3 3% Al_2SiO_5 97%	Melting	About 1810	Shepherd & Rankin	41, 65 (1909–10)
Magnesium metasilicate	$MgSiO_3$	Inversion α to β (clino-enstatite), and reverse	About 1375	Allen & White	32 (1909)
β-Calcium metasilicate, (Wollastonite)	$CaSiO_3$	Inversion to α-$CaSiO_3$ (pseudo-wollastonite), and reverse	1190	"	6, 32 (1906–9)
Calcium orthosilicate	Ca_2SiO_4	Inversion α to β and reverse	1420	Day & Shepherd	8, 11, 19 (1906–7)
Calcium orthosilicate	Ca_2SiO_4	Inversion β to γ and reverse	675	"	"
Tricalcium silicate	$3CaO.SiO_2$	Formation of 2 phases by dissociation	About 1900	Shepherd & Rankin	61, (1911)
Eutectic of spinel and periclase	$MgO.Al_2O_3$ and MgO	Melting	About 1950	"	41, 65 (1909–10)
Albite	$NaAlSi_3O_8$	"	Below 1200‡	Day & Allen	1, 4 (1905)
Oligoclase-Andesine	$Albite_3$ $Anorthite_1$	"	1345†	"	"
Microcline	$KAlSi_3O_8$	"	Below 1200‡	"	"
Andalusite	Al_2SiO_5	Change to sillimanite	1300 and above**	Shepherd & Rankin	41, 65 (1909–10)
Cyanite or disthene	Al_2SiO_5	"	1300 and above**	"	"
α'-Magnesium metasilicate, (Enstatite)	$MgSiO_3$	Change from unstable form to β-$MgSiO_3$ (clino-enstatite)	1300**	Allen, Wright & Clement	13 (1906)
β'-Magnesium metasilicate, monoclinic amphibole§	$MgSiO_3$	"	1150 and above**	"	"
γ'-Magnesium metasilicate, orthorhombic amphibole§	$MgSiO_3$	"	1150 and above**	"	"

* The eutectic compositions are given in percentages by weight of the two compounds named.
† See note (†) to Table I.

‡ The purest natural albite showed signs of melting when heated a few minutes at 1200°, and again when heated for four hours at 1100°. Small amounts of certain impurities might, however, lower the melting point considerably, while others would raise it. No determinations of melting point on chemically pure albite or orthoclase have been made. The best statement that can be made, therefore, is to say that the melting point is probably below 1200°. The facts concerning microline are similar.

** These temperatures differ from the others in the tables, in not being fixed physical points. The change is from an unstable into a stable form and is not reversible. The figures merely represent the temperatures at which the change is rapid enough to become observable within a reasonable length of time.

§ Both of these have been called kupfferite by different authors.

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Geophysical Laboratory, Carnegie Institution of Washington, March, 1911.

Art. XXXI.—*On the Separation of Cerium by Potassium Permanganate*; by Edwin J. Roberts.

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

One of the most useful methods for the separation of cerium from the rare earth metals which accompany it depends upon its oxidation by potassium permanganate according to the equation:

$$3Ce_2O_3 + 2KMnO_4 + H_2O = 6CeO_2 + 2KOH + 2MnO_2.$$

This action takes place in a cerous nitrate solution provided some neutralizing agent is present to take up the nitric acid set free. Stolba, in 1878,* used zinc oxide for this purpose, and other investigators† have since used the method. Drossbach,‡ Böhm,§ Muthmann and Weiss,‖ Meyer¶ and others have used alkali hydroxides or carbonates in place of zinc oxide. More recently, Meyer and Schweitzer** have studied this process, using sodium carbonate. They give the equation:

$$3Ce(NO_3)_3 + KMnO_4 + 4Na_2CO_3 + 8H_2O =$$
$$3Ce(OH)_4 + Mn(OH)_4 + 8NaNO_3 + KNO_3 + 4CO_2,$$

and use two different solutions for the precipitation. One, for the complete removal of the cerium, contains one molecule of permanganate to nearly five of sodium carbonate; the other, for the purification of the cerium, contains one molecule of permanganate to less than three of sodium carbonate. It is obvious from the above equation that in the first case large amounts of other earths will be precipitated with the cerium by the excess of alkali, while in the second case the nitric acid will be in excess at the end of the process, leaving considerable amounts of cerium in solution. The object of the present work was to study the process carefully and to produce, if possible, a sharper separation of the cerium.

When a little potassium permanganate solution is added to a hot neutral solution containing cerous nitrate, the red color of the permanganate is instantly bleached, and a brown precipitate appears. If the addition of the permanganate is continued, the color is bleached more and more slowly, the liquid becomes distinctly acid to litmus, and finally the red color becomes permanent. If a little alkali is now added, the color is again bleached, and if the liquid is kept neutral, or very nearly so, the red color will not be permanent until all the cerium is precipitated. The action seems to be as follows: the cerous nitrate is oxidized by the permanganate, probably according to the equation:

* Jahresber., 1878, 1059.

† Muthmann and Rölig, Ber. chem. Ges., xxxi, 1718; James, Jour. Am. Chem. Soc., xxx, 982.

‡ Ber. chem. Ges., xxix, 2452.

§ Zeit. angew. Chem., 1903, 1129.

‖ Ann. Chem., cccxxxi, 9.

¶ Zeitschr. anorg. Chem., xxxvii, 378.

** Zeitschr. anorg. Chem., liv, 104–120.

$$3Ce(NO_3)_3 + KMnO_4 + 3H_2O = 2Ce(NO_3)_4 + Ce(OH)_4 + KNO_3 + H_2MnO_3. \quad (1)$$

The ceric nitrate formed then hydrolyzes:

$$Ce(NO_3)_4 + 4H_2O \rightleftarrows Ce(OH_4) + 4HNO_3. \quad (2)$$

If no alkali is added, the accumulation of nitric acid in the liquid checks the process by reversing the action in equation (2), and also in equation (1), for when a little of the mixed precipitate of hydrated ceric and manganese dioxides was treated, after washing, with dilute nitric acid and warmed, a strong permanganate color was produced. The addition of alkali at this point of course simply removes the free acid and allows the action to become complete. The fact that the oxidation and precipitation take place even in the presence of appreciable amounts of free nitric acid makes it possible to secure a better separation than would otherwise be the case, for if the liquid is kept perfectly neutral the small amounts of trivalent earths which are locally thrown down by the alkaline precipitating solution will not be re-dissolved, while if the liquid is distinctly acid during the whole process they will tend to re-dissolve on stirring. These considerations give the theoretical conditions for the process. As to the choice of a neutralizing agent, it is of course desirable to use no compound of a metal which is precipitated by oxalic acid or which is not easily separated from the rare earths, as, for example, zinc oxide or calcium carbonate. Magnesium oxide was tried, but does not give as good results as the alkali carbonate, and is not so easily controlled. Sodium carbonate seems to be the simplest and most convenient neutralizing agent for the purpose.

The solution used for the precipitation is made by dissolving 158·03 grams (one mol.) of potassium permanganate and 424·00 grams (four mols.) of dry sodium carbonate in any convenient amount of water. The solution should be kept in glass-stoppered bottles and should not be allowed to come in contact with organic matter. Solutions of pure permanganate and of pure sodium carbonate, of any convenient strength, are also needed. The process is carried out as follows: The rare earth solution, which should not contain other salts than nitrates, is heated to boiling in a large porcelain dish, and, if not already neutral, is neutralized with the sodium carbonate solution. The solution of permanganate is added in small quantities, until the red color just begins to be permanent, and the mixed solution of permanganate and alkali is then added very slowly, with constant stirring, the liquid being kept nearly at the boiling point during the whole process. A faint color of permanganate is maintained all the time in the liquid, a little of the pure permanganate solution being added if at any time the color is entirely bleached. This is important, as the constant acidity of the liquid is thereby insured. When the cerium is nearly all precipitated, the color is bleached more slowly after each addition of the precipitant, and the effervescence is less noticeable. The acidity of the liquid should now be tested from time to time, which may be done with litmus paper if only a slight excess of permanganate is present. Small amounts of the mixed solution or of sodium carbonate are added, until the liquid is nearly neutral to litmus, and still is faintly colored with permanganate. The whole is heated and stirred for about ten minutes, and filtered hot. The precipitate is washed with boiling water till the washings give no precipitate with ammonia. If the liquid at the end of the precipitation is faintly acid, the filtrate usually contains a trace of cerium giving a faint yellow color with ammonia and hydrogen peroxide, while from the precipitate a preparation of cerium chloride may readily be obtained which shows no absorption bands in a thickness of 15^{cm} of very concentrated solution. The presence of a little cerium in the filtrate, where the earths in the latter are to be subjected to fractional crystallization, is usually not objectionable.

To insure the complete removal of the cerium, the liquid at the end of the precipitation must be made absolutely neutral, when a filtrate is obtained which gives no test for cerium with hydrogen peroxide. Before testing, the excess of permanganate is removed from the filtrate by boiling with a few drops of alcohol. After re-filtering, the other earths are precipitated by oxalic acid. The precipitate of cerium and manganese hydroxides is dissolved in strong hydrochloric acid, the solution diluted and precipitated with oxalic acid and the cerium oxalate re-converted to nitrate. On repeating the process with this material, a pure cerium preparation is obtained, which gives an oxide of the characteristic pale yellow color. The process was thoroughly tested on several different kinds of material. A mixture containing as much as thirty-five to forty per cent of praseodymium and neodymium yielded pure cerium in two operations.

Attempts were also made to extract the first cerium and manganese precipitate with dilute nitric acid, in order to remove the last traces of praseodymium and neodymium without recourse to a second permanganate treatment. The precipitate obtained in the usual manner was thoroughly washed on the filter, then transferred to a large dish and heated nearly to boiling with a large volume of water. Nitric acid was then added carefully until the liquid began to show the permanganate color. The whole was heated for about fifteen minutes, and the precipitate filtered off and washed. This cerium preparation, when freed from manganese, gave a pale reddish oxide, showing that the neodymium and praseodymium are not entirely removed from the first precipitate by extraction with dilute nitric acid.

ART. XXXII.—*New Paleozoic Insects from the Vicinity of Mazon Creek, Illinois;* by ANTON HANDLIRSCH, Imperial Natural History Museum, Vienna.

[Continued from p. 326.]

Order PROTOBLATTOIDEA Handlirsch.

Family EOBLATTIDÆ Handlirsch.

ANEGERTUS, new genus.

Anegertus cubitalis, new species. Fig. 32.

An insect of about 60mm, the anterior wings of which measure 45mm and are nearly elliptical with a somewhat broadened

FIG. 32.

FIG. 32. *Anegertus cubitalis* (negative). ×2.

apical half. Costa marginal and equally curved; subcosta long, nearly straight and reaching almost to the tip. The costal area comparatively broad, with numerous oblique, ramous veins, bridged over by cross veins. Radius straight, parallel to and very near the subcosta, its sector rising very near the base, diverging but little from the radius and sending off only 2 short branches near the end. The media is likewise somewhat reduced and cleft in the apical half into 2 branches. The cubitus on the contrary shows an extraordinary development occupying nearly half the wing and is cleft into 2 main branches at about a quarter of the wing length. The anterior of these branches splits by repeated forking into 6-7 twigs; the posterior sends forth partly forward, partly backward, a number of forked twigs. The anal area, which occupies more than a third of the hind margin, is limited by a strongly curved vein and filled by about 6 veins which are sometimes forked and run in a regular vault toward the posterior margin. Cross veins numerous.

Prothorax comparatively large and disciform; the head broad and free, with strongly vaulted lateral eyes. One of the legs, probably of the second pair, is preserved; it is comparatively long and robust. If I am not mistaken, the posterior legs are directed backward in the middle line of the fossil, close together, a situation presupposing large and approximated coxæ. I have no doubt about the close relationship of this fossil to *Eoblatta* from Commentry, which has likewise a reduced sector and media and an expanded cubitus.

Holotype in Peabody Museum, Yale University, Cat. No. 43.

Family ASYNCRITIDÆ, new family.

Comparatively clumsy with a short, stout body, covered and exceeded in length by the singularly specialized wings, which are strongly dilated in their apical half. The small disk-like pronotum is pear-shaped. Meso- and metanotum fused to a solid complex, each of them broader than long. Coxæ very large, femora and tibiæ of the posterior legs very short. The segments of the abdomen much broader than long. Anterior wings with a broadly rounded apical margin, a marginal costa and a long subcosta, fusing near the tip of the wing with the costa. Sector rising at a quarter of the wing length, diverging widely from the radius and giving off but few branches, directed forward, parallel to the radius. Media free, forked only in the apical half. Cubitus free, with broken branches forming a polygonal network. The smaller interstices with straight cross veins, the broader ones, like the costal area, filled by a polygonal network. Anal area reaching nearly half the length of the wing, containing a few veins regularly curved backward toward the apical margin. The posterior wings seem to have been quite similar to the anterior pair with the exception of the fan-like anal area, which attains to about half their length.

ASYNCRITUS, new genus.

Asyncritus reticulatus, new species. Fig. 33.

Length of the thorax and abdomen 28^{mm}. Length of the wings 28^{mm}. Pronotum but a little longer than broad. Posterior femora only as long as the pronotum. Anterior wings

FIG. 33.

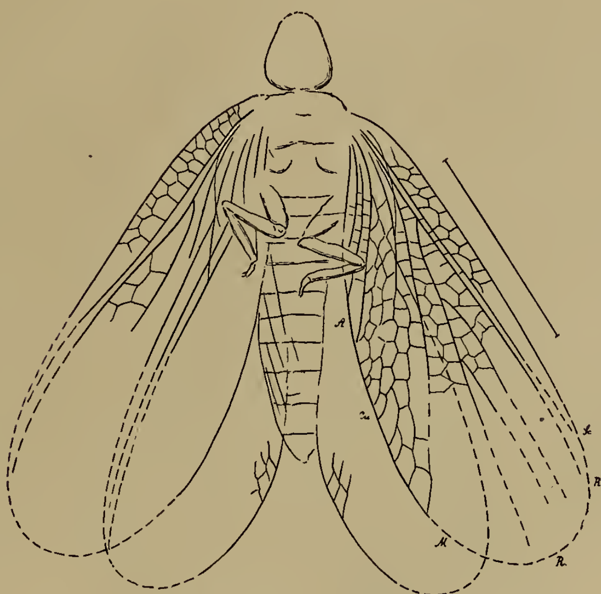


FIG. 33. *Asyncritus reticulatus.* × 2·2.

about two and a half times longer than broad, their greatest breadth falling in the third quarter. Sector running obliquely to the middle of the apical margin, sending forth but 2 branches directed forward, their interstices being filled by an irregular network. Costal area with 2 rows of cells. Radio-medial space with 2 rows of large polygonal cells. Media with a simple fork. Cubitus split into about 8 branches, all angularly broken, some of them falling in the anal furrow. By the aid of the cross veins the whole cubital space takes on the aspect of a network. One sees only 4 anal veins, but 2 others may have existed.

By this singular specialization of the venation *Asyncritus* differs from all other Protoblattoidea. It is so characteristic that the establishment of a new family is justified.

Holotype in Peabody Museum, Yale University, Cat. No. 44.

Family EPIDEIGMATIDÆ, new family.

This family is based on a slender Protoblattoid with a nearly semi-elliptical disciform pronotum, long and somewhat waved

FIG. 34.

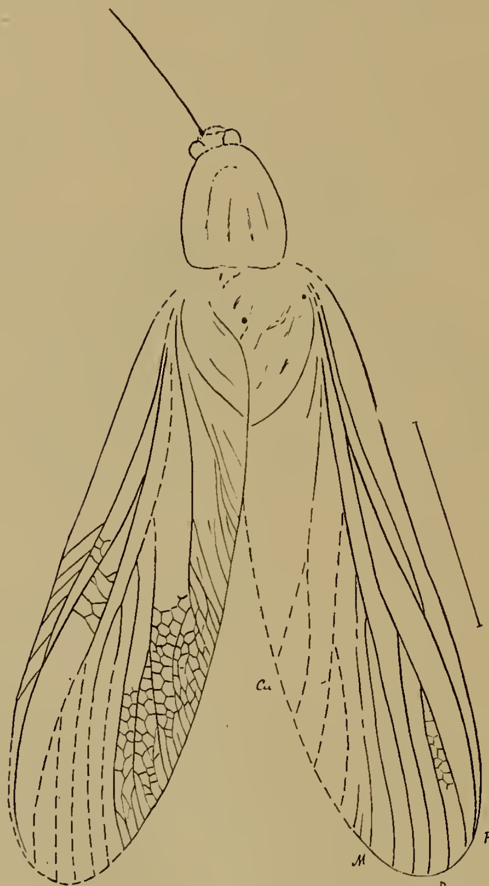


FIG. 34. *Epideigma elegans* (positive and negative combined). × 3.

anterior wings, the subcosta not uniting with the costa but with the radius as in some of the Protorthoptera. The anal area strongly shortened and limited by the characteristic strongly curved furrow. Costa marginal. Sector rising in the middle of the wing, giving off but a few branches, directed backward toward the apical margin. The media free, sending some branches obliquely backward, the last of which reaches the posterior margin. Cubitus of a moderate development, splitting into numerous irregular branches which form, by the aid of cross veins, an irregular network and often take the character of intercalary veins.

EPIDEIGMA, new genus.

Epideigma elegans, new species. Fig. 34.

Prothorax somewhat longer than broad, of a nearly semi-elliptical shape. Head comparatively small, not quite concealed under the pronotum and bearing large, strongly vaulted, lateral eyes. Antennæ long and slender. Anterior wings 28^{mm} long with a somewhat waved costal margin and with a broad costal area, filled by oblique branches of the subcosta and of the radius. Radius reaching nearly to the tip. Sector rising at about one-third of the length, diverging comparatively far from the radius and giving rise to only 2 branches. Media independent of the radius and cubitus, slightly waved and traversing the middle of the wing. Of its 3 branches, which extend obliquely backward, the first is forked and has, like the second, a few short apical veinlets with the aspect of intercalary veins. The cubitus is cleft near the base into 2 main branches, both splitting into numerous twigs, running obliquely backward and taking part in the formation of a network. All main interstices are filled by a more or less regular polygonal network. The very short anal area hardly reaches one-fifth of the length of the wing and is limited by a sharply curved furrow.

Holotype in Peabody Museum, Yale University, Cat. No. 45.

Family CHELIPHLEBIDÆ Handlirsch.

By the discovery of a new species this family loses in some degree its provisional character and can with more certainty be added to the Protoblattoidea. It seems to be most nearly related to the Eucænidæ, having like those broad and short front wings with a broad costal area, the veins of which are not arranged in regular comb-like manner, but are irregular and ramified. The subcosta unites with the costa; the radius remains simple and its sector sends forth but few branches, directed obliquely backward. The media free and splitting into only few branches. The cubitus more richly ramified. Pronotum disciform and comparatively small, equal in length and breadth.

Cheliphlebia mazona, new species. Fig. 35.

The only parts present are the nearly circular prothorax of about 8^{mm} in length and a 34^{mm} long portion of an anterior wing, which probably attained a length of 40^{mm}. Costa strongly

FIG. 35.

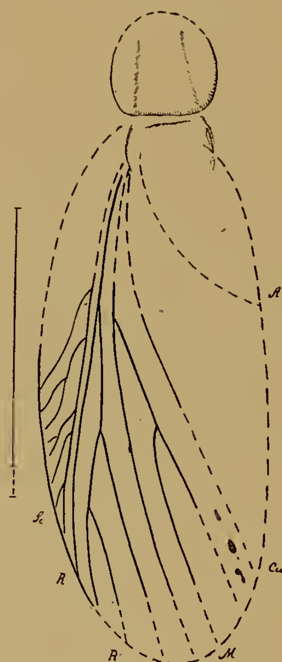


FIG. 35. *Cheliphlebia mazona.* × 1·8.

curved; subcosta nearly straight, with irregularly waved ramified branches that attain about three-quarters the length of the wing. Radius very near the subcosta and not reaching the tip of the wing, simple and uniting with the costa at a short distance below the subcosta. Sector rising at one-third of the length, giving off only 2 oblique branches. Media cleft before the middle into an anterior simple and a posterior forked branch. Cubitus and anal area not preserved.

Holotype in Peabody Museum, Yale University, Cat. No. 46.

Family EUCÆNIDÆ Handlirsch.

The finding of new specimens allows a more exact description of this family to be given. What I had previously held for the whole radial system is only the radius (*s. str.*) without the sector, giving off some branches forward. What I thought to be the media evidently is the long radial sector, rising near the base and sending forth some long branches, directed obliquely backward. A part of the veins designated by me as belonging to the cubitus must therefore be attributed to the media, which is not abundantly forked. The cubitus, too, does not show a conspicuously rich embranchment. In the posterior wing the sector seems to be much more expanded and in consequence of this the media and cubitus are strongly reduced; the anal area is large and fan-like. Coxæ of the hind legs very large.

Eucænus Scudder.

Eucœnus ovalis Scudder. Figs. 36–39.

The Yale collection contains a male and two females of this species which may be easily distinguished by the presence of

Fig. 36.

Fig. 37.

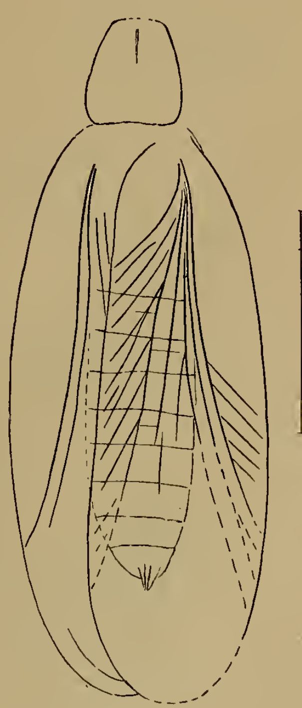


Fig. 36. *Eucœnus ovalis.* ♀ ×3. Fig. 37. *Eucœnus ovalis.* ♀ ×3.

FIG. 38.

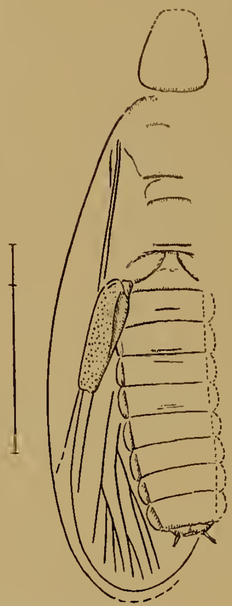


FIG. 38. *Eucœnus ovalis.* ♂ ×3

FIG. 39.

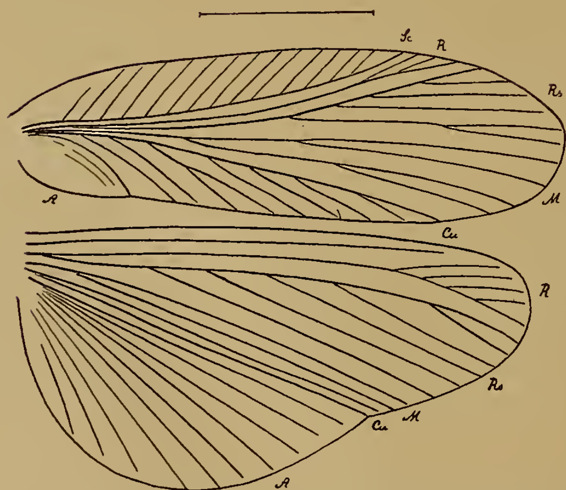


FIG. 39. *Eucœnus ovalis* (reconstruction). ×3.

an ovipositor. The cerci are short. The ninth segment of the male is of the same size as the preceding. All the segments are laterally produced into blunt lobes. Pronotum comparatively smaller in the male than in the female. Coxæ of the posterior legs large, the femora robust and short. Ovipositor extending but little beyond the end of the abdomen.

Anterior wing of the ♂ 23mm long, of the ♀ 24–25mm.

Besides these three individuals, the collection contains another female which does not have the wings lying over the abdomen as is usually the case, but they are spread laterally, therefore permitting of a more exact determination of the veins. Unfortunately in this individual only the basal half of the wings is preserved. This specimen is somewhat smaller than usual, having a wing length of scarcely 22mm. As far as I can see, the cubitus is cleft in one of the wings into but 4

Fig. 40.

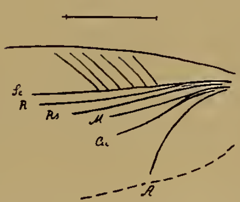


Fig. 40. *Eucœnus minor* (left wing). ♀ ×2·5.

Fig. 41.

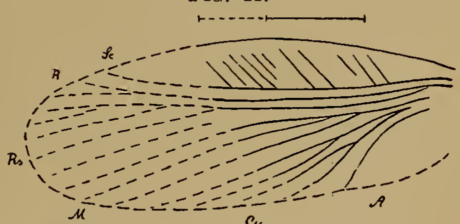


Fig. 41. *Eucœnus minor* (negative of right wing). ♀ ×2·5.

Fig. 42.

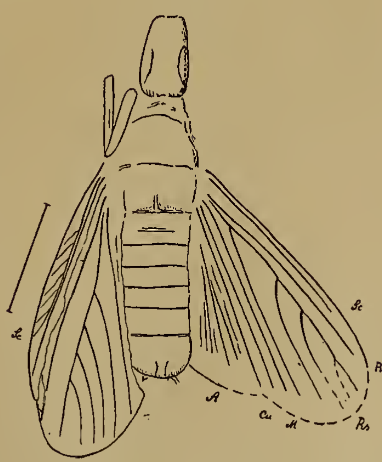


Fig. 42. *Eucœnus mazonus.* ×2·5.

branehes and it seems possible that this individual may belong to a species distinet from *ovalis* Scudder or at least to a variety, for which I propose the name *E. minor* m. (figs. 40, 41).

Plesiotypes in Peabody Musenm, Yale University. Cat. Nos. 47–50.

Eucœnus mazonus Melander. Fig. 42.

Much smaller than *ovalis* Scudder with a narrower pronotum and a very stout body. Length of thorax and abdomen 15^{mm}, equal to the anterior wing. Costal area of the anterior wing comparatively narrow. Radial seetor of the posterior wing with 4 large branches, occupying nearly the whole anterior half of the wing, pushing to one side the media and cubitus, which are redueed to 3 parallel veins. The large anal area fan-like, with numerous veins. Pronotum one and two-thirds times longer than broad. Anterior leg delicate, the tibia as long as the pronotum. Probably a male.

Plesiotype in Peabody Museum, Yale University, Cat. No. 51.

Eucœnus pusillus, new species. Fig. 43.

Resembling *E. mazonus*, but of a smaller size. The abdomen more slender, the eostal area of the anterior wing broader.

FIG. 43.

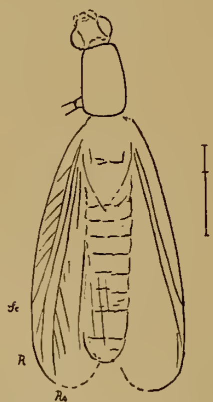


FIG. 43. *Eucœnus pusillus*. ×4.

Radius eleft at the end, the seetor with (?) 5 branehes. Length of the pronotum nearly 5^{mm}, of the wing 11^{mm}.

Holotype in Peabody Museum, Yale University, Cat. No. 52.

Eucœnus rotundatus Handlirsch. Fig. 44.

The experienee gained by the study of the new material has led to another determination of the veins of *E. rotundatus*

Handlirsch, as is shown in fig. 44. What I previously had called media evidently is the sector and the complex of veins formerly regarded as cubitus contains also the media.

Holotype in the U. S. National Museum.

FIG. 44.

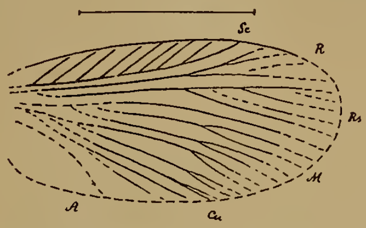


FIG. 44. *Eucœnus rotundatus* (new reconstruction).

Family ANTHRACOTHREMMIDÆ Handlirsch.

Three of the fossils in the Yale collection seem to be of a near relationship with *Anthracothremma* Scudder. A common characteristic of these forms is a greatly reduced and shortened anal area, a shortened subcosta and the tendency of all veins to stretch in the direction of the longitudinal axis of the wings. In all these species the media is of a comparatively small extent.

PERICALYPHE, new genus.

Pericalyphe longa, new species. Fig. 45.

A slender insect with anterior wings 50^{mm} long which are at least four times longer than broad. The subcosta is strongly reduced and unites with the radius. Costal area narrow, traversed by short, stiff veinlets. The simple radius not quite attaining the apex; its sector rising beyond the first third of the length and sending off 9 simple and very regular parallel branches, directed toward the apical border. The quite independent medial vein remains undivided. The cubitus, running in a large curve toward the end of the hind margin, sends off 6 long branches, some of which are ramified. All of these take the direction of the sector branches and of the media. Only one or two short branches near the base run obliquely to the posterior margin. The anal area, limited by a curved furrow, reaches but one-fifth of the wing length. Very indistinct cross veins probably fill all the interstices.

In the posterior wing the subcosta is produced almost to the tip but likewise unites with the radius.

The disproportionately small pronotum forms a semicircular disk of scarcely 5^{mm} in length. Meso- and metathorax are of a size proportional to that of the whole insect. The posterior leg is long and robust, its femur 15^{mm} long and not thickened toward the base.

This fossil seems to have its place very near *Anthracothremma*, but it differs in having a simple medial vein and many more branches of the radial sector and cubitus.

Holotype in Peabody Museum, Yale University, Cat. No. 54.

FIG. 45.

FIG. 45. *Pericalyphe longa.* ×1·5.

MELINOPHLEBIA, new genus.

Melinophlebia analis, new species. Fig. 46.

A single anterior wing, 22^{mm} long, having the apical half distinctly dilated, the anterior margin straight and the subcosta reduced to little more than half the length of the wing and uniting with the costa. Costal area comparatively broad with numerous short and oblique veins. Radius very near the subcosta, reaching not quite to the tip and not ramified. The sector originating but little before the middle of the wing, scarcely diverges from the radius and sends off 4 parallel

FIG. 46.

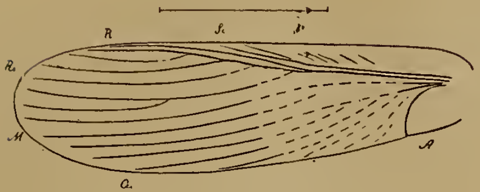


FIG. 46. *Melinophlebia analis.* × 2·7.

branches that curve toward the apical margin, the first of them being forked. The media apparently forming but one fork, whose branches run parallel with those of the sector. The cubitus runs parallel with the media to the end of the posterior margin and its (about) 5 branches take the same direction. The anal area being limited by a strongly curved furrow extends about one-seventh of the wing length. Cross veins have probably been present but are not now discernible.

This species shows how a wing of a blattoid type may have been transformed into a termite wing.

Holotype in Peabody Museum, Yale University, Cat. No. 55.

SILPHION, new genus.

Silphion latipenne, new species. Fig. 47.

Anterior wing 30^{mm} long, 25^{mm} only being preserved. Apical half conspicuously enlarged. Anterior margin nearly straight. Subcosta extending a little beyond the middle of the wing, uniting with the costa and giving off but 3 veinlets directed

FIG. 47.

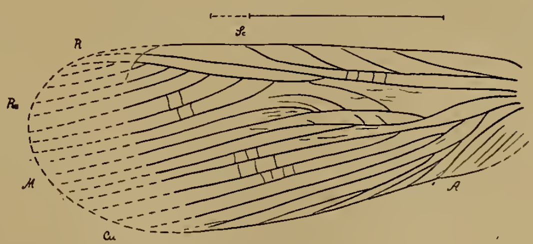


FIG. 47. *Silphion latipenne.* × 2·2.

obliquely toward the costa. Radius nearly straight and at a moderate distance from the subcosta. Sector rising somewhat before the middle of the wing, with 7 simple and parallel branches running toward the apical margin. Media forked at a quarter of the length, each of the main branches again cleft into 2 branches. The anterior main branch gives off before its division 2 short branchlets, swinging forward and outward, the first of which unites with the base of the radial sector. The cubitus runs nearly straight toward the end of the apical margin, sending forth backward 3 branches, the first of which splits into 5, the second into 2 twigs. All these veins hold the same direction as the branches of sector and media and are bridged over by numerous cross veins. Anal area very short, but not so broad as in *Melinophlebia*, and limited by a less strongly curved vein; it is filled by about 4 simple veins and reaches not quite a fifth of the length of the wing.

I have no doubt of the close relation of this species with *Melinophlebia*.

Holotype in Peabody Museum, Yale University, Cat. No. 56.

FIG. 48.

FIG. 48. (*Protoblattoidea*) *minor*. ×3.

FIG. 49.

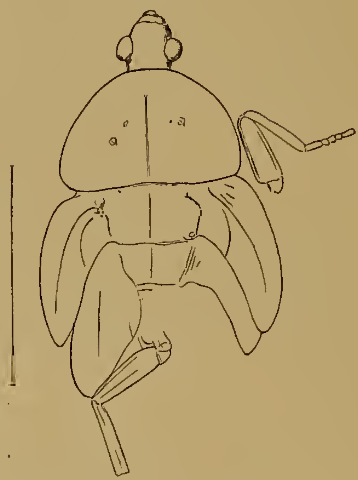


FIG. 49. (*P.*) *sellardsi*. ×2.

(*Protoblattoidea*) *minor* and (*P.*) *sellardsi* Handlirsch.
Figs. 48, 49.

The Yale collection possesses the types of two larval forms, described by Sellards as belonging to the true Blattoidea but supposed by me (Fossil Insects, p. 152) to be members of the Protoblattoidea. Having now examined the types, I can verify my opinion.

One of these larval forms, (*Protoblattoidea*) *minor*

Handlirsch (Fossil Insects, t. 15, f. 15), has a very singular organ at the apex of the abdomen (see fig. 48). A careful examination shows that it reaches as far as the eighth segment and bears a longitudinal suture. There can be scarcely any doubt that it is a larval ovipositor. On one side of this organ a distinct cercus is preserved. The sides of the segments are lobate, the wing cases somewhat spread outward and backward. The comparatively short and stout legs are inserted very near the middle line. The head with its large eyes lies free in front of the pronotum. Head, body and ovipositor together have a length of 22^{mm}.

It is very possible that this larva is of *Eucœnus* or a related form.

Another larva, contained in my work under the name (*Protoblattoidea*) *sellardsi* Handlirsch (p. 152, t. 15, f. 14), seems to be closely related to the above mentioned species, the stout

Fig. 50.

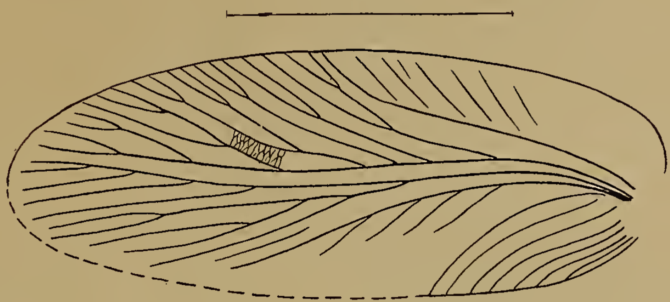


Fig. 50. *Adeloblatta sellardsi.* × 2·3.

and short legs being very similar to *Eucœnus*. This fossil (see fig. 49), with comparatively shorter wing cases than (*P.*) *minor*, is probably in a more juvenile stage but nevertheless much larger (somewhat more than 30^{mm}), so that it must be considered as a distinct species.

Holotypes in Peabody Museum, Yale University, Cat. Nos. 57, 58.

Order BLATTOIDEA Handlirsch.

Family ARCHIMYLACRIDÆ Handlirsch.

Adeloblatta sellardsi (Handlirsch). Fig. 50.

Etoblattina hilliana? Sellards, Amer. Jour. Sci. (4), xviii, 1904, p. 213, pl. 1, fig. 4.

Phyloblatta sellardsi Handlirsch, Foss. Insects, 1906, p. 205, t. 21, f. 15.

Sellards' first figure did not show clearly enough the ramification of the media and so I was misled into placing the species in my genus *Phyloblatta*. But now, having before me the type, I see that the 5 branches of the media rise from the posterior side of the main vein. The first of them splits into 5 twigs, the following being no farther cleft. The cubitus is comparatively short and sends forth but 4 branches. The radius gives off 6 ramified branches and an apical fork. Subcosta reaching about the middle of the nearly elliptical wing. Anal area of one-third of the wing length and filled by 6 regular veins. The interstices are bridged over by rugous and twisted cross-veins.

These characteristics induce me now to place the species in the genus *Adeloblatta* Handlirsch.

Holotype in Peabody Museum, Yale University, Cat. No. 59.

FIG. 51.

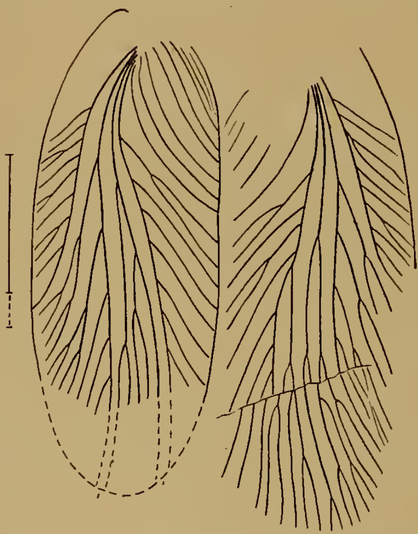


FIG. 51. *Phyloblatta diversipennis* (negative). ×2·9.

Phyloblatta diversipennis, new species. Fig. 51.

The two anterior wings, 24mm long, of a rather large species, of a nearly elliptical shape. Subcosta reaching three-fifths of the length. Costal area comparatively broad, with more than 10 partly ramified veins, 8 of which are preserved. Radius reaching to the apical margin and slightly waved. Of its 4 or 5 branches only the first 2 or 3 are ramified. The media occupies a comparatively narrow space in the apical margin and sends forth in the right wing (left of the negative) 2 very long forked branches, directed forward and outward. Cubitus attains the end of the apical margin and sends 8 oblique branches toward the posterior margin, few of them being ramified. In the left wing (right of the negative) there is a long forked branch, rising in front of the cubitus. Anal area two-fifths of the wing length and filled by 7 regular veins. I see nothing of cross veins.

Holotype in Peabody Museum, Yale University, Cat. No. 60.

FIG. 52.

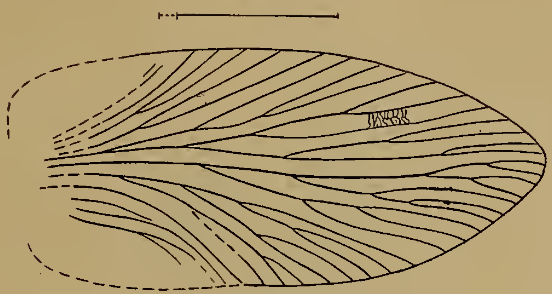


FIG. 52. *Orthomylacris contorta.* ×3.

Family MYLACRIDÆ Scudder.

Orthomylacris contorta, new species. Fig. 52.

An anterior wing of 23mm. Slender and of a pointed cordiform shape, strongly vaulted. The costal and radial area on the one hand, and the medial, cubital and anal areas on the other, divide the wing into two nearly symmetrical halves. The bundle of 4 or 5 subcostal branches extends beyond the middle of the anterior margin. The radius sends forth very obliquely 2 3-branched, a forked and a simple branch: the media 2 3-branched, a forked and a simple branch obliquely backward. The cubitus occupies about the middle third of the posterior margin and has a 3-branched and a forked branch. Anal area at least twice as long as broad. Structure leather-like.

Holotype in Peabody Museum, Yale University, Cat. No. 61.

PLATYMYLACRIS, new genus.

A very broad form, the pronotum of which is nearly twice as broad as long. Anterior wing twice as long as broad, obliquely cordiform. Costal area reaching nearly three-quarters of the length. The subcosta and its branches not curved forward but backward. Radius composed of 3 long forks. Media giving rise to but 3 branches, directed backward. Cubitus with its 6 branches occupying the whole free posterior margin. Anal area very broad, its length only one and a half times its breadth, filled by numerous simple veins.

This genus is sufficiently distinguished from all the Mylacridæ known to me by the singular radius and the broad and short anal area.

FIG. 53.

FIG. 53. *Platymylacris paucinervis.* ×1·9.

Platymylacris paucinervis, new species. Fig. 53.

Shoulder very much produced. Subcosta composed of 3 branched veins, showing the tendency to curve toward the radius and being therefore posteriorly concave. The radius splits quite near the base into 3 long branches, forming short apical forks. The media traverses nearly the middle of the wing, and gives rise to but 3 main branches directed obliquely backward, the first of which rises very near the base and makes a long fork. The cubitus goes to the end of the posterior margin and bends near to the media in the basal part, its first branches being forked. The anal area is filled by about 12 veins. Length of the fossil 37^{mm}, of the anterior wing 30^{mm}.

Although the shape of this insect reminds one of *Paromylacris rotunda* Scudder, with which Sellards has attempted to identify it, the venation proves to be quite different.

Holotype in Peabody Museum, Yale University, Cat. No. 62.

Larva of (*Blattoidea*) *melanderi* Handlirsch? Fig. 54.

A larva, 17^{mm} long, belonging to the group designated by some authors as *Dipeltis* and probably referable to the Mylacridæ. The comparatively short middle and posterior legs with their approximate coxæ are easily to be distinguished. The lateral lobes of the segments are very clearly preserved.

Plesiotype in Peabody Museum, Yale University, Cat. No. 63.

Fig. 54.

Fig. 54. (*Blattoidea*) *melanderi*? ×2·6.

Order SYPHAROPTEROIDEA, new order.

This new order is based on a comparatively small insect which I am not able to place in any one of the other orders and which evidently represents an extinct offshoot of the Palæodictyoptera. From it none of the more highly specialized groups of insects can be derived.

Meso- and metathorax very similar, apparently not yet grown together. Abdomen slender, diminishing backward, its first segment being the largest, the eighth with an appendix, probably an ovipositor. The two homonomous pairs of wings are of a quite equal shape and lie obliquely backward, not covering the abdomen; the second pair being somewhat shorter but, like the first pair, nearly trigonal and apparently not provided with an anal fan. The costa marginal, the subcosta and radius strongly advanced toward the anterior margin. Subcosta reaching but half the length of the wings, uniting with the costa and sending forth some short oblique veinlets. Radius parallel to the subcosta and costa, reaching the tip of the wing and sending forth some short oblique veinlets toward the costa. The radial sector rises very near the base and diverges strongly from the radius, the interstice being bridged over by

4 or 5 straight and simple cross veins. The 5 (in the anterior wing) or 4 (in the posterior wing) simple branches of the sector run obliquely to the oblique apical margin and are united by a few straight cross veins. The media is reduced to a simple independent vein and likewise the cubitus, which has but a short strongly diverging branch near its apex. The first anal vein is moderately straight and apparently sends 2 branches backward. All the main veins are united by isolated and widely spread cross veins. There is no doubt that the wings were of a delicate membranous texture.

This fossil somewhat resembles certain Megasecoptera, but lacks certain characteristics of this order, such as the temporary fusion of cubitus, media and radius, the shortened subcosta and the position of the wing being also quite different; further, an ovipositor has never been found in the Megasecoptera. The want of intercalary veins and the strongly reduced media and cubitus do not allow this fossil to be put among the Ephemeroidea.

Family SYPHAROPTERIDÆ, new family.

SYPHAROPTERA, new genus.

Sypharoptera pneuma, new species. Figs. 55, 56, 57.

Thorax and abdomen together having only a length of 13mm, the front wing of 12mm. Meso- and metathorax each somewhat broader than long, the first segment of the abdomen nearly

FIG. 55.

FIG. 55. *Sypharoptera pneuma*. ×4·6.

quadrate, the second a little shorter, the third, fourth, and fifth again longer, and the eighth longer than broad. The ovipositor is nearly as long as the eighth segment, on the apex of

Fig. 56.

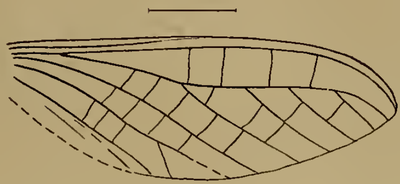


Fig. 56. *Sypharoptera pneuma* (anterior wing). × 4·6.

Fig. 57.

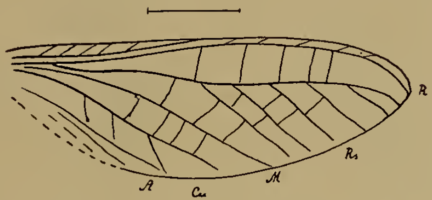


Fig. 57. *Sypharoptera pneuma* (posterior wing). × 4·6.

Fig. 58.

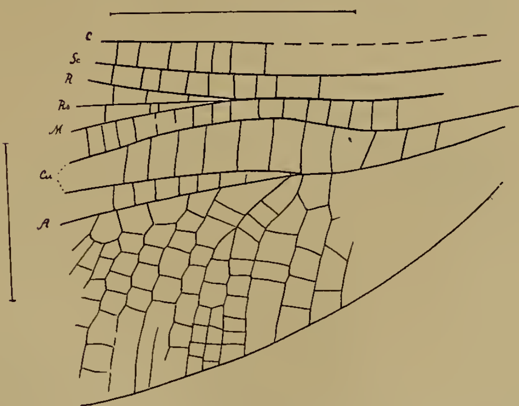


Fig. 58. *Paralogopsis longipes* (posterior wing). × 2·3.

which it is inserted. Unfortunately nothing is preserved of the terminal segments. The wings have their greatest breadth before the middle and are three times longer than broad. The first branch of the sector rises about in the middle of the wing.

Holotype in Peabody Museum, Yale University, Cat. No. 64.

Order PROTODONATA (Brongniart).

Family PARALOGIDÆ Handlirsch.

PARALOGOPSIS, new genus.

Paralogopsis longipes, new species. Fig. 58.

An insect whose wings may have had a length of about 100^{mm}. The basal parts only being preserved, it is difficult to give an exact description, but as this part is very similar to the American genus *Paralogus*, described by Scudder, it becomes possible to classify the fossil.

The costa marginal, being separated from the subcosta by a single row of cells; both veins are strongly convergent, so that we can suppose that the subcosta was not very long. Going farther backward, we find a very thick vein which must be the radius, apparently fused with the basal portion of the media. On one and the same point of this vein rise 2 branches which I suppose to be the sector and the media. The subcosta-radial space is filled by a single row of cells, just as is the space between the media and the next following waved vein, which I must call the first branch of the cubitus. Near the base we find an oblique bridge reaching the last main vein or analis. This bridge evidently is the second main branch of the cubitus, temporarily uniting with the anal vein; farther outward the cubitus again becomes independent. The interstices between the two cubital branches and the anal vein show but one row of cells. The anal vein sends off numerous more or less broken branches and intercalary veins toward the posterior margin, all being united by cross veins.

The front wings are narrower than the hind wings (16^{mm} and 20^{mm}), slightly reduced toward the base and not angular.

One of the legs, probably of the posterior pair, is preserved; its femur must be described like the tibia as very slender and reaches 24^{mm}.

I cannot say whether my interpretation of the sector is right or not. Should the opinion of Mr. Sellards, who supposes that the crossing of sector and media was complete in the Palæozoic Protodonata, be ratified, the vein which I consider to be the sector should be added to the media. In any case we will await new discoveries before deciding this question. In the European Protodonata I have not seen a sign of such a crossing and even *Paralogus* Scudder does not confirm Sellards' opinion.

Holotype in Peabody Museum, Yale University, Cat. No. 65.

Order MEGASECOPTERA Handlirsch.

Among the fossils now examined there is a very shadowy one showing nothing but the four wing cases of a nymph.

The very characteristic situation of these larval wings in the stone is due to their primitive position on the sides of the thorax and their being strongly spread outward. The base and general appearance is not that of wings which have been laid back over the abdomen. They are all nearly equal, and shape as well as venation—the subcosta and radius running parallel to the tip, the characteristic anal vein, etc.—points to a member of the Megasecoptera.

I believe this discovery will confirm my opinion that the Megasecoptera have been heterometabolous insects, for the wing

FIG. 59.

FIG. 59. *Lameereites curvipennis* (wing cases in situ). ×1·8.

FIG. 60.

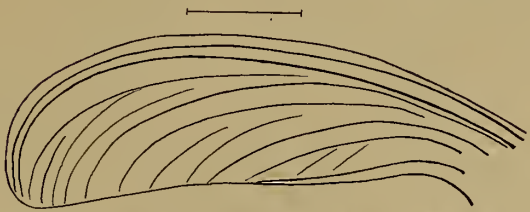


FIG. 60. *Lameereites curvipennis* (wing case of first pair). ×4·5.

cases of a holometabolous form would hardly have been preserved in such a manner and position.

This highly interesting fossil, certainly representing a new species and genus, may be called in honor of my highly estimable opponent, *Lameereites*, new genus, *curvipennis*, new species (see figs. 59, 60).

Holotype in Peabody Museum, Yale University, Cat. No. 66.

? Family PROCHOROPTERIDÆ, new family.

The fossil inducing me to establish—though with some hesitation—a new family, probably will prove to be an aberrant and somewhat more highly specialized member of the Megasecoptera, but it is possible that in the future we will be forced to consider it as the type of a peculiar order.

PROCHOROPTERA, new genus.

Prochoroptera calopteryx, new species. Figs. 61-63.

The body is comparatively robust, but always slender. Head apparently small. The second of the three thoracic segments somewhat larger than the two others and distinctly limited. Prothorax about semicircular, mesothorax tun-like. The base of the abdomen as broad as the thorax, the first segment being twice as broad as long, the following segments becoming gradually shorter and, beginning with the sixth, also narrower.

FIG. 61.

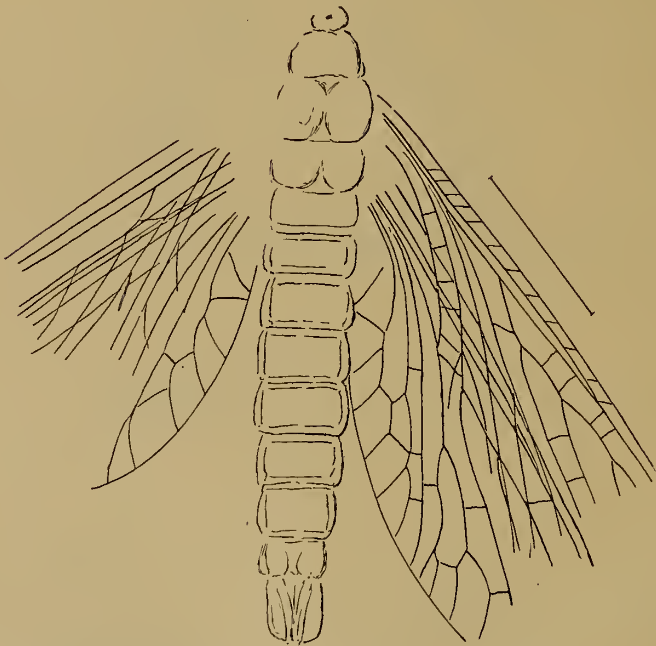


FIG. 61. *Prochoroptera calopteryx*. ×3.

The eighth segment comparatively small, the ninth elongated and provided beneath with a slit-like sexual organ, limited laterally by longitudinal ridges. Cerci not preserved.

The two homonomous wing pairs laid obliquely backward and apparently not to be folded over the abdomen. The anterior margin nearly straight, the posterior strongly curved.

The greatest breadth situated below the middle. Costa marginal. Subcosta produced somewhat beyond the middle and united with the radius, these two veins very near the anterior margin. Sector rising at about one-third of the length, moderately diverging from the radius and giving off 2 branches. The media sends a branch in the form of an

FIG. 62.

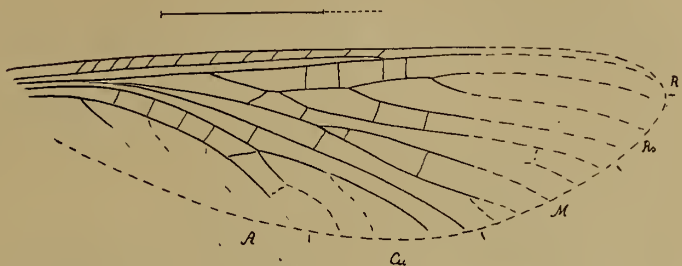


FIG. 62. *Prochoroptera calopteryx* (fore wing). × 3.

FIG. 63.

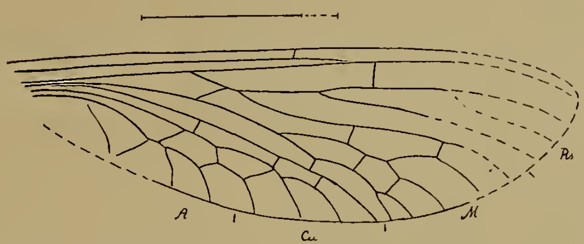


FIG. 63. *Prochoroptera calopteryx* (hind wing). × 3.

oblique cross vein to the sector, continuing its course as a branch of the latter. The stem of the media soon forks again and these forked branches are broken on the points of insertion of the cross veins. First cubital branch simple, free; the second split into 3 twigs. Anal vein of the anterior wing forming a regular vault and giving rise to 3 oblique branches, directed backward. In the posterior wing the anal vein is broken and has also 3 branches. The whole medio-cubital and anal area, by the breaking of the veins at the insertion of the cross veins, chiefly in the hind wing, has a very singular aspect which recalls some Neuroptera, for example, *Raphidia*. The small number of regularly arranged cross veins, the shape of the homonomous wings, the fusion of the sector with the media, seem to indicate a close relationship with the Megasecoptera.

The length of the whole insect is 29^{mm}, that of the anterior wing about 32^{mm}, and of the posterior wing 28^{mm}.

Holotype in Peabody Museum, Yale University, Cat. No. 67.

Art. XXXIII.—*A New Family of Reptiles from the Permian of New Mexico;* by S. W. Williston.

It is now more than thirty years since the late Professor Marsh described in this Journal (May, 1878) three new genera and four new species of vertebrate fossils from the Permian of New Mexico. Three years later Professor Cope published a brief note on a small collection of vertebrate fossils from the same region, with descriptions of two new species.* The only other references to the New Mexico Permian deposits or fauna that I can find in the literature, either paleontological or geological, are brief descriptions by Professor Case of four new reptiles based upon the Cope collection, at present preserved in the American Museum of New York City.

The collections of Permian vertebrates in the Yale Museum, inclusive of Marsh's types, were made by the late David Baldwin of Farmington, New Mexico, in Rio Arriba County, in the interval between November 1877 and December 1880. Mr. Baldwin believed them all to be of Triassic age, and so labelled them. From 1880 to 1888 Mr. Baldwin was in the service of Professor Cope collecting fossils, chiefly from the adjacent Wasatch and Puerco formations; and sometime in the early part of this period made the relatively small collections of Permian fossils now in the American Museum, coming from the same horizons and localities as did his previous ones collected for Marsh.

The Yale collections have never been thoroughly studied till recently; a part, indeed, including the type of the genus and species herein described, had never been unpacked from the boxes in which it was originally received so long ago. And it is unfortunate for science that these specimens have remained so long buried in the basement of Peabody Museum. Although I was an assistant of Professor Marsh at the time of their reception, I had no suspicion that the collections were as extensive as they prove to be.

By the kindness of Professor Schuchert I have recently had the privilege of studying this material, a privilege for which I would here express my sincere thanks. Not only were all the Permian vertebrate fossils of the Yale collections brought together and placed at my disposal, but the full staff of preparators was engaged in their preparation for more than two months.

The known New Mexico Permian deposits, so far as I can learn from the notes of Mr. Baldwin, are chiefly in the vicin-

* American Naturalist, xv, 1020, 1881.

ity of the Gallinas mountains, east of the Nacimiento mountains, reaching as far east as the peak El Cobre north of the Chama river. They overlie the Carboniferous, apparently conformably, and are overlain by the Morrison beds of the Jura-Cretaceous, with more or less of the Trias doubtless intervening. The Permian fossiliferous strata are in the lower part of the Red Beds and are several hundred feet in thickness. The matrix in which the fossils are enclosed is variable, consisting of red, white, and reddish brown sandstones, and red and black clay. There is an entire absence of all concretionary material and pebbly conglomerates, both of which are highly characteristic of the Texas deposits.

In the examination of these Permian fossils preserved in the Yale Museum I have distinguished with more or less assurance at least ten genera of amphibians and reptiles; I found no trace whatever of fish remains. These genera are: *Nothodon* Marsh, indistinguishable from *Diadectes* Cope, published ten days earlier; *Sphenacodon* Marsh, the type of which is indistinguishable from *Dimetrodon* Cope, published five days later; *Ophiacodon* Marsh, closely allied to the genus which Case has called *Theropleura* Cope on somewhat questionable evidence; *Eryops* Cope, a species of which was described by Marsh as *Ophiacodon grandis; Clepsydrops* Cope, represented by very characteristic limb bones; "*Dimetrodon*" *navajoicus* Case, not a true *Dimetrodon*, but a short-spined Pelycosaur, probably belonging to a new genus; *Dimetrodon* Cope, represented by very characteristic specimens either closely allied to or identical with species from Texas; "*Ctenosaurus*" *rugosus* Case, which is not a real *Ctenosaurus* v. Huene from the Trias of Europe, but a new genus which I shall describe and figure later as *Platyhistrix*, gen. nov.; a pelycosaurian reptile with long flattened spines, probably new; one or two other reptiles which I cannot at present determine; *Aspidosaurus* represented by a new species which I shall describe as *novamexicanus;* and the genus *Limnoscelis* herein described. In addition, Case has named the genera *Elcabrosaurus* (melius *Elcobrosaurus*) and *Diasparactus* from vertebræ in the Cope collection.

In this examination I was especially struck by the absence of forms characteristic of the Upper or Clear Forks division of the Texas Permian, such as the Pariotichidæ, and especially *Labidosaurus*, *Diplocaulus*, etc. *Diplocaulus* may not be a characteristic guide fossil, because of its occurrence in the Illinois beds that are probably lower than the Wichita division, but the Pariotichidæ are reliable. Not only is there an absence of forms characteristic of the Clear Fork division, but forms such as *Diadectes* and *Clepsydrops* have never been found in Texas in the upper beds. The evidence thus seems to indicate, almost conclusively, that the New Mexico beds are the stratigraphical equivalent of the lower or Wichita division of the Texas beds. The presence of certain forms, like those of *Dimetrodon*, either closely allied to or identical with Texas species, indicates a faunistic relationship between the New Mexico and Texas faunas. On the other hand, the majority of the New Mexico genera, and perhaps all the species, will be found to be distinct from those of Texas, indicating either interrupted communication between the two not very widely separated regions during these Permian times, or different environmental conditions. The latter conclusion seems the more probable one, since those forms most nearly allied are chiefly from the red clays and red sandstones quite like those of the Texas deposits, while most of the unlike forms come from sandstones or clays unlike anything in Texas. Furthermore, the entire absence of concretionary material, pebbly sandstones, and apparently of all fish remains, may also indicate different environmental conditions. Remains of sharks and dipnoans are rather abundant in Texas deposits, and while they may not be absolutely characteristic of marine or brackish waters, they probably are. Of interest is the fact that there is not a single fragment in the New Mexico collections that is even suggestive of *Naosaurus*. perhaps the most widely distributed, and at the same time fragmentary and tantalizing of Texas fossils.

A full discussion of the Yale collection of New Mexico Permian fossils would be beyond the limits of a single magazine article, and will be given elsewhere, with figures of some of the more characteristic specimens and of Marsh's types. I restrict myself here to a description of a remarkable new family of reptiles, coming from the very base of the deposits in the vicinity of El Cobre.

Limnoscelidæ, family new.

Limnoscelis paludis, genus and species new. (Figs. 1–7.)

The description of this genus and species is based upon two specimens, both from the same immediate locality in Rio Arriba County, New Mexico, and both enclosed in a like matrix, a dark, rather fine-grained sandstone, in nodular form. These two specimens seem to be specifically identical, as the slight differences observed between them may well be due to age or conditions of fossilization. Of one of them (No. 809), there is a nearly complete skeleton save the skull and front feet, and a part of one of the hind feet; the preserved parts lie, for the most part, in orderly articulation. The second specimen (No. 811) is almost perfect, the only missing parts that I observe being the right hind foot, and perhaps a part of the left hind foot, both which had been more or less exposed and the bones somewhat weathered. This skeleton lies in the most orderly relations, with all its parts in close articulation, save such as had been disturbed by gravitation. It is without break, at least as far as the proximal third of the tail; some of the smaller caudal vertebræ may be missing, but, fortunately, the tail seems to be quite complete in the other specimen. This more perfect specimen (No. 811), which may be considered the type of the species, was found among unpacked material only a few weeks before my departure from New Haven became necessary, and its preparation has not been quite completed. When fully worked out from the matrix and prepared for exhibition, it will be one of the most notable specimens of a reptile ever obtained from the Permian deposits of America.

The skeleton is evidently that of an animal which had died peacefully in some pool or body of water undisturbed by waves or currents; nor does it show any indications of extraneous forces. The animal at death rested with its ventral side downward upon a hard bottom, since all the bones had fallen, so far as was possible with their natural articulations, to a level, as is the case with fossils preserved in marine deposits. The skull and limbs are in complete articulation, the vertebral column curved gently to the left, the pectoral and pelvic girdles intact and in position, and with all the bones of the limbs closely articulated, so far as they are preserved, at least, save a few of the terminal phalanges. The sacral vertebra is attached to the ilia, but the vertebræ immediately preceding and succeeding it had fallen to the level of the pubes and ischia. As the specimen lies in place it measures three feet and four inches to the hind end of the ischia, while the articulated or nearly articulated tail of No. 809 has a length of forty inches to where the centra measure ten millimeters in diameter. Yet smaller, unarticulated vertebræ among the unassociated material indicate a possible length of the tail of forty-four or forty-five inches, or a total length for the skeleton of about eighty-four inches.

Skull.—The skull of *Limnoscelis paludis* is remarkable in many respects, and fortunately this part of the specimen which serves as the type is remarkable for its completeness and perfection of preservation. Like the remainder of the skeleton, with which it was in close articulation, it lay upon its ventral side, slightly depressed by its own weight in fossilization, and a little skewed to the right. As collected, it was broken in eight or ten pieces, the bone so firm that it permits the matrix to be removed very completely, which has been done by the skillful head preparator of the Yale Museum, Mr. Hugh Gibb; not quite completely yet, the anterior palatal region being still invisible. Since the mandibles are clearly in natural relations with each other save for the slight twisting, and the upper part of the

FIG. 1.

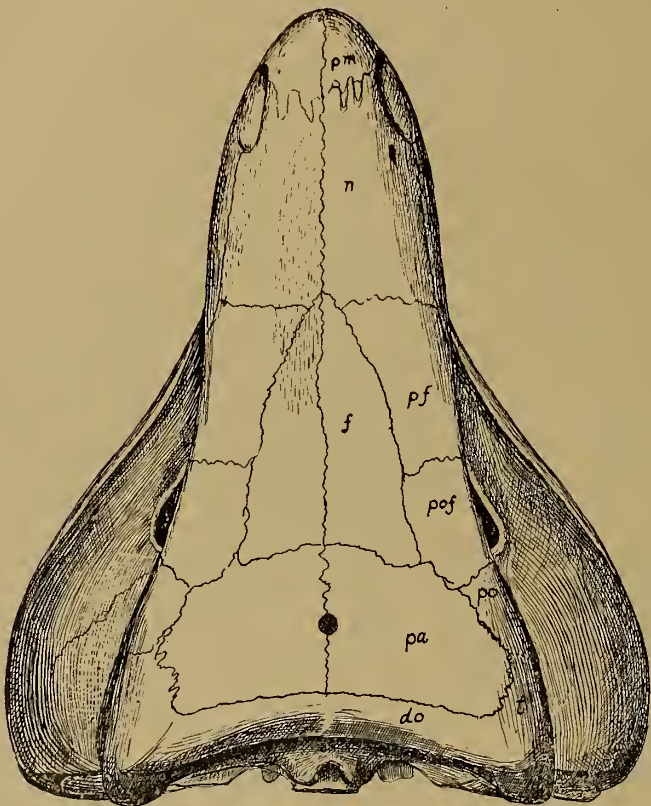


FIG. 1. *Limnoscelis paludis* Will. Skull, from above two-fifths natural size. *pm*, premaxilla ; *n*, nasal ; *l*, lachrymal ; *f*, frontal ; *pf*, prefrontal ; *pof*, postfrontal ; *po*, postorbital ; *pa*, parietal ; *do*, dermoccipital ; *t*, tabulare.

skull is undisturbed : the obliquity has been corrected in the drawings—a matter of no difficulty. In a later paper, a restoration of the skeleton and photographs of the skull and other parts will be given. Some facts of interest, especially the mandibular and maxillary teeth, were made out from the separated pieces before they were cemented together, characters which will again become visible when the preparation of the

FIG. 2.

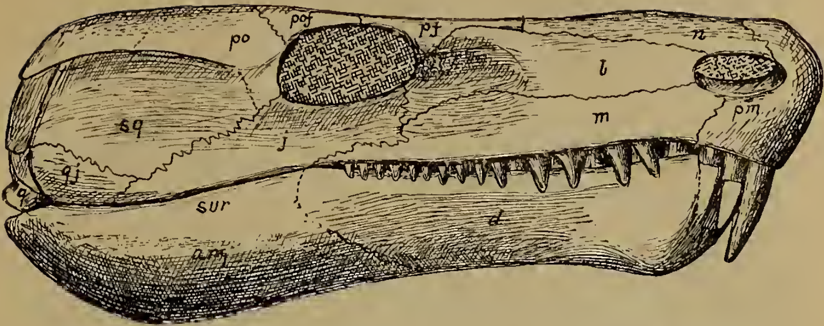


FIG. 2. *Limnoscelis paludis*, Skull, from side, two-fifths natural size. *pm*, premaxilla; *n*, nasal; *l*, lachrymal; *m*, maxilla; *pf*, prefrontal; *pof*, postfrontal; *po*, postorbital; *j*, jugal, *sq*, squamosal; *qj*, quadratojugal; *q*, quadrate; *d*, dentary; *sur*, surangular; *ang*, angular.

FIG. 3.

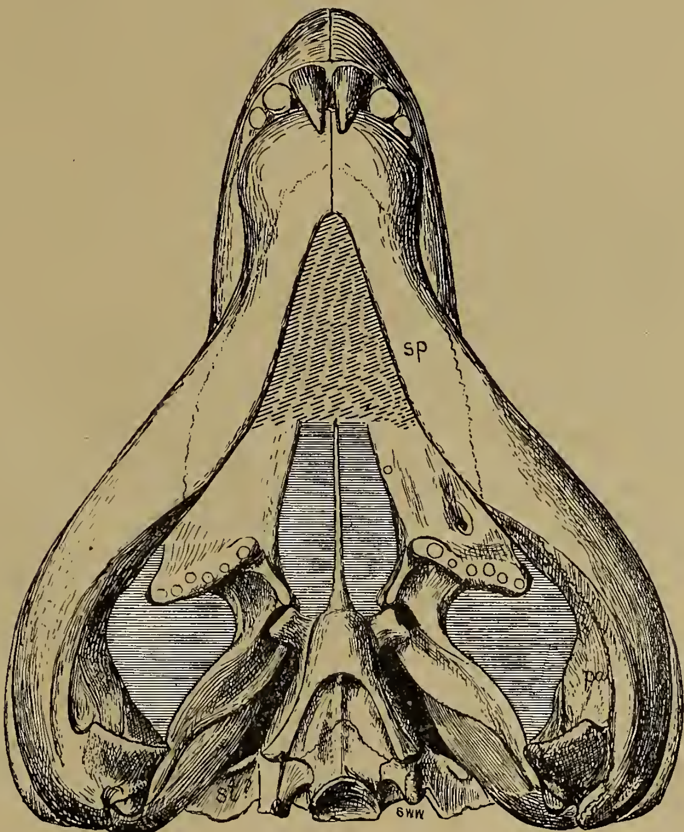


FIG. 3. *Limnoscelis paludis.* Skull, from below, two-fifths natural size. *sp*, splenial; *pa*, prearticular; *st*, (?) stapes.

skull is completed. The surface of the skull is almost smooth, with feeble indications of small pits.

The skull of *Limnoscelis* is remarkable among terrestrial reptiles for its elongated form and highly developed incisor teeth. The upper surface is nearly in one plane from the margin of the occiput to near the extremity of the rostrum, somewhat convex above in front of the eyes, and the parietal region is moderately convex on the sides. Fortunately the sutures of the skull nearly everywhere are quite distinct, even visible in the photograph as serrated or zigzag lines. A few cracks are present, but they are not confusing save in a few cases, but those are in the most important part of the skull, the posterior temporal and occipital region. The sides of the skull, with the mandibles in place, are of nearly uniform height, that at the nostrils being quite what it is at the temporal region, unless there has been a slight depression in the latter place. From just in front of the orbits the skull widens very rapidly, the orbits themselves being nearly wholly concealed in top view by the overhanging roof of the skull. In front of the orbits there is a rather deep depression on each side. Back of the orbits there seems to have been a nearly vertical wall for some distance, and then convex broadly outward. The nares are of considerable size, oval in shape and situated close to the anterior end of the skull. The orbits are relatively small and situated far back, the distance between orbits and nares being greater than the extent of the skull posteriorly. They are oval in outline, somewhat narrowed in the specimen, their planes nearly parallel to each other and nearly vertical, the posterior part turned a little outward.

The premaxillæ are very massive bones, strongly protuberant in front. The suture uniting them with the nasal is strongly digitative, beginning at the front end of the nares. Each premaxilla has three large, conical and recurved teeth. In the specimen the interior one on the right side had been lost before fossilization, but its mate is complete; the second and third teeth are successively smaller, but of the same character as the inner one, long, conical and recurved. The bases of two are present on one side, with indications in the matrix of their length. Doubtless when the skull is finally prepared, the missing parts will be found. The long tooth lies in the specimen as I have figured it, directed downward and backward, and closely applied to the end of the mandible.

The maxilla has quite the same relations as in the other American cotylosaurs where it is known, a rather narrow bone united with the premaxilla below the nares, with the lachrymal throughout nearly its whole length above, and with the jugal posteriorly below the orbit, which it joins by a long, oblique, serrated suture. The precise number of teeth I cannot be sure of. On the left side the teeth are hidden by the obliquely compressed mandibles from the outer side; on the right they are not perfect. Before the parts were cemented together, Mr. Gibb worked out the left maxillary and mandibular teeth from the inner side in large part, and these have been used to complete the figures in the drawing. There are at least eighteen in the maxilla, and perhaps more. The anterior ones are longer and stouter, conical like the incisors, and somewhat recurved. Their attachment to the bone is more or less pleurodont. The posterior teeth are shorter, but are also nearly circular at their bases. There is but one row. The nasals are very large bones, occupying nearly the whole of the upper surface of the skull in front of the orbits, and are gently convex or flat. The lachrymals, as in probably all cotylosaurians, are elongate, forming the posterior border of the nares and a part of the anterior border of the orbits. As in the Diadectidæ, and quite unlike the condition in the Pariotichidæ, the small frontals do not take any part in the orbital border, which is formed by the prefrontals and postfrontals; as in the Diadectidæ, both these bones are short and broad, extending little beyond the orbit in front or behind. The parietals are short, broad bones forming most of the superior surface of the skull back of the orbits; the parietal foramen is of the usual size, very unlike the enormous one of the Diadectidæ. The sides of the skull back of the orbit are formed chiefly by the squamosal, very clearly distinct from the small quadratojugal on the lower posterior margin, but not distinguishable at present from the postorbitals and epiotics quite to my satisfaction. Back of the parietals are the narrow transverse dermoccipitals, which seem to be quite distinct from a small bone at the outer angle, which doubtless is the tabulare (epiotic). The structure of the posterior part, the occipital region, is somewhat confusing, and I do not feel at all sure of my determinations. The discussion of this region I reserve for a later paper, hoping that additional material may be forthcoming. The structure of the palate, so far as it has been developed in the specimen, is most interesting, so closely resembling the "rhynchocephalian" type, that a few years ago, had it been found without other parts of the skull it would have unhesitatingly been located in the "Diapsida" and "Diaptosauria." The specimen has not yet been thoroughly cleaned in the anterior part, so that I can say nothing of the vomers. The palatines and united pterygoids are, as in *Labidosaurus* and *Pariotichus*, separated by a more or less elongated interpterygoidal space. The eminence in the region of the transverse, if the bone be distinct as I think it is, is crowned by a row of five or six teeth, evidently more or less conical in life, but unpreservable in the preparation of the skull. In front of these teeth I can find evidence of but a single tooth, located as I have marked; I am not quite sure of it, but in all probability there were others. Opposite the front end of the basisphenoid, the pterygoid on each side articulates with a stout basipterygoid process of the basisphenoid, quite as in the lacertilians, the first evidence I have seen among the Permian vertebrates of a real articulation at this place. The pterygoid has a pit or depression on the inner side for the head of this large process. Back of these processes the pterygoids resemble remarkably the like processes of the lizards, or *Sphenodon*, a not very wide, rather stout, obliquely placed process reaching backward to articulate with the lower inner side of the quadrate. In the middle the large basisphenoid is conspicuous; unlike that of the Diadectidæ, it is stout and rounded below, where it gives off the basipterygoid processes. Anteriorly it gives off the so-called parasphenoid. But the "parasphenoid" in this case is a thin vertical plate, thickened posteriorly to join the anterior end of the basisphenoid, very much as in *Trinacromerum* among the plesiosaurs. In the specimen the front part lies obliquely in the matrix an inch or more in width, with the lower margin, that visible in its normal position, narrow. Behind the rounded median convexity of the sphenoid, the bone is broadly concave in the middle, on either side of which the usual basisphenoid process is directed downward, backward and outward, to end in a rather stout projection. In the middle of this concavity the sutural line for union with the basioccipital is evident. The occipital condyle is quite flat or even concave, as in *Diadectes* and *Pareiasaurus*, a strong indication of relationship. On either side of the basioccipital I think I have interpreted the bones of the posterior palatal and occipital regions, but I prefer to wait before publishing my conclusions in the hope of getting material of this form the coming season.

The mandibles of *Limnoscelis* are very powerful, indicative of the carnivorous habits of the animal in life. They lie in perfect relation to each other, save that they are a little skewed to the right. They are broadly separated behind, with a long convexity on the sides, and again expanded at the front end. The teeth are only partly visible from without; the one or more large ones in front opposing the premaxillary teeth are wholly hidden, nor can the number be made out with certainty. The postarticular process is small, not extending back of the quadrate, or if so, but for a few millimeters only. Externally the suture separating the angular from the surangular passes forward near the middle of the bone, and backward nearly to the extremity, On the inner side of the mandible the structure is peculiar. A broad flange is directed inward, nearly vertically, opposite the middle of the articular surface, concave in front. The suture separating the prearticular from the articular is very conspicuous, passing back over the flange. In front the prearticular passes far forward, between the upper opening to the cavity of mandible and the elongated foramen near the middle of the inner side before the middle of the bone antero-posteriorly. A fracture of the mandible a little in front of the articular shows a large cavity with an elongated opening above back of the teeth. The elongated vacuity is bounded by the angular below, by the splenial in front, by the prearticular above behind, anteriorly apparently by the coronoid. The splenial is very broadly visible on the under side of the mandible, the suture between it and the dentary beginning some distance in front of the posterior end of the median symphysis, and extending back nearly as far as the posterior end of the internal vacuity. On the left side a piece about two inches in extent of this bone has been peeled off from the dentary, showing the bone to be thin, not more than six or eight millimeters in thickness. In front, the splenial turns upward to cover the inner side of the mandible below the teeth and apparently partly covering the internal vacuity in front. Interesting is the fact that the existence of a separate prearticular is demonstrated beyond doubt in this specimen, and also that the splenials meet in a median symphysis in front as in *Labidosaurus*, and probably all the Cotylosauria.

Vertebræ.—Eighteen presacral vertebræ have been cleared of the matrix in a continuous series curved to the left. The lengths of these vertebræ are almost exactly the same throughout; in front of them the vertebræ above the pectoral girdle have not yet been exposed; the space in which they lie corresponds exactly with that of five vertebræ following them, and that is doubtless the number hidden in the matrix. In front of these the atlas and axis have been partially exposed, giving twenty-five as the total number of presacral vertebræ. The first of the series exposed below, the eighteenth presacral, has a shallow fossa or flattened surface on the under side in the middle, which fossa increases in depth posteriorly, a very characteristic feature which seems to separate this form from anything hitherto described and especially *Diasparactus* Case. The outline of the centra both on the sides and below, antero-posteriorly, is deeply concave. The arch has a marked resemblance to that of *Diadectes*, so far as they have been worked out, save that there is no trace of a hyposphene anywhere in the series and the rib articulation is continuous from the arch to the centrum, as in *Labidosaurus*. All the observed ribs are single-headed, but expanded, that is without an emargination distinguishing the head from the tubercle. In *Diadectes*, or at least in such species as I have been able to study of this genus, the ribs anteriorly are distinctly double-headed. The transverse processes are short throughout the series, scarcely extending on the sides beyond the margin of the zygapophyses. This character has been given by Case as a distinctive one for his genus *Diasparactus*, but, in a large species of *Diadectes* from Texas I do not find any appreciable difference in the prominence of the processes, at least in the posterior presacral region. The spines are moderately elongate through the series, thickened and somewhat rugose at the upper end. There are large intercentra between the centra below, and as the vertebræ lie in the matrix a considerable space is left between the adjacent vertebræ for cartilage, indicating a very flexible, though not very firm spinal column. The spines, of the posterior part of the column at least, are about one inch in length. The first presacral spine is rather broad and expanded above, the second and more anterior ones are more slender. There is but one sacral vertebra, which has a very broad, stout, sacral rib on each side, turned directly downward so as to cover nearly the whole of the inner side of the ilium at its junction with the ischium and pubis, its antero-posterior width being 60^{mm}, its vertical width where it joins the ilium, 40^{mm}. The ribs immediately in front and behind are small and slender and do not seem to touch the ilium at all. Case has described *Diadectes* as having two sacral vertebræ, but in the specimen in the Chicago collections, of a large species, the structure of the sacrum seems to be quite as in *Limnoscelis*; and this is also the case in a new genus of Diadectidæ, which Professor Case will describe from a specimen in the University of Chicago collections, collected by Mr Miller.

The first chevron occurs at the hind end of the third caudal vertebra, the first one visible above the ischia from below; the first three or four of the caudal vertebræ have short, free ribs, as in other genera of American Cotylosauria. The tail, as preserved in specimen No. 908, is rather slender, with rather short spines and chevrons, rather precluding the idea that the animal was marked natatorial in habit. The terminal vertebræ are a little elongated.

Pectoral Girdle and Extremity.—The pectoral girdle lies in very orderly arrangement, with little if any distortion. Both clavicles are in articulation with the interclavicle, scapulæ and cleithra. The clavicles have the usual cotylosaurian form, curving under the anterior end of the interclavicle and the anterior margin of the coracoid, curved and somewhat spoon-shaped below. The long, dilated, scapular part is curved upward in a vertical plane and obliquely backward in the articulated skeleton, reaching nearly to the upper end of the scapula, flattened from side to side above. The cleithrum is small and vestigial, smaller than in *Diadectes*, a slender, cylindroid bone, reaching quite to the superior anterior angle of the scapula, but not expanded over the end, as in the temnospondyls. It is dilated at its lower end to articulate with the attenuated upper extremity of the clavicle, lying between the clavicle and the front margin of the scapula. It is only a little more than

FIG. 4.

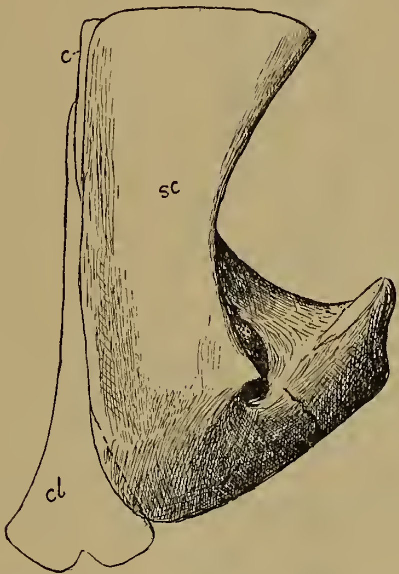


FIG. 4. *Limnoscelis paludis.* Left pectoral girdle, two-fifths natural size. *c*, cleithrum ; *cl*, clavicle ; *sc*, scapula.

two inches in length. The scapula is very short. The blade above is narrow, thinner and curved outward on its front part, thickened at its posterior superior border. Its upper end is truncated, and doubtless had a supra-scapular, cartilaginous continuation, possibly the representative unossified of the upper end of the cleithrum. The glenoid fossa is deep and large, the stout metacoracoid extending far back relatively. The posterior border of the scapula is curved nearly uniformly from the angle to the extremity of the preglenoid facet, which is large and flattened. There is a distinct supra-glenoid fossa a little below the middle of the bone, between the borders, which diverge nearly the middle of the length of the scapula; it is pierced in the usual temnospondyl way for the passage of the

FIG. 5.

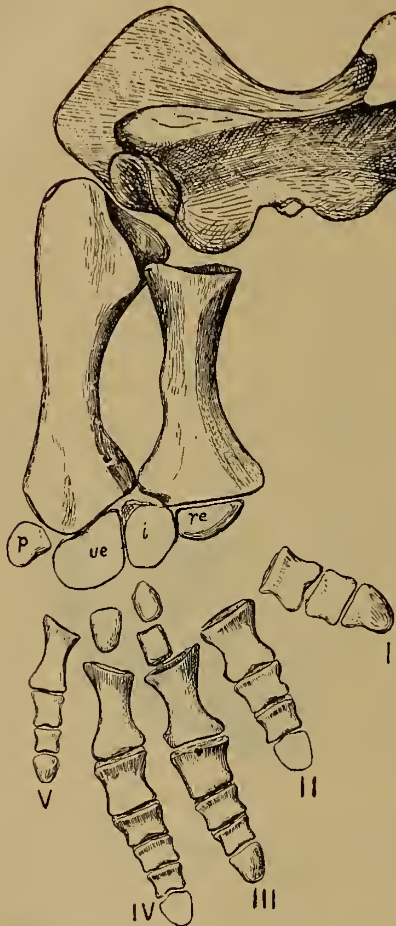


FIG. 5. *Limnoscelis paludis.* Right front leg, dorsal view, two-fifths natural size. *re*, radiale; *i*, intermedium; *ue*, ulnare; *p*, pisiform.

supraglenoid canal. I have observed this foramen in this position in scapulæ which I refer to the genus *Ophiacodon*, but usually in the *Pelycosauria* the opening pierces the bone in front of the scapular margin. I had supposed that this foramen was characteristic of these old orders of reptiles, never having seen any reference to it in literature of other orders of vertebrates. But, I am surprised to find that it is quite typical of certain lizards, and it perhaps occurs in other reptiles. In the present reptile I have observed for the first time in any form other than the amphibia, the inner opening of the foramen or canal back of the border of the subscapular fossa which I have called the glenoid foramen. That the canal perforates the bone to open in the glenoid fossa I am not prepared to affirm. I find, however, that the foramen is also present in the Diadectidæ, and perhaps in all cotylosaurians. Its presence removes the last distinguishing character between the temnospondyl and cotylosaurian pectoral girdles. One may distinguish them now only by the smaller size of the cleithrum in the reptiles.

The suture separating the metacoracoid (coracoid auct.) is situated not far back of the supracoracoid foramen, which is unusually large. The limits of the coracoid (procoracoid auct.) are not distinguishable ; the bone is thinned, rounded on the anterior angle, which is slightly underlapped by the clavicle, and, with the metacoracoid, is curved inward nearly to a horizontal plane, approaching its mate of the opposite side, but separated by the stem of the interclavicle. The interclavicle reaches a little further back than the hind angle of the metacoracoid, and is of moderate width ; its front part is dilated and mostly hidden from view, as in the other Permian reptiles.

In each skeleton there is a pair of bones found lying just back of the coracoids, and nearly below the vertebræ, of the nature of which I am not fully satisfied, though there would seem to be little doubt but that they are unusually large hyoids. They are about three inches in length, greatly expanded on their distal, thin end, with a somewhat curved and narrowed shaft, deeply concave in outline on one side, less so on the other, thickened and truncate for articulation at the proximal end. The two bones in each specimen lie with the thin ends nearly in apposition, as though they had joined each other in life.

Humerus.—The humerus is a remarkably short and thickset bone, resembling that of *Diadectes* more closely than that of any other genus that I know. The ectocondyle is more expanded and turned inward than in that genus, however, nor is the proximal expansion so much twisted from the plane of the entocondyle as is the case with the humeri of more terrestrial Permian reptiles. The entocondylar foramen is large, situated not far from the lower extremity of the lateral process. The ulnar expansion is broad and flat, and occupies a plane divergent from that of the proximal inner side of about forty-five degrees. The capitellum is very large and rounded, situated on the outer angle of the bone, as seen from the ventral side, and is remarkably close to the lateral process. The ectocondyle is remarkably stout and protuberant, and is directed almost rectangularly, or even at an acute angle backward, terminating very near the middle of the bone transversely, and above the groove for the ulna on the dorsal side. It is an interesting fact that not only the structure of the humerus, but also the whole anterior limb, resembles, not only that of *Diadectes*, but also that of the amphibian *Eryops*, suggesting similar habits in all three animals, and possibly too genetic affinities. There is a moderately stout ectepicondylar process, as in *Desmospondylus*, *Seymouria*, *Diadectes*, *Eryops*, etc. It is situated a little below the lateral process on the radial side.

Radius, Ulna.—The radius and ulna are very like those of *Diadectes* and *Eryops*, rather short and stout bones. The two lie in position on each side, as shown in the figure, the upper end of the radius partly lodged in the lower end of the sigmoid fossa, and the two are in one plane. The radius has the capitulum truncated and hollowed for articulation with the humerus, the extremity strongly convex on the dorsal, flattened on the ventral side. The shaft of the bone is moderately narrowed, and its two borders are nearly symmetrically concave. The lower extremity is more expanded, with its end truncate and flattened for articulation with the radiale and intermedium, the inner side the thicker. Just above the inner distal angle there is a characteristic protuberance, which evidently came in close contact with the ulna. The ulna is a more slender bone and is a little longer; it is thick and massive at its upper end, the shaft more slender than that of the radius, and the lower end moderately expanded. Its radial border is deeply concave, its inner border nearly straight to the lower fifth. The sigmoid fossa is deep, winding obliquely about the bone, and fits accurately the curved trochlear surface on the distal and dorsal side of the humerus. Evidently the elbow joint was a strong and firm one. The distal extremity of the ulna is subtruncate, its border somewhat oblique to that of the radius, but with the angle broadly rounded for articulation with the pisiform. Both radius and ulna have the dorsal side convex, the ventral more flattened.

Front Foot.—Lying in close articulation with the radii and ulnæ are the proximal carpal bones, four in number on each side, the radiale, intermedium, ulnare and pisiform. The pisiform is a small bone, thinned along its free border and articulating in its usual position between the ulna and ulnare. The ulnare, the largest of the carpal elements, is an irregularly oval bone, articulating rather broadly with the ulna and the intermedium, but without distinct facets for the other carpal elements. The smaller intermedium is much thickened, articulating with the ulna, ulnare and the radius, with a very small free border between the ulna and the radius. The radiale is the smallest of the three, almost vestigial in fact, elongate-ovate in shape, with the radial border straight and flattened, the outer and obtusely pointed; it merely touches the intermedium. The ventral surface of all three of these bones is flattened, the dorsal more rounded, that of the radiale obsolete. Especially remarkable is the fact that all of these proximal carpal bones save the ulnare are very small, smaller than in *Diadectes* even, and much smaller than in other known Permian reptiles.

The remaining bones of the right foot were found nearly all connected, for the most part in the relations of the living animal. The foot had been slightly twisted in fossilization, disturbing somewhat the relations of the metapodials. Of the phalanges all were found in association save two terminal ones, the distal phalanges somewhat confused in the three middle fingers. The three distal carpal bones were found in the positions shown in the figure, but there were no traces of others, and they could have hardly escaped notice had they been fossilized with the others. Evidently these nodular bones represent the centrale and the third and fourth carpalia. Fortunately the bones of the left foot were found in the matrix in as natural relations as one could wish, and they will be so retained in the prepared skeleton. The block containing the distal carpals and the digital bones had been separated in collection from that containing the fore-arm and proximal carpals, and was not accurately readjusted. The three carpal nodules are quite as in the other hand with no traces of others; from which facts I have no doubt that they were the only ones ossified, and they but imperfectly. Of the digits the bones of the three middle toes were all in perfect articulation save the ungual phalanges of the second and fourth digits, which are missing. Of the first digit, the ungual phalange is also missing and the phalanges of the fifth have not been adjusted to the metacarpal. However, these digits were preserved in perfect articulation in the right foot. From these facts, which I have given in detail because of their importance, it is certain that the phalangeal formula is, as is seen in the figure, 2, 3, 4, 5, 3, fixing for the first time the foot structure in an American cotylosaurian, and save for *Procolophon*, which has been referred (wrongly I believe) to another group, in a member of the order. My figure was made by simply tracing the outlines of the various bones as they lie in position and transferring them. The only doubt that remains is the precise width of the space I have left for the carpal elements, it may be a trifle too broad. As is seen, the foot is remarkably broad and flat, lying in the matrix in nearly one plane, with the phalanges short, the ungual ones broad and hoof-like, as in *Diadectes*, and probably also *Eryops*. The foot resembles that of *Diadectes* somewhat save that the proximal carpal bones are large, and the distal row seems to be fully ossified in that genus.

Three years ago I expressed the opinion that the phalangeal formula 2, 3, 4, 5, 3(4) was the primitive one for land reptiles, if not for land vertebrates, as observed in *Eosauravus copei*. Broom is of the opinion that this is the formula in *Propappus* and he has proven it to be that of *Procolophon*. *Dromopus agilis* Marsh, as figured by the author and Matthew, shows a

FIG. 6.

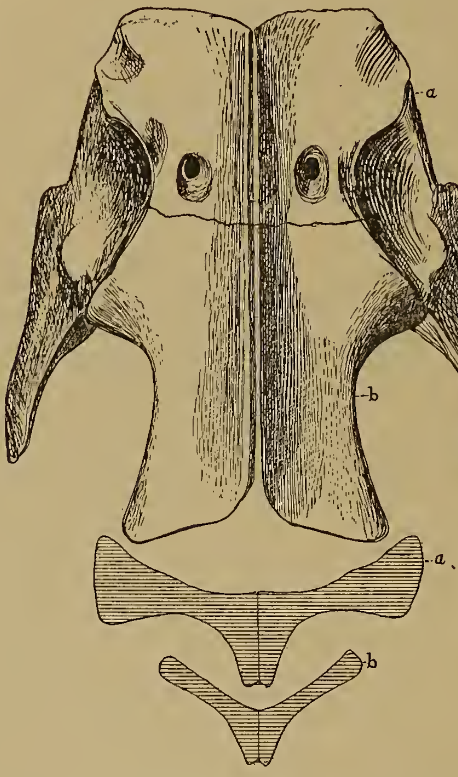


FIG. 6. *Limnoscelis paludis*. Pelvis, from below, two-fifths natural size. *a*, cross-section through pubes at *a*; *b*, cross-section through ischia at *b*.

similar phalangeal formula. These footprints are from near the upper part of the Coal measures in the vicinity of Osage, Kansas. Marsh thought that they were made by a lacertilian rather than an amphibian, a natural error considering the lacertilian form of the prints. They probably come from some microsaurian reptile not unlike *Eosauravus copei*.

Pelvic Girdle and Extremity.—The pelvic girdle lies in natural articulation, with but little disturbance; the right pubis is a trifle compressed, and the extremity of the left ilium had been broken off and turned aside before fossilization. Both femora are closely articulated in the acetabula, directed obliquely dorsad and cephalad. The pubes and ischia lie in a subhorizontal position, with a protuberant carina along the middle, deeper anteriorly. This keel, however, is not formed by the downward deflection of the margin of the bones, but by the increased depth of the symphysis, as will be seen from the cross sections of the figure, sections made at points of fracture in the specimen. The ischia have an angular margination in the middle, the sides curving outward and upward to the rounded posterior angle. The sutural division between ischium and pubis is at about two-fifths of the length from the front end of the pelvis. The pubic foramen is remarkably large at the bottom of a rather deep fossa situated a little back of the ischio-pubic suture, and not far from the acetabular border. The acetabulum is deep and large, with an overhanging, nearly horizontal roof-like process, at the upper posterior part. In life the cavity looked almost directly outward. The ilium is relatively small; it is flattened and thinned above and in front, with a rather stout, narrow process directed backwards and a little outward, nearly horizontal. Upon the whole, the structure of the pelvis is nearly identical with that of *Diadectes* and *Pariotichidæ*, and even of *Eryops* and *Cacops*, save in the form of the ilium; in *Diadectes*, broader above and not produced backward; in the temnospondyls without iliac projections either in front or behind. While there is but a single sacral vertebra in *Limnoscelis* and *Diadectes*, in *Cacops* there are two, a precise reverse of what has always been supposed to be diagnostic characters of these two classes of vertebrates. The femur is of the characteristic *Diadectes* type, short, stout, and expanded, with a heavy, protuberant trochanter, and a large digital fossa. The trochanter has a large facet, 20 or more millimeters in diameter, looking backward, and is rugose; the adductor ridge is pronounced and oblique. The tibia, like the femur, is short and stout, with a greatly expanded upper end, and a strong cnemial protuberance. The outer side is deeply concave in outline, the inner nearly straight. The lower extremity is much thickened. The fibula is a more slender bone than the tibia, and is longer. Its proximal end is thickened and subquadrate in shape; the lower end is thin and considerably expanded.

Hind Foot.—As already stated, the foot bones of specimen No. 811 were more or less weathered. From the wash, numerous toe bones and the ends of the epipodials with attached tarsals had been gathered up by Mr. Baldwin, and some of them still retain enough of their original matrix to show their relationships, but how many of them are irretrievably lost

FIG. 7.

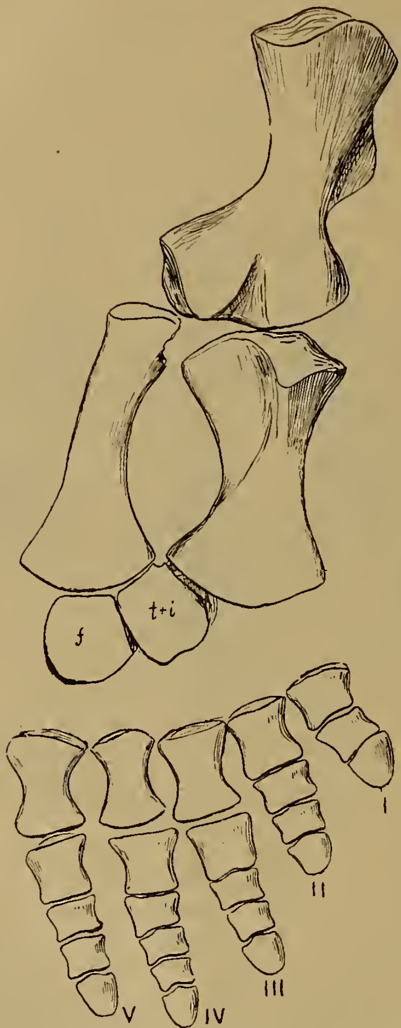


FIG. 7. *Limnoscelis paludis.* Right hind leg, dorsal view, specimen No. 809, two-fifths natural size. *t–i*, fused tibiale and intermedium ; *f*, fibulare.

cannot be determined at present. Fortunately, however, in specimen No. 809, the tibiæ and fibulæ of both sides were preserved in position with the tarsal bones attached, fortunately so, since one would hardly have identified the tarsal bones correctly had they been found isolated, so very different are they from the corresponding bones of the *Pariotichidæ* or *Pelycosauria.* The tibiale, or intermedium, is nearly cuboidal in shape, with a slight notch only between the articular faces for the tibia and fibula. Its outer facet is thickened for union with the fibulare, but I see no perforating foramen between the two bones. The distal and inner facets are also very broad, subquadrate in outline, with rounded angle. The fibulare is a larger bone, but much thinner than the tibiale; its tibial side is the thickest. I identify these two bones as the usual fused tibiale and intermedium, and the fibulare, but it is not impossible that the tibiale has been entirely lost, after fusion, and what really remains are the intermedium and fibulare. I have so far found no evidence satisfactory to me that the tibiale and intermedium are ever present in adult reptiles as distinct bones. I am aware that Broom has provisionally recognized a separate intermedium in *Howesia* and that other instances have been cited, but I think they are all open to doubt. The separation of the intermedium of the hand is a very persistent character in the Amniota, Man, himself, even having the same bones that are found in the temnospondyls in the proximal row of the carpus. In the tarsus, however, there was an early specialization, as far back as early Carboniferous times, and I do not think there was ever a reversion to the amphibian type.

Of the left foot of specimen 908 only these two tarsal bones and a number of separated toe bones have been recovered. Of the right foot, however, all the bones of the toes were preserved in their natural relations in the matrix, or with but slight distortions, the metatarsals all lying in one plane, apparently quite in the positions they occupied in life. The block containing them had the phalanges of the first toe, the first one of the second toe, the first two of the third toe and all four of the fifth toe in close articulation, those of the first and fifth toes strongly flexed. With this block, but separated, were the phalanges of the middle toes, the two each of the second and third and all five of the fourth toe severally connected by matrix, but not positively attachable to the basal bones of their respective digits, because of the effacement of the matrical surfaces in collecting. That they belong with these toes is, however, beyond doubt, both because of their perfect anatomical association and the peculiarities of the matrix. The formula as is thus seen is, like that of the front feet, the primitive one for reptiles, 2, 3, 4, 5, 4. The phalanges, as of the front feet, are all remarkably short and broad, and I may also add, relatively thin. The ungual phalanges, as have been described for *Diadectes*, which they resemble, are short, broad and hoof-like rather than claw-like, with a thin rounded extremity, the bones possibly encased in a horny nail in life. I can hardly conceive of a foot of this character being used for burrowing, notwithstanding Case's comparison of the similar feet of *Diadectes* with those of the gopher. The right front foot, as preserved in the matrix, had the tibia and fibula, with their attached proximal carpals, pressed downward somewhat below the proximal ends of the metatarsals, but not a vestige is preserved in the matrix of centrale or tarsalia, nor is there any tarsal bone preserved with either specimen save the four sets of proximal ones. It is not at all impossible, however, that vestigial, nodular tarsalia may have been ossified, but it is not very probable that they were. Chondrification was evidently here a specialization, and in accordance with the almost universal rule among terrestrial vertebrates we should expect that the process would develop more rapidly in the hind than in the front feet.

No indications whatever of ventral ribs are present in either specimen. In their place, however, the whole ventral region was covered by a sort of plastral sheath of imperfectly ossified or calcified material. Patches of this sheath were found scattered about in the matrix below the posterior vertebræ and adjacent regions, some of them two inches or more in diameter. I have not yet had an opportunity to examine the substance microscopically, but to the unaided eye it appears to be loose bone tissue. It is quite certain that the animal did not have distinct ventral ribs, or osseous dorsal scutes.

Habits and Relationships of Limnoscelis.—It is almost superfluous for me to point out, so evident will it be to every one, that *Limnoscelis* must have been a subaquatic or marsh-dwelling reptile. Of the poorly ossified or cartilaginous carpus and tarsus the evidence is almost positive, and there can be but one explanation, subaquatic habits. The limbs as a whole indeed are strongly suggestive of the turtles. The relationships of the genus are unquestionably closest with *Diadectes* of any forms that we know, from which it differs chiefly in the elongated skull, the conical, prehensile teeth, the absence of the ear cavity posteriorly, the small size of the parietal foramen, the smoothness of the skull surface, the non-expanded ribs, their apparently single-headedness throughout, the absence of hyposphenes, and the feebly ossified carpus and tarsus. It agrees with *Diadectes* especially in the general structure of the limbs, the arrangement of the skull bones, especially the union of the prefrontal and postfrontal over the orbit, the general structure of the vertebræ, with the cylindric or prismatic spines, etc. It agrees with both *Diadectes* and *Pareiasaurus* in the very characteristic flattened occipital condyle; and I believe that when we know more of the structure of the skull of the latter genus, we shall also find more evidences of affinity in these groups, to such an extent that the three genera, and *Propappus* also, may perhaps be placed in the same suborder of reptiles.

Art. XXXIV.—*New Elasmobranchs from Solenhofen in the Carnegie Museum ;* by C. R. Eastman. (With Plates I–III.)

Several years ago, through the generosity of Mr. Andrew Carnegie, the Museum founded by him in Pittsburgh received a notable enrichment of its collections illustrative of vertebrate and invertebrate palæontology, especially from European horizons and localities. By its acquisition of the famous Bayet Collection, through the gift of Mr. Carnegie in 1903, the Pittsburgh Museum was at one stroke placed in the front rank of American institutions as regards representation of the ancient life-history of the globe in Old World formations. Remarkable not only for its size and great wealth of fossil species, but also for the excellent character of the material, this collection is one of the largest and scientifically most important that has ever been brought together by a single individual, and in certain respects it stands unrivalled save by the larger public institutions abroad.

The great strength of the Bayet Collection may be said to lie in its magnificent series of vertebrate remains, especially fishes, from European Mesozoic and Tertiary strata. Within this category is to be included first of all the splendid suite of fishes and flying reptiles from the Lithographic limestone (Upper Jura) of Solenhofen, Bavaria, and from the corresponding deposits of Cirin, France. Next in order of importance may be reckoned the fish and reptilian remains (including at least one complete Pterodactyl) from the Lias of central Europe, and "blue Lias" of Dorsetshire. Nor would any mention of this collection be complete which failed to speak of the large variety of exquisitely preserved marine fishes, crocodiles, and plant remains from the Upper Eocene of Monte Bolca, Italy.

So much by way of brief comment on the surprising richness of the collection which has found a final resting-place in the Carnegie Museum, and which embraces the material about to be described in the following pages. For an opportunity to study the entire assortment of fossil fishes belonging to the Carnegie Museum, and for many privileges and courtesies enjoyed during his temporary connection with the institution, the writer is greatly indebted to the kindness of the Director, Dr. W. J. Holland, and desires hereby to express his hearty appreciation of the manner in which work upon the collections has been encouraged and facilitated by Dr. Holland and his assistants.

It is not the purpose of the present article to notice all of the interesting specimens of sharks and rays from Solenhofen belonging to the Carnegie Museum, but rather to signalize the characters of a few new or little known forms, reserving more detailed descriptions and a review of the entire Upper Jurassic piscine fauna until some later season. The species to which special attention is directed are referable to four genera, as follows: *Cestracion*, *Phorcynus*, *Squatina* and *Rhinobatus*.

Family Cestraciontidæ.

Genus Cestracion Cuvier.

To this existing genus, commonly known as the Port Jackson shark, have been referred certain skeletal remains not as yet satisfactorily distinguished from it which occur in the Lithographic limestone of Bavaria. The holotype of the so-called "*Acrodus falcifer*" (= *Cestracion*) of Wagner is preserved in the Palæontological Museum at Munich, and other imperfect portions of the skeleton are to be seen in the collections of the British Museum. None, however, exhibits the body outline and fin-characters at all satisfactorily.

Cestracion falcifer Wagner.

(For reference to literature see Woodward's Cat. Fossil Fishes British Museum, 1889, pt. 1, p. 332.)

The typical example of this species shows every indication of being an adult individual, and is estimated to have had a total length of about 40^{cm}. In it the two dorsal fin-spines are seen to be of unequal size, both are gently recurved, and the one in advance of the anterior dorsal is inserted at a point about midway between the pectoral arch and the origin of the posterior dorsal fin. It would appear from the published figures, also, that the pelvic fins arise opposite the first dorsal, and the shagreen granules are described by von Zittel as "schaufelförmige oder körnelige," without being markedly differentiated in size. To this species has also been referred by von Zittel (Handb. Palæont. vol. 3, p. 77) a smaller but better preserved individual, having a total length of only $12{\cdot}5^{cm}$, or less than one third as large as the type. According to the author just named, the smaller specimen, which he regards as the young of *C. falcifer*, has feebly striated lateral teeth, and is provided with enlarged stellate tubercles in the dorsal region. The description of this feature reads: "Neben den schaufelförmig gestalteten Chagrinschuppen liegen in der Rückenregion kurze gekrümmte Stacheln, welche sich auf einer vierstrahligen Basis erheben."

It cannot escape notice that the smaller example just referred to presents characters in common with the well preserved specimen in the Carnegie Museum from the same horizon and locality, immediately to be described as the type of a new species; and it seems proper to associate under the latter head the small shark which the late Geheimrath von Zittel regarded as the young of *C. falcifer.*

Cestracion zitteli, sp. nov.

(Plate I.)

The example which is here regarded as typical of a distinct species merits special attention on account of its being probably the most perfect post-Liassic Cestraciont shark which has thus far been discovered in the fossil state. Agreeing in principal characteristics with the small form described by von Zittel as the young of *C. falcifer*, as above stated, its features are nevertheless judged to be sufficiently distinctive as to warrant a separation from that species.

The more important differences relate to the position of the dorsal fins, form and relative size of the dorsal fin-spines, number and size of the vertebral centra, and presence of a series of enlarged radially ridged and acutely conical shagreen tubercles along the back. A comparison of characters displayed by the dentition in the type specimen of *C. falcifer* is impossible, as the teeth are unfortunately not preserved, but in the small Munich example, which may be with entire propriety associated with the type now under description, the lateral teeth are said to be "mit eine Anzahl von Zacken versehen." This statement may be understood to mean that the oral surface is faintly rugose, transversely striated perhaps, or else that the coronal margin is slightly indented. In any case, however, the teeth must have been exceedingly minute.

A summary of the chief features of interest presented by the type specimen may be given as follows: Form of body slender and elongate, total length from extremity of snout to that of the vertebral column about 15^{cm}. Vertebral centra varying somewhat in length, being more compressed in a longitudinal direction underneath the second dorsal fin. About 25 centra occupy the interval between the bases of the two dorsal fin-spines, and it is noteworthy that these latter abut almost directly against the column, as if they had been deeply implanted in the flesh. The spines themselves are of relatively large size, smooth, sharply pointed distally, and only slightly arcuate or recurved.

Portions of the fin-membrane or shagreen covering of the pectoral pair, as well as the greater part of the pelvic, anal, and caudal fins, are preserved. The anal is nearly opposite the posterior dorsal and, except for being more sharply pointed, resembles it in form and proportions. The pelvic pair is decidedly acuminate, and placed midway between the anal and pectoral pair. The pelvics slightly exceed the second dorsal in size, which latter is somewhat higher and longer than the first dorsal; and the depth of the pectorals is about one-third greater than that of the pelvic pair. Nearly the entire front margin of the right pectoral fin is preserved, but the distal portion of the left pectoral is either concealed or broken away. The same is true of the terminal part of both lobes of the caudal. The general outline of body and position of all the fins is shown in the accompanying illustration (Plate I). In this the shaded area immediately behind the head indicates a piece broken away from the containing rock.

The specific name is bestowed in honor of the memory of the late and deeply lamented Geheimrath Karl von Zittel, of Munich.

Genus Phorcynus Thiollière.

Phorcynus catulinus Thiollière. (Plate II.)

Our knowledge of this species has depended hitherto solely upon the type specimen, which lacks the anal and is in other respects incomplete. It must be regarded, therefore, as an extremely fortunate occurrence that a second and more perfect example of this forerunner of modern Dogfishes should have been discovered a half-century after the first was found, and should provide the means of further enlightenment concerning this genus and species.

The total length of the Carnegie Museum specimen, which bears the catalogue number 4780, is a trifle less than 40^{cm}.

It is a little difficult to determine the exact length of the head, but it was apparently contained between five and six times in the total length. The outline of the cranial roof, including the orbits on either side, and that of the lower jaw, is clearly shown. In the ethmoidal region and elsewhere in the body, the rounded or polygonal tesseræ of the endoskeletal cartilage are beautifully displayed, and the same remark applies to the fine shagreen granules occurring throughout the integument. Just beneath the orbital cavity are to be seen impressions of a few minute teeth, each provided with one principal and a pair of lateral cusps.

The vertebral column is preserved intact almost to the extremity of the tail, being flexed upward to support the upper caudal lobe. Ninety-six vertebral centra are to be counted in continuous series, and it is probable that not more than five or six are missing from the posterior extremity. The centra are of the usual hour-glass form, and do not call for any special comment.

Both the median and paired fins are very well preserved. The pectorals are large, lappet-like, not abruptly truncated distally as in modern representatives of Scyllium, but obtusely pointed, as is the case in Cretaceous species of Palæoscyllium. The low pelvic fins arise at a point opposite the middle of the first dorsal. The endoskeletal supports consist of at least a dozen segmented radialia. The first dorsal arises at about the middle of the back, is of triangular form and moderate height, with twelve or more strong radialia. The second dorsal is similar to the first, but smaller, and the gently rounded anal lies directly beneath its posterior half. The tail is strongly heterocercal, in this respect differing from Palæoscyllium and resembling the recent Ginglymostoma.

A minor feature which deserves perhaps casual mention is the preservation within the intestinal tract, near the vent, of portions of undigested food, including small ganoid scales, fragments of a small finely striated dorsal fin-spine (doubtless the young of some Cestraciont shark), and a number of small Echinoid spines, besides a few Foraminifera tests.

An outline drawing of this highly interesting shark is given in the annexed illustration (Plate II).

Genus Squatina (Aldrovandi) Duméril.

Squatina minor, sp. nov. (Plate III.)

Type. Complete skeleton, Carnegie Museum (Cat. No. 4737).

In general like the contemporary species of *S. alifera*, but distinguished from it by its smaller size (total length 49^{cm}), relatively narrower disk, and more posterior position of both dorsal fins. The first dorsal arises at a point about one-third the distance between the hinder extremity of the pelvic fins and tip of the tail, the second dorsal midway between the latter point and origin of the first dorsal. Dentition and other characters as in the typical species.

The differential characters given in the foregoing diagnosis are considered of sufficient weight to warrant a specific separation between the form here described and its larger contemporary which accompanies it in the same locality, *S. alifera*.

Not more than two or three examples of the latter form have thus far been brought to light, so far as published information shows, and the holotype of the new species here made known is unique. Hence the genus Squatina must be regarded as represented very sparsely, and by not more than three species, at the time of its advent in the Upper Jura of Solenhofen.

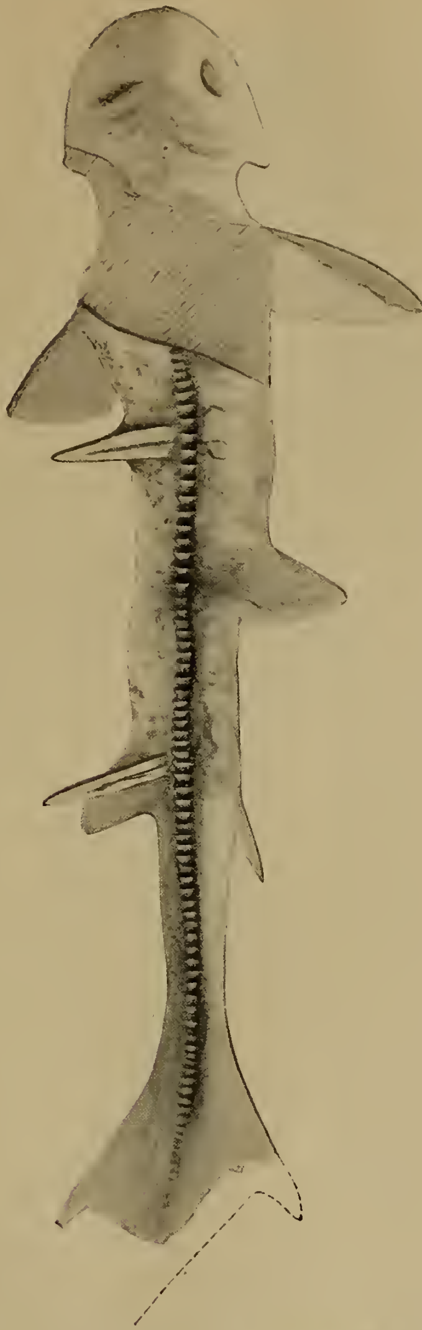
Genus Rhinobatus Bloch (Schneider).

Rhinobatus bugesiacus (Thiollière).

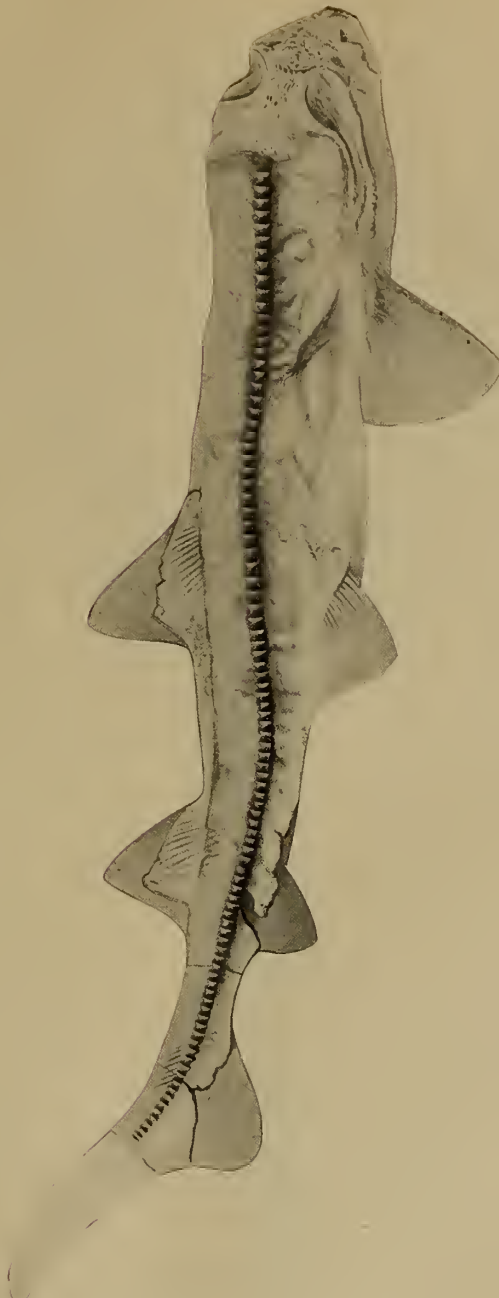
As recognized by Dr. A. Smith Woodward, the type of Wagner's so-called *Spathobatis mirabilis* is only a large variety of this species, which was founded by Thiollière upon a complete skeleton from the Lithographic stone of Cirin (Ain), France.* The Bavarian specimen serving for the type of Wagner's species is a magnificent example measuring $1{\cdot}7^{m}$ in length, with well developed clasping organs, and preserved in counterpart. The original of Wagner's and Zittel's studies is in the Munich Museum, and the opposite half now forms part of the exhibition series of the Carnegie Museum. It is noteworthy as being probably the largest and most perfect example of a fossil ray thus far discovered.

* Thiollière's final work, a large folio published shortly before his death, bears the title: Description des Poissons Fossiles provenant des gisements coralliens du Jura dans le Bugey. Lyons, 1854.

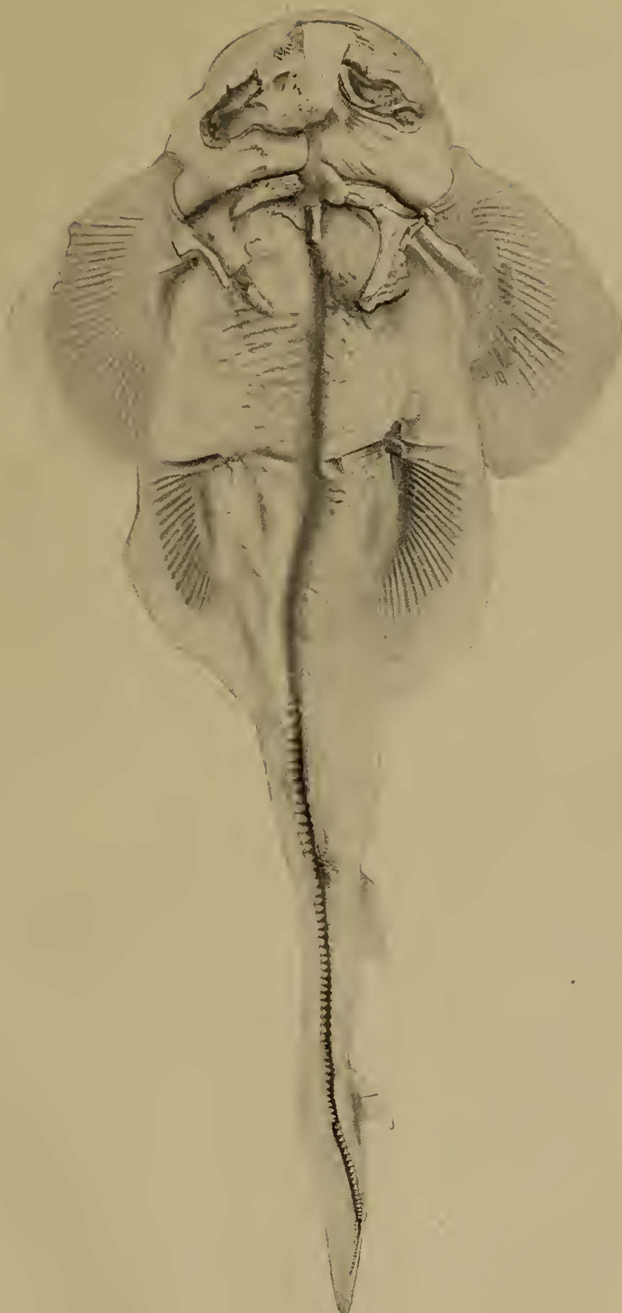
The close affinity between Phorcynus and the type of Wagner's genus Palæoscyllium appears to have been overlooked by students of fossil fishes generally. The former is conjecturally associated with Squatina by Smith Woodward.



Cestracion zitteli, sp. nov. × 7/6. (Carnegie Museum Cat. No. 4423.)



Phorcynus catulinus Thiollière. ×1/2. (Carnegie Museum Cat. No. 4780.)



Squatina minor, sp. nov. × 1/3. (Carnegie Museum Cat. No. 4737.)

Art. XXXV.—*Contributions to the Geology of New Hampshire, No. V; Petrography of Tripyramid Mountain;* by L. V. Pirsson.

Introductory.—In a previous paper in this Journal* Prof. Wm. North Rice and the author have described the geology of Tripyramid Mountain and discussed its structure and probable origin. It was there shown that the mountain was probably laccolithic in nature, and concentric in the arrangement of the different rock-types composing it. The outer border against the granite of the region is formed in considerable part of a gabbro, which is succeeded by a broad inner shell of monzonite, and this in turn encloses a core of syenite. In one place the gabbro is separated from the monzonite by a narrow zone of norite. In the gabbro and outer granite a few narrow dikes of lamprophyric character were observed, while with small aplite dikes and stringers all the rocks of the complex are reticulated. For further details the reader is referred to that article; the present paper is devoted to the description of the rock-types mentioned above, and to the consideration of their petrographic relations. Outside of various references to their mineral composition and megascopic appearance by Hitchcock,† the only investigations which have been made of these rocks appear to consist in a chemical study of the constituents of the gabbro by E. S. Dana‡ and an examination of it in thin section by G. W. Hawes,§ and these studies are referred to later.

In this paper the rocks will be considered in the following order: syenite, monzonite, norite, gabbro, aplite and lamprophyres.

Syenite, var. Umptekite (Nordmarkose).

A comparison of specimens and of sections shows great uniformity in this rock in all the exposures seen. The freshest material was found in a block which had fallen from the outcrops above down on the South Slide, and this was therefore selected as the type for description and analysis.

Megascopic.—Phanerocrystalline; medium grained; pale flesh-colored; dominantly feldspathic, but dotted with black anhedra and prismoids of hornblende 2–4^{mm} by 1^{mm} in size; feldspars mostly equidimensional, 1–5^{mm}; the great majority composed of flesh-colored orthoclase, but mingled with them a considerable quantity of grains of a white sodic feldspar; gran-

* Vol. xxxi, p. 269.

† Geology of New Hampshire, vols. i and ii.

‡ Composition of the Labradorite Rocks of Waterville, this Jour. (3), vol. iii, p. 48.

§ Geol. of New Hampshire, vol. iii, pt. 4, Mineralogy and Lithology, by G. W. Hawes, p. 166, 1878.

ular fabric; fracture rather crumbly; luster dull and slightly earthy, showing incipient alteration.

Microscopic.—The study of the thin sections proves the following minerals to be present: apatite, iron ore, zircon, hornblende, augite, biotite, labradorite, microperthite and quartz. The *iron ore*, in rather sparing grains, and the *apatite*, in small, relatively long prisms, present nothing unusual. The *zircon*, in rather short, thick prisms, bounded by 100 and 110, shows an unusually distinct cleavage parallel to 110, and the grains, though rare, are rather large.

Augite was observed in only two cases; in one it was seen as a group of minute prismoids in one of the feldspars; these were well bounded in the prism zone by 100, 110, and 010; were of a pale yellow, had an extinction angle of 40°, and were twinned on 100. In the other case it formed the core of a hornblende crystal, as described below.

The *hornblende* is the most interesting mineral in the section. It is an alkalic variety, occurring in short, thick, not very well-defined prisms. It consists mostly of a brown kind with the following properties, c on $\mathfrak{c} = 25°$; $\mathfrak{a} - \mathfrak{c} = 0{\cdot}018$; $\mathfrak{c}$, yellow-brown; $\mathfrak{b}$, yellow-brown; $\mathfrak{a}$, pale ocher-yellow, and absorption $\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$. This is frequently capped by masses and fibrous tufts of a greenish blue variety, in which $\mathfrak{c} > c = 18°$: birefringence low, not over 0·010, and $\mathfrak{c}$, strong blue-green, $\mathfrak{a}$, very pale greenish gray. These quantities are of course not exact; they represent approximations which are the average from a number of sections. The relations of the two hornblendes to one another, and to augite, were well shown in a single crystal, a drawing of which is given in the adjoining figure, No. 1. It consists of a core of colorless augite, around which the brown hornblende has grown in parallel position; at the top and bottom are cappings of the bluish green hornblende terminating above in acicular tuftings; there are also some enclosed ore grains. Examination of this section in convergent light shows that it is not cut parallel to 010 but between that and 110, since the trace of an axial hyperbola crosses the field. The scheme of absorption, with the strongest color in $\mathfrak{c}$, is like that of barkevikite; the mineral is unlike it in the very wide extinction angle, while on the other hand this character agrees with Brögger's kataphorite, whose absorption is strongest in $\mathfrak{b}$. It is thus intermediate between the two

Fig. 1.

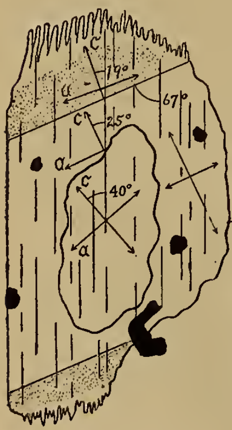


Fig. 1. Intergrown hornblende and pyroxene.

and the colors have this intermediate character. The blue-green variety, which at first thought suggests arfvedsonite, differs from this in that c is nearest c (18°) and the strongest absorption lies in c, while in arfvedsonite these properties lie in a. It appears to be in fact closely allied to the hastingsite of Adams and Harrington, which has c on c = 25°, c and b deep blue-green, a, yellow-green.

The *biotite* is not abundant, occurring in occasional small, well-formed tablets of the ordinary pleochroic brown variety.

The *feldspars* consist of labradorite in small amount, associated with much microperthite. The former is in relatively thin tables elongated parallel to 010, well twinned according to albite and Carlsbad laws, and having the composition Ab_1An_1; these serve as cores to masses of much more highly sodic feldspar, or anorthoclase, which have grown around them in parallel orientation; these masses as a whole have no definite outward form, and they constitute the white feldspar spots seen on the surface of the hand specimen.

The *microperthite* is by far the most abundant mineral in the rock; it presents no unusual features, being the ordinary intergrowth of orthoclase and albite; it is somewhat altered to kaolin, and this accounts for its lusterless surface in the specimen, and the half per cent of water shown by the analysis. It is not intended by this to convey the idea that the rock is badly altered, for such is not the case; only that the feldspar is to some degree changed.

A small amount of *quartz* is present in the interstices between the feldspars; it has a distinct tendency in places to micrographic intergrowth with them.

The order of crystallization is the normal one, beginning with apatite, zircon and iron ore, then hornblende, then labradorite followed by microperthite, whose final stage of consolidation was simultaneous with that of the small remnant of silica as quartz.

Mode.—The mineral composition of the rock is essentially that shown by the calculated norm, and the mode is therefore normative. The differences between the mode and norm consist in that the greater part of the calculated pyroxene, with some of the iron ore and a little soda of the feldspar, is present as hornblende; the hypersthene and a little orthoclase are represented by biotite; the adjustment of these differences frees enough silica to convert the small quantity of normative nephelite into albite and yield a little free quartz.

The composition is then approximately:

Apatite	0·5
Iron ore	4·0
Biotite	1·0
Augite	1·0
Hornblende	6·0
Labradorite	6·5
Microperthite	80·0
Quartz	1·0
Total	100·0

Texture. The rock has a thoroughly normal granitoid texture, and shows no tendency to the trachytoid one so often exhibited by alkalic syenites. The fabric is inequigranular-seriate, and consertal, composed of irregular nearly equant grains.

Chemical Composition.—For the chemical analysis of this rock, and also of others given later, I am indebted to the late Mr. C. J. Monahan, a promising young chemist, who at one time was assistant in the Sheffield Chemical Laboratory. It is given in the adjoining table, and the analyses of some other closely related syenites are quoted for comparison.

Analyses of Syenites.

	I	II	III	IV	V	VI	VII
SiO_2	62·12	63·71	62·99	59·01	63·20	60·60	1·035
Al_2O_3	17·57	16·59	14·25	18·18	17·45	16·79	·173
Fe_2O_3	2·16	2·92	2·78	1·63	3·60 (Fe₂O₃ + FeO)	2·77	·014
FeO	2·59	0·66	5·15	3·65		2·17	·036
MgO	0·86	0·90	1·30	1·05	0·75	2·14	·021
CaO	2·37	3·11	2·72	2·40	1·40	4·47	·043
Na_2O	6·78	8·26	4·86	7·03	6·90	4·40	·110
K_2O	4·79	2·79	6·35	5·34	5·88	4·57	·051
H_2O+	0·48	0·19	0·18	0·50	·50	0·61	----
H_2O-	0·09	----	----	0·15	----	0·25	----
TiO_2	0·84	0·86	0·16	0·81	0·46	0·90	·010
P_2O_5	0·23	----	----	tr.	----	0·28	·001
MnO	tr.	0·20	0·18	0·03	----	0·15*	----
Total	100·88	100·19	100·92	99·95	100·14	100·10	----

* BaO.

I. Syenite, var. Umptekite, Tripyramid Mt. C. J. Monahan, analyst.

II. Syenite, var. Umptekite. Shore of the Umpjavr, Kola Peninsula, Lapland. W. Ramsay, Fennia 11, No 2, p. 205, 1894. W. Petersson, anal.

III. Syenite, var. Umptekite, Beverly, Mass. F. E. Wright, Tscher. Mitt. xix, p. 318. F. E. Wright, anal.

IV. Syenite, var. Umptekite, Red Hill, New Hampshire. W. S. Bayley, Bull. Geol. Soc. Amer., iii, p. 243, 1892. W. F. Hillebrand, anal. Total includes BaO 0·08, Cl 0·12.

V. Syenite, var. Nordmarkite, Tonsenaas, Norway. Brögger, Zeit. f. Kryst, xvi, p. 54, 1890. G. Norsberg, anal.

VI. Syenite, var. Plauenite, Plauen near Dresden, Saxony. Anal., H. S. Washington. This Journ., xxii, p. 129, 1906.

VII. Molecular proportions of No. 1.

These analyses show that the Tripyramid rock agrees in composition very closely with other syenites of alkalic type. The magnesia, lime and total alkalies have proportions very similar to those in the original umptekite of Ramsay, the chief difference being in the relative proportions of the alkalies. It is not very unlike one of Brögger's nordmarkites. All of these are alkalic, and to emphasize this Washington's analysis of the well-known syenite of Plauen, which is of subalkalic type, is introduced for comparison. The difference in proportions and amounts of the alkalies, lime and magnesia is striking.

Classification.—Considering the fact that this is an alkalic syenite, with an alkalic hornblende as the predominant ferromagnesian mineral, it must be classed with those types which have been termed umptekite. This, notwithstanding the small amount of labradorite present, which is an unusual feature in these rocks, and which a somewhat higher percentage of magnesia might have prevented by uniting with the lime to form more hornblende, or pyroxene.

In the quantitative system the position of the rock is shown in the following calculation of its norm and place from the analysis:

Or	28·36
Ab	55·54
An	3·34
Ne	1·14
Di	6·37
Hy	0·60
Il	1·52
Mt	3·25
Ap	0·34
Total	99·46

$$\frac{\text{Sal}}{\text{Fem}}=\frac{88{\cdot}38}{12{\cdot}08}=7{\cdot}3,\ \text{Persalane}$$

$$\frac{\text{L}}{\text{F}}=\frac{1{\cdot}14}{87{\cdot}24}<\frac{1}{7},\ \text{Canadare}$$

$$\frac{K_2O'+Na_2O'}{CaO'}=\frac{161}{12}=13,\ \text{Nordmarkase}$$

$$\frac{K_2O'}{Na_2O'}=\frac{51}{110}=0{\cdot}46,\ \text{Nordmarkose}$$

The rock is, therefore, persalic, perfelic, peralkalic, and dosodic, and its coördinates are 1, 5, 1, 4. The six per cent of hornblende is not sufficient to make the mode abnormative and it may therefore be termed grano-nordmarkose.

Monzonite (Monzonase).

Megascopic.—As exposed in the bare rock surfaces of the "V," and for a long distance down Slide Brook, and correspondingly on Avalanche Brook up to the limits mentioned on the North Slide, this type has the following megascopic characters on a freshly fractured surface. Phanerocrystalline; medium to coarse grain; dominantly feldspathic; whitish, but dotted with blotches consisting of grouped anhedra of hornblende and some biotite; feldspars generally anhedral to subtabular, white, sometimes pale pink, 1–5^{mm} in dimensions, generally dull and lusterless; hornblende blackish-brown, pitchy looking, altered; fabric apparently equigranular; fracture rather crumbly; rock partly decomposed; weathers pale brown. Except for the alteration of the ferromagnesian minerals the rock resembles strikingly in color, granularity, and fabric, including the grouping of the ferromagnesian minerals, a specimen of feldspathic monzonite from Monzoni, which I owe to the kindness of Dr. H. S. Washington.

Microscopic.—Under the microscope the following minerals are disclosed: Andesine, orthoclase, and hornblende essential; iron ore, zircon, allanite, apatite, augite, biotite, and quartz accessory; with chlorite, epidote, muscovite, kaolin, and limonite as alteration products.

Of the *feldspars*, the andesine has a pronounced tabular development, yielding elongated sections which commonly show both Carlsbad and albite twinning, the latter with very thin lamellæ. Measurements showed it to have the composition Ab_3An_5. These feldspars, which attain a length of 5^{mm}, are rather thickly scattered in a divergent manner through the section, and are filled in between, and surrounded by, broader fields, or formless masses, of orthoclase, in the manner common in many monzonites. The orthoclase shows no perthite intergrowth with albite; it is considerably kaolinized, but not uniformly so; the andesine does not show this but contains in places much sericitic white mica, and this is also sometimes seen in the orthoclase.

The *hornblende* is almost entirely changed to masses of chlorite and grains of epidote, stained to a greater or lesser extent with limonite, but a few unchanged pieces were found which prove it to have been a brownish green variety of common hornblende, with pleochroism between that color and colorless. It surrounds cores of a colorless augite, or accompanies it.

Iron ore appears occasionally in rather large grains, often associated with *apatite;* the latter is rather abundant and the stout crystals are sometimes 0·5^{mm} long. *Zircon* is also abundant, in short thick crystals up to 0·5^{mm} in length, well developed and having the forms *m*(110) and *p*(111). One crystal of *allanite* was seen surrounded by epidote. A few shreds of brown *biotite* in the chlorite point to a former greater abundance of this mineral. The *quartz* appears here and there, associated with the orthoclase; as usual, it is the last mineral to crystallize, and a poor, but yet distinct, tendency to micrographic fabric shows that it is original and not secondary from alteration. Its total amount is small.

Mode.—The rock is too altered and rather too coarse-grained to yield an accurate ratio of the relative quantities of the component minerals by the Rosiwal method, but a rough approximation, gained by study of a hand-specimen and the thin sections, is as follows:

Alkalic feldspar	40 per cent.
Andesine	40 " "
Hornblende	12 " "
Diopside	3 " "
Other minerals	5 " "
Total	100 per cent.

Chemical Composition.—Although the classification of the rock appears quite clear, a chemical analysis would be desirable for several reasons, especially for comparison with the associated types; but as all attempts to obtain material, which would be fresh enough to warrant the labor of a good analysis, were unavailing, it has not been undertaken. The actual mineral composition shows, however, that it would not be essentially different from other monzonites, such as those of Monzoni and central Montana, if regard is paid to its more salic nature.

Classification.—In the quantitative classification it is easily seen that this rock is dosalic but near to persalic, it is clearly perfelic and, from the feldspar relations mentioned above, it is also domalkalic. This would place it in the rang monzonase, but in which of the three middle subrangs it belongs is uncertain, though probably in monzonose. In any event it is on the edge of the group and very close to the persalic line, on account of the abundant feldspar. In this respect it is like the monzonose from Yogo Peak, which I described under the name of syenite,* and which has since been classified as a feldspathic monzonite by Rosenbusch,† and included under monzonose by Washington.‡

In current classification this rock of Tripyramid Mountain is certainly a feldspathic monzonite, whether one uses this term according to the broad definition of Brögger, or the more restricted one of Rosenbusch, since its genetic affinities are shown by its association with the syenite.

Norite (Andose).

The occurrence of this rock on Slide Brook, between the gabbro and monzonite, has been discussed in the foregoing paper. The material selected for investigation came from the slabs exposed in places in the brook bed, sufficiently far from the contact with the gabbro to be uninfluenced by it.

* This Journal, 3d series, vol. v, 1895, p. 471.
† Mass. Gestein., 4th Aufl., 1907, p. 170.
‡ Anal. of Igneous Rocks, p. 254, 1903.

Megascopic.—Holocrystalline, medium-grained, 1–3^{mm}, mottled dark and light in color, average tone, gray; consists of formless, greenish, to greyish black, ferromagnesian mineral grains mingled with pale brownish-white feldspar ones. With the lens bronze-colored cleavages of biotite are occasionally seen and, on the feldspar cleavage, fine striations of albite twinning. Weathers brown, becoming stained by ferric oxide.

Microscopic.—The microscope discloses in thin section the following component minerals; apatite, iron ore, biotite, hypersthene, augite, labradorite, andesine, orthoclase and quartz.

The *apatite* is rather abundant for this mineral, in short to long prisms. The *iron ore*, which is titaniferous magnetite, is rather abundant, and, while sometimes showing crystal outlines, is often very irregular and encloses apatite and augite. The *augite*, in large crystals, is very irregular in form and then includes iron ore, apatite, biotite, and even labradorite. Small crystals are often quite automorphic, bounded in the prism zone by 100, 010 and 110 equally developed; these are quite free from inclusions, and often twinned on 100. The usual prismatic cleavage is good, the parting 100 was observed, but is not common. The color is a pale green; nonpleochroic. Maximum extinction angle 43°.

The *hypersthene* is in rather long, columnar crystals, poorly terminated and of good size, though occasional rounded granules also occur. It shows the usual parallel extinction and rather low birefringence. It is very distinctly, though not strongly, pleochroic, the ray parallel to $\mathfrak{c}$ being green, while $\mathfrak{a}$ is red. The rather faint pleochroism would tend to show a variety approaching bronzite in the content of iron. Along cracks there is a slight alteration to serpentine. It carries inclusions of apatite, iron ore, and biotite.

The *biotite*, of the usual deep reddish-brown variety with strong absorption, is scattered through the rock in irregular flakes. It is apt to coat the iron ore, but also occurs independently, and, as noted above, is found as a frequent inclusion in the pyroxenes. Some large poikilitic crystals were observed which included all the other constituents, even labradorite.

The *plagioclase* has the form of short, broad, book-shaped masses, which yield columnar sections when parallel to the basal plane, but much of it is quite irregular in shape. It is quite clear, and fresh, and free from inclusions. It has both albite and Carlsbad twinning; the albite twinning also shows that the crystals in many cases are curved, or bent, or even faulted, pointing to movement under pressure, and, in connection with this point the reader is referred to the discussion on the origin of Tripyramid in the preceding paper. In composition the mineral varies in some crystals from Ab_2An_3 to Ab_5An_3, that is from calcic andesine to rather basic labradorite. The average of these two is Ab_7An_6, while the average feldspar calculated from the analysis in obtaining the norm given below is Ab_8An_6, and this close approximation tends to show that the average feldspar must have about this composition. Only occasionally is it zonally built.

The *orthoclase* and *quartz* are present in small amounts not exceeding two or three per cent each. They are not intergrown, as is sometimes the case in rocks of this group, but occur independently, filling minute angular interspaces between the other minerals. In the calculated norm given below there is 10 per cent of orthoclase and 2 per cent of olivine and no quartz. This is because the biotite has been split up into olivine and kaliophilite, and the latter has used up the free silica of the quartz and become orthoclase. If we reverse this process and consider the biotite to have essentially the simple formula $K_2(Mg,Fe)_2Al_2Si_3O_{12}$, this will split up into $2KAlSiO_4$ + $(Mg,Fe)_2SiO_4$, that is into kaliophilite and olivine. With these data it may readily be calculated that the 10 per cent of orthoclase and 2 per cent of olivine of the norm are equivalent to 6·11 per cent biotite, 3·12 per cent quartz, and 2·78 per cent orthoclase = 12·02, which is what the rock modally contains.

Mode.—By observation of the section and use of the data given above the actual mineral composition of the rock is as follows:

Iron ore	11·0
Apatite	4·4
Biotite	6·0
Augite	5·6
Hypersthene	10·0
Plagioclase	56·5
Orthoclase	3·0
Quartz	3·0
Rest	0·5
Total	100·0

Thus the percentage of feldspathic components, as compared with the ferromagnesian ones, is about two to one and thus clearly places the rock in the feldspathic members of the gabbro family.

Texture.—Although in the hand specimen the rock appears quite even-granular, in the section it is seen to be inequigranular and seriate, and consertal in fabric. That is, while many of the grains are approximately equal in size, they grade down into much smaller ones, and all are closely fitted together, or conserted. The most characteristic feature of the fabric is that produced by the rather long and large sections of the tabular feldspars diversely spread through the rock, with the other components and the smaller feldspars filling in the spaces between.

Chemical Composition.—The rock was analyzed by Mr. C. J. Monahan with the result given in No. I.

	I.	II.	III.	IV.	V.
SiO_2	48·67	49·46	50·47	48·06	0·811
Al_2O_3	16·88	19·82	18·98	16·95	0·166
Fe_2O_3	4·98	5·69	4·22	4·78	0·031
FeO	6·37	5·82	6·16	7·60	0·089
MgO	4·62	1·93	5·62	5·51	0·115
CaO	8·63	10·62	11·72	7·79	0·154
Na_2O	3·85	3·38	2·75	3·37	0·062
KO_2	1·26	0·74	0·56	1·42	0·018
H_2O+	0·32	0·09	1·06	0·80	----
H_2O-	0·02	----	----	----	----
TiO_2	2·12	0·69	0·12	2·57	0·026
P_2O_5	1·85	?	?	0·63	0·013
Total	99·57	99·84	101·78	99·48	

I. Norite, andose, Slide Brook, Waterville, N. H. C. J. Monahan, analyst.
II. Norite, hessose, Near Ivrea, Piedmont. (Van Horn, Tscher. Mitt., xvii, p. 404, 1897.) M. Dittrich, analyst.
III. Norite, Eperon du Cerebriansky, west side, Northern Urals. Duparc et Pearce, Mem. Soc. Phys. e. d'Hist. nat. de Genève, p. 466, 1905.
IV. Bronzite-kersantite (andose), Hovland, Laugendal, Norway. (Brögger, Erupt. Gest. Krist. geb. III, Ganggef der Laur. p. 75, 1899.) V. Schmelck, anal.
V. Molecular proportions of No. I.

In studying the analysis it is clear that since a very considerable proportion of the lime has been used to convert the excess of alumina over soda into plagioclase, there is not enough left to turn all the magnesia and the excess of the ferrous iron, not used in iron ore, into pyroxene. These extra magnesia and ferrous iron molecules have in this case formed hypersthene rather than olivine, because there was an excess of silica present, as the residential quartz shows. Thus a norite is formed, rather than an olivine gabbro. In this connection the reader may compare this analysis with that of the olivine gabbro on a succeeding page, where, under No. VI, the norite is repeated for convenience. The gabbro differs chiefly in containing 3 per cent more of alumina and lime, and about that amount less of ferric iron. Since 3 per cent CaO = 0·59, and of Al_2O_3 = 0·29, molecularly, a larger proportion of lime is able to combine in pyroxene, a metasilicate, and, since the lower ferric iron demands less ferrous to form iron ore, the result is that, with the lower silica content, olivine is found and not hypersthene, as in the present rock.

For the sake of comparison analyses of two other norites are added. Unfortunately not many good reliable analyses of this rock, made by the latest approved methods, are available for this purpose. In this connection the reader is invited to compare Nos. I and IV ; Brögger's rock is a lamprophyric dike-rock, one of the clan attendant upon the nephelite syenite (laurdalite) intrusions of South Norway. He gives the composition as follows : plagioclase of the composition Ab_2An_1, 44·7 per cent, augite 25·3 per cent, bronzite 8·6 per cent, lepidomelane (biotite) 14·6, iron ore 5·0 and apatite 1·5 per cent=99·7. It is to be noted that, while the minerals are essentially the same as those in our norite, their relative proportions are somewhat different. Chemically, the two magmas are similar ; save for the differences in the ferrous iron, magnesia, and the lime, they are remarkably alike. The bearing of this on genetic relationships is discussed in a later place.

Classification.—In the quantitative system the position of this rock is shown by the calculation of its norm and place.

Or	10·01	
Ab	32·49	
An	23·91	66·41
Di	5·59	
Hy	10·24	
Ol	2·01	
Mt	7·19	
Il	3·95	
Ap	4·37	33·35
H_2O	0·34	
Total	100·10	

$$\frac{Sal}{Fem}=\frac{66·41}{33·35}=2·2=2, \text{ Dosalane}$$

$$\frac{L+Q}{F}=\frac{0}{66·41}=0,=5, \text{ Germanare}$$

$$\frac{Na_2O'+K_2O'}{CaO'}=\frac{80}{86}=0·9=3, \text{ Andase}$$

$$\frac{K_2O'}{Na_2O'}=\frac{18}{62}=0·29=4, \text{ Andose}$$

It is, therefore, dosalic, perfelic, docalcic and dosodic, with coördinates 2.5.3.4. Comparing the norm with the mode previously given, no critical mineral appears in notable amount ; the mode is therefore a normative one, and since the texture is granular it may be termed *grano-andose.* In qualitative systems the rock is a norite, of feldspathic character.

Gabbro (Hessose).

The material selected for investigation is from the Black Cascade on Slide Brook. The gabbro on Avalanche Brook is of somewhat finer grain, but the sections show that it is petrographically similar.

Megascopic.—Holocrystalline ; medium to coarse grain ; general color dark grayish to black ; dominantly composed of feldspar of a deep smoky-gray color in roughly tabular crystals, 10^{mm} across the cleavages of *b* (010) and lath shaped, 10^{mm} by

2–3^{mm} on the *c* (001) cleavage; the latter clearly striated by the albite twinning; rarely the feldspar shows a blue opalescence; occasional grains of dark greenish ferromagnesian minerals, black ones of iron ore, and glittering, bronzy specks of biotite are also seen. Resembles anorthosite from many Canadian and Adirondack occurrences. Weathers with a dark gray crust.

Microscopic.—In thin sections the following minerals are found to be present; labradorite feldspar, pyroxene, olivine, iron ore, biotite, apatite.

The *feldspar* is in the form of flat tables parallel to *b* (010): it is unaltered and clear, save for swarms of slender dark microlites orientated parallel to three different systems; they appear as lines, dashes and dots. In places these microlites are somewhat larger, and it can then be seen that they are sometimes birefringent, have an index of refraction greater than the feldspar, and sometimes change in their length for short distances into black opaque bodies. They appear like the inclusions of a similar character found in the feldspars of gabbros and anorthosites from other localities, but their exact nature could not be determined. The feldspar is twinned according to the albite and pericline laws, but rarely according to the Carlsbad. It is sometimes zonally built and the optical properties show in addition a feature sometimes, though rarely, seen in that one albite lamella has a different relation of the Ab and An molecules which compose it from another twin lamella lying beside it. Such feldspars have been described by Michel Lévy,* Federoff† and the writer.‡ The average composition of the feldspar as determined by optical methods is Ab_7An_{13}, while that reckoned from the chemical analysis of the rock is Ab_2An_3—the first equals $Ab_{21}An_{39}$, the second $Ab_{26}An_{39}$. This feldspar was also analyzed by E. S. Dana, and while made on material too impure to yield definitely exact ratios, since at that time the later methods of obtaining pure material were unknown, the results also sufficiently indicate it to be a basic labradorite.

The *pyroxene* is of a very pale brown color; in places filled with minute microlites like the feldspar, it does not show the diallagic parting parallel to *a* (100); it contains numerous grains of iron ore and scales of biotite but no feldspar; its form is entirely irregular, filling spaces between the feldspars; it shows no sign of alteration; the maximum angle of *c* on c was measured as 40°.

* Mineraux des Roches, p. 84, 1888.
† Zeitschr. für Kryst, vol. xxiv, p. 130, 1894.
‡ Bull. Geol. Soc. Amer., vol. vi, p. 412, 1895.

The *olivine* is clear and colorless, unaltered save for a slight serpentinization along cracks; while at times it is shapeless, and fills spaces between other constituents which determine its form, in other cases it shows more distinct crystal outlines; it is often included in feldspar in minute grains; the only inclusions are occasional granules of iron ore and specks of biotite, but in some places shadowy spots under high powers reveal themselves to be thin sheets of magnetite, which when seen on end appear as lines, but viewed flatwise are found to be skeleton crystals presenting remarkable patterns of grating structures, such as have been described by petrographers in olivines from various localities.*

The olivine of this rock was analyzed by E. S. Dana† on extracted grains with the following results:

	A.	B.	C.	D.	
SiO_2	38·85	0·647	0·050	0·597	0·597 =1·04
FeO	28·07	0·389	0·012	0·377	
MnO	1·24	0·017	....	0·017	0·1146=2·00
MgO	30·62	0·765	0·013	0·752	
CaO	1·43	0·025	0·025		
Al_2O_3	trace				
Total	100·21				

Since the amount of alumina is practically nothing the lime must be due to a little admixed pyroxene. If, from the molecular ratios shown in B, a sufficient amount of iron, magnesia and silica be deducted, as in C, to convert the lime into pyroxene, the final ratios available for olivine are given in D, which gives an excellent result for the olivine formula. There is an unusually large amount of iron present, the mineral being practically $Fe_2SiO_4.3Mg_2SiO_4$, and thus belonging to the variety hyalosiderite, which explains the presence of iron ore separated out along the cracks, where alteration has taken place, and thus confirms Rosenbusch's‡ view that in such cases the olivine of gabbro rocks is one with a large content of iron.

The *iron ore* is shapeless, and only in one section was distinct crystal outline seen, that of a hexagon. It is observed in relatively large masses and in small grains; the large masses, like those of the pyroxene, have their form conditioned by the surrounding minerals, and in a number of cases the ore was found completely enclosing automorphic labradorite. This shows that the period of crystallization for the ore lasted long after that of the basic labradorite, a phenomenon which Rosen-

*Petrography of the Little Belt Mts., 20th Ann. Rep. U. S. Geol. Surv., (Pt. III, p. 481, 1900).

† Loc. cit.

‡ Massigen Gesteine, 4te Aufl. 334, 1907.

busch* likens to the structure of meteorites. The specks of metallic iron mentioned by Hawes† I was not able to find, but some pyrite was observed.

The *biotite* is of a deep red brown and very pleochroic; while it occurs in isolated flakes it is usually seen as a mantle coating the ore grains.

Apatite is not common, but is seen occasionally, often in slender prisms in feldspar.

Mode.—The actual mineral composition, determined by observation of the sections and calculation from the chemical analysis, is shown in the adjoining columns:

Labradorite	63·0
Biotite	5·0
Pyroxene	14·0
Olivine	10·0
Iron ore	6·7
Apatite	1·3
Total	100·0

Texture. The texture is that of a typical gabbro, a granular one, conditioned by the short, broad laths of feldspar, with the intermingled shapeless masses of pyroxene, olivine and ores. There is no tendency to the ophitic texture by the enclosure of feldspar laths by pyroxene, indeed the only case of this kind noted was where the feldspar in one or two cases was enclosed by iron ore as previously stated.

Chemical Composition.—For a chemical analysis of this rock, I am indebted to Mr. C. J. Monahan, whose results are given in No. I of the following table:

No.	I.	II.	III.	IV.	V.	VI.	VII.
SiO_2	47·82	47·88	53·18	52·8	53·65	48.67	0·797
Al_2O_3	19·99	18·90	23·25	17·8	20·77	16·88	0·196
Fe_2O_3	2·10	1·39	1·53	1·2	0·98	4·98	0·013
FeO	6·48	10·45	1·82	4·8	7·61	6·37	0·090
MgO	4·94	7·10	2·60	4·8	1·57	4·62	0·123
CaO	11·65	8·36	11·18	12·9	9·16	8·63	0·208
Na_2O	3·51	2·75	3·97	3·0	3·33	3·85	0·056
K_2O	0·67	0·81	0·86	0·5	1·61	1·26	0·007
H_2O+	0·21	0·43	0·98	1·2	1·33	0·32	----
H_2O-	0·07	0·18	0·15	----	----	0·02	----
CO_2	none	0·12	0·34	----	----	----	----
TiO_2	2·00	1·20	0·45	0·5	?	2·12	0·025
P_2O_5	0·56	0·20	0·09	?	?	1·85	0·004
S	----	0·07	----	----	----	----	----
Cr_2O_3	----	tr.	----	----	----	----	----
NiO	----	0·02	----	----	----	----	----
MnO	tr.	0·16	0·11	----	----	tr.	----
BaO	tr.	tr.	tr.	----	----	tr.	----
	100·00	100·02	100·51	99·5	100·01	99·57	----

* Mass. Gesteine, 4te Aufl., p. 336. † Loc. cit., p. 167.

I. Olivine gabbro (hessose) "ossipite," Black Cascade, Slide Brook, Waterville, N. H. C. J. Monahan, analyst.
II. Gabbro (hessose), Split Rock Mine, Westport, Essex Co., N. Y., (Kemp, 19th Ann. Rep. U. S. Geol. Surv., Pt. III, p. 402, 1899). W. F. Hillebrand, analyst.
III. Gabbro near anorthosite, Whiteface Mt., Adirondacks, N. Y. (Bull. 228, U. S. Geol. Surv.), G. Steiger, analyst.
IV. Light band of Gabbro, Druim an Eidne, Isle of Skye, Hebrides (Geikie & Teall, Quart. Jour. Geol. Soc., vol. l, p. 653, 1894). J. H. Player, analyst.
V. Gabbro with predominant labradorite, Baste, Harzburg, Streng, Neues Jahrb., 1862, p. 963.
VI. Norite (andose). Above the gabbro, Slide Brook, Waterville, N. H. C. J. Monahan, analyst.
VII. Molecular proportions of No. I.

Gabbros, as is well known, are very variable rocks in the relative proportions of the feldspathic as compared with the ferromagnesian minerals; they can, therefore, be roughly divided into two groups, the feldspathic and the ferromagnesian ones. In the latter the iron and magnesia are very large in amount, accounting for the predominance of ferromagnesian minerals. The analysis shows the rock under discussion to belong to the former class and this accounts for the agreement of the analyses with well known feldspathic types, as illustrated in the above table. Of the banded gabbros of Skye it has nearly the same composition as the light feldspathic bands. If all of the potash were present in biotite there would be some 8 per cent of this mineral in the rock; the actual amount estimated is not so large as this, and if correct, a small amount (1·8 per cent) of orthoclase must also be in the rock. It has not been seen and may well be lost in submicroscopic intermixtures in the other feldspars. The adjustment of molecules in the calculation of the following norm also produces in it a little nephelite, which could not be found present in the rock.

Classification.—The position of this rock in the quantitative system is seen in the following calculation of its place and norm:

Or	3·89	
Ab	25·68	
An	36·97	
Ne	1·99	68·53
Di	14·03	
Ol	8·93	
Mt	3·02	
Il	3·80	
Ap	1·34	31·12
H_2O	·28	
Total	99·93	

$$\frac{\text{Sal}}{\text{Fem}}=\frac{68{\cdot}53}{31{\cdot}12}=2{\cdot}2=2\text{, Dosalane}$$

$$\frac{\text{L}}{\text{F}}=\frac{1{\cdot}99}{66{\cdot}54}=0{\cdot}03=5\text{, Germanare}$$

$$\frac{K_2O'+Na_2O'}{CaO'}=\frac{63}{133}=0{\cdot}49=4\text{, Hessase}$$

$$\frac{K_2O'}{Na_2O'}=\frac{7}{56}=0{\cdot}12=3\text{, Hessose}$$

It is, therefore, dosalic, perfelic, docalcic, and presodic, and its coördinates are 2.5.4.3. The amount of biotite is negligible and hence the mode is a normative one. The texture being granular it is *grano-hessose.* In prevailing qualitative systems it is an olivine-gabbro of feldspathic type, or rather, one should say, it would be pronounced such if its association with the monzonite and syenite were unknown, or unsuspected. By those petrographers who hold rigidly to genetic lines in classification, if these facts concerning it became known, it would, supposedly, be classed as an essexite.

Quartz-Syenite Aplite (Liparase).

It has been previously mentioned that where the rock surfaces of Tripyramid Mountain are well exposed they are found to be cut by narrow dikes, or dikelets, of aplitic character. While there is some variability in the relative proportions of the minerals composing these rocks, and in their texture, it is not so great but that they can all be placed in one well-defined group—they are *quartz-syenite aplites.* Also, they are rocks of such very simple composition that only a very brief description of them is necessary.

Megascopic.—Phanerocrystalline; very fine-grained, but not dense; usually flesh-colored but varying from whitish to pale reddish brown; persalic and predominantly feldspathic; faintly dotted at times with minute, blackish specks; apparently equigranular in texture and of firm habit; fracture not easy and hackly; often rather weathered.

Microscopic.—Alkalic feldspar essential, sometimes also quartz; iron ore, biotite and zircon accessory, sometimes also quartz.

The alkalic feldspar is mostly orthoclase, with some microperthite intergrowth of albite; soda-lime feldspar was not observed. The feldspar appears in the slide in rather equidimensional sections, which tend to be square in outline, indicating a roughly cuboid habit. The interspaces are filled with quartz which is completely anhedral in consequence; in those cases where the quartz is more abundant it tends to a rudely micrographic fabric, in that the various interspaces between several feldspars are filled by a quartz mass of uniform orientation. An occasional grain of iron ore, sparsely sprinkled flakes of light brown biotite, generally altered to chlorite, and a rare crystal of zircon complete the list of minerals. So far as the feldspars, which are the predominant components, are concerned the fabric tends to be equigranular, and equant. If the quartz be also considered the fabric is seriate, consertal, tending in some cases to graphic.

Classification.—The greatest amount of variation in any mineral is shown in the quartz; in some instances it is fairly abundant and these might be classed with granite aplites; in others it sinks to a negligible quantity and such are syenite aplites; on the average the group contains much less of it than normal granite aplites and is, therefore, classed as quartz-syenite aplite. In the quantitative classification these rocks are very clearly persalic and peralkalic, and vary between liparase and nordmarkase; the relation of soda to potash is not known, but the feldspars show so little evidence of being dosodic that it is probable the rocks vary in subrang from liparose to phlegrose. These dikes are closely allied to the syenite; they differ from it in being, on the whole, somewhat richer in quartz, and in their lack of hornblende.

Lamprophyre Dikes.

Owing to the thick covering of glacial debris, soil and vegetation on the lower slopes of Tripyramid and in the granite surrounding it, there are few places exposed in the outer zone, which would be the natural habitat of these rocks, where they can be sought for. They may, or may not, exist in considerable numbers, but they have been found only in the granite at Norway Rapids as camptonite, and in very narrow dikes cutting the gabbro at the Black Cascade on Slide Brook, as previously mentioned.

Black Cascade Dikes.

Megascopic.—Holocrystalline; fine-grained, average much less than one millimeter, compact but perceptibly granular; very dark greenish gray; shows a few rare occasional phenocrysts (perpatic fabric) of dark, smoky feldspar phenocrysts with nearly square to rectangular outlines 4 by 4 to 5 by 3^{mm}. With the lens a fine intimate mixture of feldspar, sometimes in minute laths, and ferromagnesian minerals, indeterminate save for an occasional speck of biotite. Feldspar phenocrysts show fine albite twinning. Very tough, rings under the hammer, has a splintery fracture approaching conchoidal; weathers dark green, turning brown.

Microscopic.—In the section the following minerals are disclosed; apatite, iron ore, biotite, olivine, augite, labradorite, orthoclase and nephelite and serpentine.

The *apatite* is freely distributed in minute, very long, slender needles, which are enclosed in the other components and peg them together. It is inferred from the section that the amount of P_2O_5 shown in the analysis is rather low and probably because the complete enclosure of the very minute apatite needles in other mineral grains prevented their going entirely into solution, a point emphasized by Hildebrand* and Washington† in the determination of this oxide.

The *iron ore* is also freely distributed in grains which are very small in size compared with those of the feldspar and augite; some is in the form of dust in the augite, and some appears secondary from olivine. One or two cases of larger grains were seen, and into them augite and feldspar projected, showing in this case a relatively late, or long-continued, period of crystallization. The analysis proves that the iron ore is very largely ilmenite.

Biotite occurs in small flakes and shreds, which sink to submicroscopic dimensions. It occurs in augite and feldspar. Only one instance of a larger flake, about 0·05^{mm} in diameter, was seen. As usual, it is apt to be attached to iron ore and olivine. It is a very pale-colored variety recalling phlogopite, and the pleochroism is not marked, between medium brown and almost colorless. Although rather generally sprinkled through the rock, the total amount is small, not more than two or three per cent of the total constituents.

The *olivine* is the only mineral which is not fresh and unaltered. It is mostly converted into masses of a yellowish-green serpentine, in which small unchanged fragments of the original mineral are still found. It was originally present in small irregular masses, or lumps, without good crystal form, averaging from 0·04–0·05^{mm}. It is judged, from the character of the alteration product, and the iron ore separated out, to have been a variety rich in iron.

The *augite* is of a pale brown color; the larger masses quite irregular in shape, sometimes wedged between feldspars, sometimes indented by them, and thus showing here and there a tendency to ophitic fabric. The smaller grains, however, at times have a more distinct crystal form and approach short prismoids with the faces 010, 100, and 110 developed in the prismatic zone. It has the usual wide angle of extinction. It is very impure, filled with shreds of biotite, specks of iron ore and needles of apatite, and is frequently colored dark by iron ore dust peppered through it in irregular blotches. It is the most abundant ferromagnesian mineral. Although the masses, or grains, vary in size from 0·10–0·05^{mm} and from that down, no true phenocrysts of it were seen.

The *plagioclase*, as previously mentioned, occurs in very rare, distinct phenocrysts, columnar on the *a* axis and 4–5^{mm} long. One of these was found, fortunately, to be cut perpendicular to the *b* (010) face, and having both albite and Carlsbad twinning, which permitted it to be determined as a labradorite of the composition Ab_1An_1.

* Bull. U. S. Geol. Surv., 176, p. 78.
† Chem. Analysis of Rocks, p. 151.

The plagioclase which composes the groundmass is much smaller, averaging 0·03 to 0·05^{mm} in greatest dimensions. It is developed in rather thick tablets which tend to nearly square outlines on *b* (010) and which commonly exhibit both Carlsbad and albite twinning. The crystals are usually zonal in structure, having a distinct, uniform, interior core consisting of Ab_1An_1, which passes into phases much richer in soda at the outer margins. As shown by the calculations from the analysis, the average plagioclase present is approximately Ab_3An_2.

A moderate amount of *orthoclase* is also present in grains of about the same size as those of plagioclase and it frequently shows Carlsbad twins.

In the angles between the feldspars there is seen, here and there, minute areas of a colorless substance which sometimes polarizes faintly, and sometimes does not. In some cases the latter sections yield a faint uniaxial negative cross. This is inferred to be *nephelite* and on testing with nitric acid the powdered rock was found to yield a definite, though not large, amount of gelatinous silica. Part of this must come from the olivine, but the amount seemed too large to be wholly derived from the small quantity of that mineral known to be present, and was thus held to be also indicative of nephelite. It is also possible that, in part, this interstitial material may be sodalite, as indicated somewhat by the distinct reaction for chlorine which the rock yields, though in this connection the possibility of a chlor-apatite must be considered. It may also, in part, be analcite, and in one or two cases this seemed possible, as a fairly good cubic cleavage was observed. At all events, a very small quantity of a feldspathoid is present, either wholly, or in part, nephelite, and this is also indicated in the calculation of the norm.

Mode.—The mode of this rock is a normative one and the quantities of the minerals present are those shown in the calculated norm, the only essential deviation being that a small quantity of the calculated orthoclase and olivine are really represented by the two or three per cent of biotite which the rock contains.

Texture.—The fabric which this rock presents in the section is like that shown by many gabbros, but on a minute scale. It is produced by the short divergent feldspar laths, scattered through which are the grains and masses of augite, iron ore and olivine. A somewhat similar fabric is seen in diabases when they become deficient in augite, and lose the characteristic ophitic texture, and in some basalts. It appears in some lamprophyres, as in certain kersantites where biotite replaces augite, and in spessartites with hornblende. It is a quite different type of texture from the equigranular one observed in some dikes cutting gabbros, and which have been considered aplitic in character, like beerbachite for example. The fabric is that characteristic of lamprophyres, rather than of aplites.

Chemical Composition.—A chemical analysis of the rock has been made for me by Dr. Ralph W. Langley, formerly assistant in the Sheffield Laboratory, and to whom my thanks are due in this connection. It is given in No. 1 of the following table and with it are also given analyses of some dike rocks which are of interest for comparison.

Analyses of Dike Rocks.

No.	I	II	III	IV	V	VI	VII	VIII	IX
SiO_2	50·75	50·59	52·95	41·94	50·50	51·70	47·21	0·846	0·843
Al_2O_3	17·31	17·74	14·96	15·36	17·71	19·39	20·52	0·170	0·174
Fe_2O_3	2·08	3·54	2·44	3·27	5·41	2·54	7·48	0·013	0·022
FeO	8·13	7·45	7·03	9·89	4·02	6·44	5·32	0·113	0·104
MgO	3·48	3·92	3·86	5·01	3·33	4·64	4·16	0·087	0·098
CaO	6·77	6·85	6·76	9·47	7·91	8·95	8·63	0·121	0·122
Na_2O	4·14	4·25	4·95	5·15	5·52	4·07	5·17	0·066	0·068
K_2O	2·87	2·79	1·64	0·19	3·02	0·83	0·33	0·031	0·030
H_2O+	0·56	0·55	0·55	3·29	0·45	0·92	0·34	---	---
H_2O-	---	---	---	---	---	0·15	0·10	---	---
CO_2	none	---	---	2·47	---	---	---	---	---
TiO_2	3·05	2·60	3·90	4·15	1·91	0·14	?	0·038	0·033
P_2O_5	0·10	0·27	0·76	?	0·92	0·37	0·46	---	0·002
MnO	tr	tr	tr	0·25	---	--	---	---	---
Total	99·14	100·55	100·16	100·44	100·70	100·68	99·21	---	---

I. (Andose), dike near the Black Cascade, Slide Brook, Waterville, N. H. R. W. Langley, analyst.

II (Andose), dike at Norway Rapids, Slide Brook, Waterville, N. H. C. J. Monahan, analyst.

III. Spessartite? (hornblende akerose), Belknap Mts, N. H. (Pirsson & Washington, this Jour., vol. xxii, p. 455, 1906). Washington, analyst.

IV. Camptonite (camptonose), Livermore Falls, Campton, N. H. (G. W. Hawes, this Jour. (3), vol. xxvii, p. 150, 1879).

V. Essexite, Rongstock, Bohemia (Hibsch, Tscher. Mitt. xix, Heft I, 1899). R. Pohl, analyst.

VI. Luciite-porphyrite (beerbachose), Ernsthofen, Odenwald, Hesse (Chelius, Notbl. f. Erdk., xviii, p. 15, 1897). W. Sonne, analyst.

VII. Beerbachite (beerbachose), Frankenstein, Odenwald, Hesse (Chelius & Klemm, Erl. z. Geol. Karte Hessen, x, p. 39, 1896). R. Marzahn, analyst.

VIII. Molecular proportions of No. I.

IX. Molecular proportions of No. II.

The discussion of the analysis really involves also the question of classification and is best considered under that heading.

Classification.—In the quantitative system the norm of the rock and its position may be calculated as follows:

Norm.			
Or	17·24		$\frac{Sal}{Fem}=\frac{70·44}{28·23}=2·4$, 2, Dosalane
Ab	30·92		
An	20·29		$\frac{L}{F}=\frac{1·99}{68·45}=0·03$, 5, Germanare
Ne	1·99	70·44	
Di	10·95		$\frac{K_2O'+Na_2O'}{CaO'}=\frac{97}{73}=1·3$, 3, Andase
Ol	8·48		
Mt	3·02		
Il	5·78	28·23	$\frac{K_2O'}{Na_2O'}=\frac{31}{66}=0·49$, 4, Andose
H_2O	·56		
Total	99·23		

That is, it is dosalic, perfelic, alkalicalcic and dosodic; its coördinates are 2.5.3.4 and, considering its texture, it is *grano-andose.* The attempt to classify this rock according to the general qualitative system meets with some difficulty. It shows some affinities to diabases, but the fabric is quite different from that of a typical diabase. It would be, perhaps, easiest to term it a micro-gabbro. If we consider genetic relations, and the fact that it is dike rock, the case becomes still more difficult. Does it belong to the alkalic clan of lamprophyres, or to the alkalicalcic (sub-alkalic) group, and, if the latter, is it an aplite, or a lamprophyre? If we determine that the whole group of Tripyramid rocks is really an alkalic complex, and that the gabbro should be regarded as an essexite, then it is either micro-essexite or, clearly, a lamphrophyre, one probably complementary to the quartz-syenite aplite, and the small amount of nephelite it contains would be a natural feature. If a lamphrophyre we must class it as a new type, or one of those aberrant camptonites mentioned by Rosenbusch,* in which augite entirely replaces hornblende. In favor of this view it will be seen, by reference to the table, that it has an almost identical chemical composition with the dike at Norway Rapids, which is described as camptonite in the following section. On the other hand, the composition is quite different from typical camptonites, as seen by comparing with No. IV of the table; it does not agree with them, either in minerals, or chemically. From the standpoint of an alkalic rock, though wanting brown hornblende, it classifies best in minerals, fabric and chemical composition as a micro-essexite

* Mass. Gesteine, 4[te] Aufl., p. 685.

and the small amount of nephelite it contains would then be a natural feature. Compare analysis No. V.

If we consider the gabbro as genuine gabbro and this as an attendant dike and, therefore, alkalicalcic, comparison with the analysis of the gabbro shows at once that this is aplitic (salic) rather than lamprophyric in character. One must then compare it with luciite and beerbachite; it differs from these considerably in chemical composition, especially in potash. See analyses Nos. VI and VII. Thus it differs both in minerals and in lacking the aplitic texture.

On the whole, it is, perhaps, best considered as a very fine-grained essexite and it will be further treated in the discussion of the mutual relations of the rocks of the complex.

Dike at Norway Rapids.

Megascopic characters.—Holocrystalline; dark, greenish gray, dotted with dull whitish spots about 2^{mm} in diameter; megagranular, but fine; has a somewhat silky shimmer due to abundant minute, slender feldspar laths, 2–3^{mm} long, diversely scattered among the dark greenish granules of ferromagnesian minerals, suggesting a minute ophitic texture. The whitish spots are uniformly scattered, but have no definite boundaries, and are neither phenocrysts nor amygdules; they have a fibrous structure and are the scapolite mentioned later. Fracture rough and hackly; weathers brown.

Microscopic.—The minerals observed in the section are: apatite, iron ore, hornblende, and plagioclase; these are original, while epidote, scapolite, garnet, chlorite, and titanite are present as alteration products.

The *hornblende* was originally a rich brown, pleochroic variety similar to that found in normal camptonites and generally ascribed to barkevikite. It occurs in stoutly shaped prismoids several millimeters long. It was originally interwoven with compact laths of a *plagioclase*, apparently a labradorite, but now too much altered for definite determination. Between these, and also enclosed by them, were the grains of *iron ore*, rather small and sparse, and prisms and grains of *apatite*. In these respects the rock appears like a normal camptonite.

From this condition the rock has been considerably altered, the brown hornblende, save for occasional remnants, has been bleached to a light green variety, and this has largely undergone a still further alteration into masses of green chlorite, a pale epidote, and considerable titanite. The occurrence of the titanite is similar to that observed by the writer in the alteration of a barkevikite-like hornblende in a dike rock from the Belknap Mts.* and points to a considerable amount of titanic

* This Journal, vol. xxii, p. 503, 1906.

acid in the original mineral. Shreds and grains of these secondary minerals are also spread through the rock fabric around the original hornblendes, producing confused aggregates which more or less conceal its original nature.

The feldspar has been mostly changed to a colorless mineral of low single and moderate double refraction, a prismatic columnar aggregate in structure, with good cleavage, parallel extinction, uniaxial, negative character. This must be scapolite, a not uncommon alteration product of plagioclase. Scattered about through this are grains and dodecahedrons of a colorless, isotropic mineral, with high index of refraction and without good cleavage, which is inferred to be a lime garnet.

Chemical Composition.—The alteration which this rock has undergone is essentially one of molecular rearrangement, not ordinary weathering. Therefore the chemical composition in mass has not been materially changed, and analysis seemed desirable as affording the best means for judging its original nature. This has been carried out by Mr. C. J. Monahan with the results given in No. II of the previous table of analyses. It is considered under the discussion of the classification.

Texture.—The general plan of the texture of this rock, when it was unaltered, is shown by the divergent, elongate prismoids of hornblende, intermingled with the tabular feldspars and grains of iron ore and apatite, all varying considerably in dimensions. It is inequigranular seriate, multiform (tabular, prismoidal and equant, subhedral) divergent fabric. It is the panidiomorphic-granular structure of Rosenbusch.

Classification.—In the quantitative system the position of this rock is shown by the following calculation of its norm and place:

Norm.	
Or	16·68
Ab	31·44
An	21·13
Ne	2·27
Di	8·80
Ol	8·74
Mt	5·10
Il	5·02
Ap	0·67
H_2O	0·55
Total	100·40

$$\frac{Sal}{Fem}=\frac{71·52}{28·33}=2·5=2, \text{ Dosalane}$$

$$\frac{L}{F}=\frac{2·27}{69·25}=0·03=5, \text{ Germanare}$$

$$\frac{K_2O'+Na_2O'}{CaO'}=\frac{0·98}{0·76}=1·3=3, \text{ Andase}$$

$$\frac{K_2O'}{Na_2O'}=\frac{0·30}{0·68}=0·44=4, \text{ Andose}$$

It is dosalic, perfelic, alkalicalcic, and dosodic; its coördinates are 2.5.3.4 and it is therefore andose. The original mode, which cannot now be quantitatively determined, was not a normative one, since hornblende was present in large amount and is therefore a critical mineral. The texture, though fine, is megascopically granular. Hence the rock is a *hornblende-grano-andose.*

The classification of this rock, according to genetic qualitative system, meets with difficulty. In the fact that it consists essentially of brown hornblende and labradorite it at once suggests camptonite, so common a dike rock in this petrographic province. Reference to the table of analyses shows that it differs considerably from the type given in No. IV. On the other hand, this rock has a chemical correspondence with a dike rock from the Belknap Mts., No. III, which was called by the author spessartite, because in mineral composition, texture, and mode of occurrence it agreed with that type as described by Rosenbusch, although chemically it corresponded only in a general way. From the genetic standpoint the Belknap rock, being a member of a clan of alkalic rocks, could not be spessartite, which should belong to the attendants of the common granite-diorite set of magmas. In the present case, however, the allegiance of the dike is less clear, but, all things considered, it may, perhaps, best be termed a camptonite. It is of interest to observe that this dike, and the previous one, furnish a good example of how quite similar magmas may develop different mineral compositions according to different local conditions. The former consisted of augite, olivine, biotite, and plagioclase, this one of brown hornblende and plagioclase. A difference in the quantity and kind of mineralizing vapors may have determined the formation, of hornblende, rather than the other ferromagnesian minerals.

General Petrology.

From the standpoint of general petrology there is nothing remarkable, or particularly novel, in the rocks of Tripyramid, so far as the individual types are concerned. Their interest centers chiefly in two features: the association which the rocks present, and their origin in relation to the surrounding granite and gneisses.

In regard to the association of types, this may be seen by the mention of them: umptekite (alkalic syenite), quartz-syenite-aplite, monzonite, norite, gabbro and camptonite. To the uninitiated there may seem nothing remarkable in this assemblage, but to petrographers, who in these later years have been considering the genetic relationships of rocks, especially as they are found associated in differentiated complexes, it is significant, and to many who hold very definite views on this matter it may seem unnatural. For, if the syenite, monzonite and camptonite come naturally together as an alkalic group, then they should not be associated with norite and gabbro, for these are members of the alkalicaclic (or sub-alkalic) rock series. It is recognized, of course, that rocks consisting of ferromagnesian minerals and lime-soda feldspars occur in the alkalic rock series, and to one of these with certain mineral and chemical features the name of essexite has been given. It is also understood that these rocks, of which essexite stands as a good example, show by the kinds of pyroxene and hornblendes they contain, by presence of more or less nephelite, or sodalite, and similar peculiarities, which may be regarded as tribal markings, their allegiance to the clan from which they have sprung.

At this point the writer desires to say that with this view, recognizing the genetic relations existing between rock series, he is in hearty accord and that he believes the demonstration of it, made during the last fifteen or twenty years, to have been one of the most important results of petrologic research. But the question which the Tripyramid assemblage brings to mind is, how far can this be carried, and how invariable are the associations of given rock types? There are some perhaps who, insisting upon the law of invariability, would say that in this case the gabbro and norite are not really such, but are certain types, or aberrant forms, of essexite. But if we hold this view, then the definition of essexite becomes so broad and general as to lose any specific value. So far as one can see there are no chemical, or mineral, peculiarities about the Tripyramid gabbro which would differentiate it from the usually accepted types of that rock, or any grounds on which we could call it an essexite beyond the fact of its association. But if we do this and thus push the genetic view of classification to its limit, we shall have to admit that rocks (in some cases) are not to be classified as kinds according to the inherent properties which they possess, but by these and their associations. Thus we shall find rocks whose inherent properties are similar in two, or perhaps more, places in our classification. But what if we find such a type alone, by itself, without any associations, a not uncommon occurrence? Then we shall be unable to classify it, or else we shall have to adopt the procedure of sometimes classifying rocks by one method and sometimes by another, a process which can scarcely commend itself as an orderly or logical one. This, to the writer's mind, is one of the chief difficulties of rock classification as based on genetic association and descent, and at present no practical way of solving it appears. It has also indirectly been brought forward by Whitman Cross* in a recent paper treating of this subject.

* Natural Class. of Ign. Rocks, Quart. Jour. Geol. Soc., lxvi, p. 481, 1910.

The geology of Tripyramid, as it is now known, indicates that a body of monzonitic magma, as this appears to be the main rock mass, after, or during intrusion, has so differentiated that the outer part has developed into gabbro and an inner part into alkalic syenite. This does not seem illogical, for the intermediate position of monzonite with respect to alkalic and sub-alkalic rocks has long been recognized, and its chemical similarity to the generalized earth magma of Clarke and Washington clearly perceived. But if a monzonite magma is thus really intermediate, it cannot be expected to always differentiate in one direction alone, to the alkalic side. From it we must expect to get intermediate series, running in various directions and connecting the alkalic with the sub-alkalic rocks. Thus

Alk. Granite—Alk. Syen.—Foyaite—Essexite—Shonkinite, etc.

Monzonite

Common Gran. Quartz Diorite—Diorite—Gabbro—Peridotite

in the present case our series runs diagonally as shown above. The norite is simply a phase between the monzonite and gabbro. It seems to realize the idea expressed by Cross in saying: "Given an intermediate monzonitic magma, is it not natural to suppose that its descendent magmas must be intermediate in many respects between the series from foyaitic and dioritic parent magmas and that a shifting of conditions may throw the dominance of characters one way or the other?"* Considered from this point of view, the two dike rocks previously described would be merely products of the monzonite magma, whose differentiation paths were towards essexite, rather than towards the gabbro, and whose complementary derivatives are to be seen in the quartz-syenite aplites.

The other interesting feature of these rocks is their origin with respect to the surrounding older ones. Recently the view has been put forward that the alkalic rocks are due to the fusion and absorption of particular kinds of sediments by sub-alkalic magmas. Jensen† regards these sediments as having been Archean saline beds, while Daly,‡ on the other hand, considers them to have been masses of carbonate rocks, and that juvenile carbonic acid assisted in the process. The latter also suggests that some alkalic rocks may have been formed by simple differentiation, by "splitting" of the magmas assisted

* Op. cit. p. 484.

† Distribution, Origin and Relationships of Alk. Rocks, Proc. Linn. Soc. N. S. Wales, xxxiii, p. 491, 1908.

‡ Origin of the Alk. Rocks, Bull. Geol. Soc. Amer., xxi, p. 87, 1910.

by juvenile gases. Neither author offers a discussion of the chemical aspects of the case, the hypotheses being founded on geological and mineralogical occurrences and associations.

It would be out of place to discuss these views in this place, but it may be pointed out that they can scarcely be appealed to for an explanation of the alkalic syenite of Tripyramid. For, since the magma was ejected through and into a granite bathylith with gneisses and acid schists above, there could have been neither saline beds nor carbonate masses operative upon it. It might be suggested that the syenite was formed by the action of such acid rocks on the monzonite or gabbro, but this has already been considered in the former paper. In this respect Tripyramid is like Red Hill and the Belknap Mts., occurrences of alkalic rocks to the southward, which have been studied and, in part, described by the writer.* In them also the intrusions have been through and into gneisses and schists and there is no evidence of saline beds or carbonate rocks having taken part. These cases seem to fall under the alternative view suggested by Daly,† and it therefore appears that some alkalic magmas and rocks are formed without the aid of particular sediments.

It has been suggested that the border zones of concentric masses have been produced by absorption of the enclosing rocks. This could not have been the case at Tripyramid, for it is clear that the gabbro could not have been made from the monzonite magma by the absorption of either granite, gneiss, or schist. It must be regarded either as a separate intrusion, or as a differentiation product.

Summary.

This article deals with the rocks of Tripyramid Mountain, which is shown to consist of alkalic syenite (umptekite), monzonite and gabbro with associated dikes of quartz-syenite aplite and lamprophyres allied to camptonite. These various types are described and, in most cases, chemical analyses of them given. The latter show in the case of the basic dikes that magmas of similar composition may produce rocks mineralogically different. The systematic positions of the various types are also discussed and in conclusion the bearing of the facts observed on the subjects of genetic classification, and on the origin of alkalic rocks, is treated.

Sheffield Scientific School of Yale University,
New Haven, Dec. 1910.

* This Jour., xx, p. 344; xxii, pp. 439, 493, 1905–1906; xxiii, pp. 257, 433.
† Op. cit. p. 113.

Art. XXXVI.—*An Occurrence of Strüverite*;* by Frank L. Hess and Roger C. Wells.

The mineral described in this paper belongs to the tetragonal system, crystallizes like rutile and contains titanium, tantalum, columbium, iron and tin. It is apparently a new mineral and at one time we contemplated giving it a specific name in order to differentiate it from ilmenorutile and suggest its chemical composition, but this was not done for reasons which will be noted. In accordance with modern views, the mineral may probably be regarded as a new member of an isomorphous series of minerals crystallizing like rutile and containing some or all of the metals named.

In 1908 Prior and Zambonini described a mineral from Craveggia, Northern Piedmont, which differs from ilmenorutile in possessing a little more tantalum, in relation to columbium, than had been found in any ilmenorutile up to that time.† After noting its crystallographic similarity to ilmenorutile and the possibility of considering it a solid solution of mossite and tapiolite in rutile, Prior says: "We propose to reserve the name strüverite for those members of the series rich in tantalic acid and to keep the name ilmenorutile for those, like the Norwegian specimens, in which niobic is the prevailing acid." Since the name ilmenorutile is reserved "for those minerals in which niobic is the prevailing acid," a fair inference would lead one to suppose that their mineral carried a preponderance of tantalum oxide, but as analyzed by Prior it showed Ta_2O_5 and Cb_2O_5 only "in about equal amounts,"—23·5 per cent of each,—so that the columbium oxide is in molecular excess as 88 : 53. It is evident that their definition of strüverite does not fit their mineral, although their mineral suggests the possibility of others having more tantalum. In other words, they named a mineral which was yet to be found.

The mineral described in this paper carries 35·7 per cent Ta_2O_5 and 6·4 per cent Cb_2O_5 and would seem to deserve a new name, but as it has been covered by the definition of strüverite we shall defer to that name in order to avoid overburdening the literature of mineralogy. At the same time we hope that the custom of proposing names for unknown extrapolated members of a mineral series will not become general.

* Published by permission of the Director of the United States Geological Survey.

† On Strüverite and its Relation to Ilmenorutile. Mineralogical Mag., xv, 78-89, 1908.

Occurrence. (F. L. H.)

The mineral is found in considerable abundance as an original constituent of the granite pegmatite dike on which the Etta claim is located, one and a half miles south of Keystone, in the Black Hills of South Dakota. While on a reconnaissance trip for the United States Geological Survey in September, 1908, I visited the claim and collected specimens.

Since the early 1880's the Etta dike has been famous as a storehouse of rare minerals. The claim which is located upon it was first worked for mica, and while being thus operated cassiterite was discovered. Out of the discovery grew the tin excitement of the Black Hills lasting through the late 80's and early 90's. Cassiterite did not prove to be in sufficient quantity to pay for mining, and latterly the dike has been worked for spodumene, which is used as an ore of lithium. The Etta dike is in some ways one of the most remarkable pegmatites known, and although it has been described in geological literature a number of times, some of its features merit attention at this time. It has a roughly oval outline, and is about 150 by 200 feet in horizontal dimensions. Some of its component minerals are gigantic. The crystals of spodumene are probably unequaled in size by any other known occurrence, single crystals reaching 42 feet in length with a cross section of approximately 3 by 6 feet. It is said that 37 tons of spodumene were mined from one crystal. Cassiterite has been found in masses weighing from 50 to 60 pounds each,* and irregular aggregates of columbite weighing 600 pounds.†

In parts of the dike are finer-grained masses predominantly composed of honey-yellow muscovite and white feldspar, both microcline and albite. The microcline shows some crystal faces from one-half inch to several inches across, and is partly flesh-colored. The albite is pure white and occurs in thin plates which reach an inch or more in breadth. The muscovite is in flakes ranging from minute scales to plates three-fourths of an inch across. Through these masses are mixed other minerals in greater or less profusion,—white beryl, small spodumene crystals, cassiterite in small particles, quartz, secondary opal, and strüverite.

Columbite occurs in considerable quantity, in most places as individual crystals ranging from small ones up to those weighing several pounds, with some larger aggregates such as those mentioned above. The crystals are tabular, in many specimens from one-third to one-half longer than wide, though some

* Blake, W. P. Tin; Min. Res. of the United States for 1883-4. Geol. Surv. Washington, 1895, p. 607.

† Personal communication, A. M. Lane, Keystone, S. D.

are nearly square, and the thickness ranges from about one-eighth to two-thirds of the length, Even in most of the very small crystals the tabular form may be distinguished.

Near a point where columbite crystals were especially thickly sprinkled through the dike and where the general texture was comparatively fine-grained, little aggregates of a black, opaque metallic mineral whose luster and color were indistinguishable from columbite but whose crystal form was less distinct, were found rather thickly impregnating the dike for several feet. It was evidently an original mineral in the dike and occurred completely imbedded in microcline, beryl, and muscovite. In the specimens examined none appeared to be entirely surrounded by quartz and none was found in spodumene. From a hasty field examination the mineral was thought to be another form of columbite, but later the surrounding gangue, which in the piece used was mostly microcline, was dissolved with hydrofluoric and sulphuric acids and it was found that the crystals showed no resemblance to the crystal habit of columbite as it occurs in the Etta dike. A slight movement in the dike had crushed most of the crystals so that good speci mens for optical measurements were hard to obtain. The separated crystals had been exposed to the action of the acids for about six weeks, and while to the unaided eye they were bright and smooth, W. T. Schaller, to whom they were referred for crystallographic determination, found them to be too badly etched to give a good reflection. He therefore extracted fresh crystals from the matrix and upon these made the crystallographic determinations which are quoted in the next paragraph. The largest crystals collected are about 5^{mm} long by 1·8 to 2^{mm} across the exposed cross sections. The largest aggregate is 16^{mm} across. The powder and streak are nearly black with a slightly greenish tinge. The hardness is 6–6·5 and the specific gravity 5·25. The mineral is opaque in thin section and neither cassiterite nor rutile appears to be enclosed in it, although such a possibility was suggested by the analyses to be described.

Mr. Schaller remarks :

"The small crystals, generally from 1 to 3 millimeters in length and hardly as thick, closely resemble twinned and distorted crystals of rutile, mossite, tapiolite, etc. They are tetragonal, twinned on the *e* (101) face and elongated in the direction of the $(1\bar{1}1):(111)$ intersection edge. The crystals are very poorly adapted for measurement, the faces being rough and reflecting light poorly. The forms present are $a\{100\}$, $e\{101\}$, $s\{111\}$. The habit of the crystals resembles very closely a so-called black rutile described by Headden and

Pirsson.* Their material was probably identical in character with that here described.

In addition to the forms as illustrated by Pirsson, there is often present, on the crystals examined, a narrow face of *e* between a and *a*. The measurements on which the identifications are based follow.

	Measured.	Calculated for rutile.
e	*s* = 27°51′ — 28°59′	28°26′
e	*a* = 56 30 — 57 20	57 13
s	*s*′ = 55 57 — 56 50	56 52
a	*a* = 66 10 — 66 30	65 34
a	*e* = 10 30	8 21"

The mineral does not appear to be radioactive to any considerable degree, but after 15 days' contact of a polished specimen with the sensitive side of a photographic plate, the microcline surrounding the strüverite gave a distinct radiograph, the plate remaining unaffected under the strüverite.

Although it occurs in considerable quantity, the mineral gives little promise of having commercial value as an ore of tantalum, owing to the high titanium content.

Chemical Analysis. (R. C. W.)

The mineral was separated from the gangue almost completely by crushing and panning. The resulting black grains were dried at 100°. Under the microscope there were visible only the black opaque mineral and a few grains of silica.

Suitable tests showed that the essential constituents were titanium, tantalum, columbium, and iron. There were small amounts of tin and silica and a trace of aluminum. Phosphorus, calcium, manganese, molybdenum, rare earths, tungsten, and heavy metals were proved absent. It was concluded that zirconium was also absent because after repeated precipitations of the sulphates of the bases with hydrogen peroxide in the presence of a phosphate no residue finally remained.† With less than one per cent of sulphuric acid present in this last operation, much tantalum and titanium, and to a less extent columbium, are precipitated by the phosphate. But the separation of zirconium is based on the fact that it is almost certainly precipitated in the presence of one per cent of sulphuric acid and possibly in the presence of even more.

The density of the fragments was found by the pycnometer to be 5·25. Since the approximate density of titanium oxide is 4·0, of iron titanate 4·8, of iron columbate 5·9 and of iron tanta-

* Headden, W. P. and Pirsson, L. V. on Black Rutile from the Black Hills. This Jour., 3d ser., vol. xli, 1891, p. 249.

† W. F. Hillebrand, Bull. 305 U. S. Geol. Survey, p. 141.

late 6·9, the mineral evidently contained a heavier constituent than titanium or iron and the presence of tantalum was thus first suggested.

While the analysis of this mineral was in progress the paper by Prior and Zambonini appeared* and other suggestive papers upon the analysis of chemically similar minerals have recently been published. A method for analyzing columbite has been published by E. S. Simpson but is not intended to be used when titanium is present.† W. B. Giles has described the opening up of minerals containing columbium and tantalum.‡ Weiss and Landecker,§ Hauser and Finckh‖ have worked on the separation of these elements.

When it was desired simply to get the mineral into solution, fusion with acid sodium sulphate was employed. The melt was dissolved in 5 or 10 per cent sulphuric acid.

The colorimetric determination of TiO_2 gave 45·8 per cent as an average of several experiments and readings, the series being 47·4, 44·2, 46·4, 45·3, 46·5, 45·3, 43·6, 45·6, and 47·6. All of the precautions mentioned by Merwin¶ with regard to the influence of sodium sulphate, etc., were not considered, but about 5 per cent of sulphuric acid was present in the standard and sample compared.

Since the mineral was not attacked by boiling with dilute sulphuric and hydrofluoric acids, a determination of the state of oxidation of the iron was abandoned. Calculated as ferrous oxide, the amount present was 7·5 per cent.

By reducing the mineral in hydrogen and dissolving in hydrochloric acid 0·6 per cent SnO_2 was obtained. More, however, was obtained by fusing with bisulphate, adding to the solution sodium hydroxide in excess, filtering and adding hydrogen sulphide. This treatment gave 1·09 and 1·14 per cent SnO_2 after correcting for platinum and other impurities. The method of attack recommended by Giles** for determining tin was also tried. He states that by fusing a columbite containing tin at a high temperature with potassium carbonate and digesting in warm citric acid, the tin may be brought into solution as well as other constituents except titanium, zirconium and a little silica. From one gram after three fusions there remained only ·0475 grm. of insoluble matter consisting of ·0351 grm. Fe_2O_3 and a little TiO_2. From the soluble part, however, there was obtained only 0·7 per cent SnO_2 by hydrogen sulphide, which was less than that obtained in the previous way. In a wholly different way as much as 1·7 per cent SnO_2 was

* Loc. cit.
† Chem. News, xcix, 243, 1909.
‡ Chem. News, xcix, 1, 1909.
§ Zs. anorg. Chem. 64, 65.
‖ Ber., 1909, 2270.
¶ This Journal (4), xxviii, 119.
** Chem. News, xcix, 27, 1909.

obtained in one experiment. The mean of all was 1·3 per cent.

A few words may be said upon the results of fusing the mineral with sodium carbonate. It was attempted to make a separation of titanium and other bases from tantalum and columbium by such a fusion and extracting the tantalate and columbate with hot water. After two fusions with sodium carbonate in one experiment, the insoluble portion (*a*) was found to be 83·8 per cent, the soluble portion (*b*) 16·5 per cent. But the separation was incomplete, for, after determining in portion (*a*) 7·8 per cent Fe_2O_3, 42·3 per cent TiO_2 and traces of other constituents, there remained 33·3 per cent unaccounted for, which was probably tantalum and columbium oxides, and in portion (*b*) there was found 4·5 per cent TiO_2. In another experiment one gram was fused with sodium carbonate and very thoroughly extracted with hot water. The residue was re-treated. Three such extractions brought 18 per cent into solution, but of this a third or 6 per cent of the mineral was TiO_2. Hence the columbium and tantalum carried titanium with them into the soluble portions, and it was not possible to extract nearly all the columbium and tantalum by even repeated treatments.

With respect to this sodium carbonate treatment the experiments of Weiss and Landecker demand consideration.* They reasoned that the carrying into solution of titanium by columbium must be due to the formation of a compound of the two which they thought could be decomposed by adding a little niter during the sodium carbonate fusion. A trial of their method was made, but it was found that titanium passes into the soluble part with columbium and tantalum just as it does when no niter is used. In their description the method of freeing titanium from columbium and tantalum by hydrogen sulphide is not clear. In view of these facts the sodium carbonate attack was abandoned.†

Another method of analysis was carried out as follows:

After a bisulphate fusion, silica, tin, and iron were removed by the use of tartaric acid, ammonia, and hydrogen sulphide. The tartaric acid was destroyed by ignition, the total acid earths dissolved by bisulphate and eventually converted into the double fluorides of potassium. These were separated by the method of Marignac. The weight of crude Ta_2O_5 thus obtained was corrected for the TiO_2 present. The total TiO_2 had already been determined. Cb_2O_5 was computed by difference. Two such experiments gave the results below, in which are collected the data for the other constituents so far determined:

* Chem. News, ci, 13, 1910.
† Compare Foote and Langley, this Journal, xxx, 401, 1910.

	1	2
H_2O	0·4	0·4
SiO_2	1·8	1·8
TiO_2	45·8	45·8
SnO_2	1·3	1·3
FeO	7·5	7·5
Ta_2O_5	37·6	30·5
Cb_2O_5 (by difference)	5·6	12·7

Although these results give a fair idea of the composition, it was concluded that a separation of the chlorides by fractional distillation might be a more advantageous method of analysis. The separation of titanium from columbium and tantalum in this way was suggested by a method of separating titanium and iron occasionally employed in steel analysis,* although, of course, the quantities are not exactly comparable.

Experiments were first made on known quantities of TiO_2 and Cb_2O_5 using sugar carbon and dry chlorine to produce the chloride in a hot, hard, glass tube, and it was found that an approximate separation could be made.

A mixture of titanium, columbium and tantalum oxides. obtained from the mineral under examination, and free from other elements, was subjected to treatments with carbon in chlorine.

Taken	0·2248 g.	Found TiO_2	0·1345 g.
		$(Ta,Cb)_2O_5$	0·0789
		Total found	0·2134 g.
		Deficit	·0114 g.

Applying the ratio of Ti to (Ta,Cb) here found to 89·1 per cent of the mineral (the total acid earths) gives TiO_2 56·2, $(Ta,Cb)_2O_5$ 32·9 per cent. This is considerably more TiO_2 than found by the colorimetric method.

Owing to the difficulty of completely converting the oxides into chlorides by the use of carbon, the apparatus was somewhat modified and chloride of sulphur tried instead. It was found possible to convert nearly half of a gram of a mixture consisting of the oxides of titanium, tantalum or columbium into chlorides in two hours. A porcelain boat was used in a long, hard, glass tube. That portion of the tube used for the condensation of the less volatile chlorides was warmed uniformly by a jacket of asbestos containing electrical resistance wire. Sufficient chloride of sulphur was introduced as vapor by merely passing the chlorine through a distilling flask in which sulphur chloride was kept gently warmed. Practically

* Blair, The Chemical Analysis of Iron, 6th ed., p. 74.

no titanium chloride or sulphur chloride condensed in the hard glass tube at a temperature of 70–80°. In fact a considerable number of wash bottles were required to collect all the vapors of titanium chloride, owing to the heat generated by the reactions which occurred with the water of the wash bottles. Unfortunately, however, a little of the columbium and tantalum chlorides passed over with the titanium, a difficulty which no style of condensing chamber seemed to wholly prevent. To decrease this loss as much as possible the condensing tube was inclined slightly so as to force the gases upward. The titanium oxide, after collection, was treated a second time to recover the small fraction of tantalum and columbium which was carried over the first time. By such a repetition *it was possible to separate nearly all the tantalum and columbium from the titanium.* The sublimed columbium and tantalum chlorides are best washed out with concentrated hydrochloric acid and after nearly neutralizing with ammonia precipitated by boiling with sulphur dioxide. The oxides thus precipitated do not run through the filter. A slight residue, partly sulphate, forms in the boat, which is with difficulty converted into chloride. It is possible that the use of carbon tetrachloride vapor might be a better agent for converting the oxides of columbium, tantalum and titanium into chlorides than sulphur monochloride.*

In analyzing the mineral it was found simpler to treat it directly in chlorine than to remove the tin and iron first. In this way three portions resulted,—a slight residue in the boat, a sublimate containing most of the tantalum, columbium and iron, and a dissolved portion containing titanium and tin. The titanium portion was nearly neutralized and precipitated by boiling with sulphur dioxide, leaving tin in solution. After ignition this precipitate was treated again in chlorine to obtain the little columbium and tantalum which escaped the first time. The columbium and tantalum oxides were precipitated together by sulphur dioxide, ignited and weighed.

The tantalum and columbium oxides, finally freed from titanium, were next subjected to the method of Metzger and Taylor for determining columbium in which the columbium sulphate is reduced in a zinc reductor and titrated with $KMnO_4$.† Metzger and Taylor found that on the average 1 grm. $KMnO_4$ was equivalent to 2·232 grm. Cb_2O_5. As in a blank experiment 1 grm. $KMnO_4$ was found equivalent to 2·458 grm. Cb_2O_5, the average 2·34 was used in computing the Cb. The results obtained by these methods were:

* A. Demarçay, Compt. rend., civ, 111–13.

† Columbia School Mines Quart., xxx, 323–24, 1909.

Residue	4·4	4·1
TiO_2	48·0	51·2
Ta_2O_5	34·0	33·0
Cb_2O_5	2·6	4·3
FeO	---	6·8

These results were corrected slightly for the residue in the boat. This residue was shown to be 50 per cent SiO_2. The remainder was computed as 90 per cent $(Ta,Cb)_2O_5$ and 10 per cent TiO_2. With these corrections the results become:

SiO_2	2·2	2·0
TiO_2	48·2	51·4
Ta_2O_5	36·6	34·6
Cb_2O_5	2·8	4·5
FeO	---	6·8

An average of the results recorded on p. 436, with the results above gives the final average in the first column below. On microscopic evidence the SiO_2 is considered to be gangue. The second column gives the composition of the anhydrous, gangue free material. The third and fourth columns give the molecular ratios.

H_2O	0·4			
SiO_2	2·0			
TiO_2	47·8	49·1	·613	·622
SnO_2	1·3	1·3	·009	
FeO	7·3	7·5	·104	·104
Ta_2O_5	34·8	35·7	·081	·105
Cb_2O_5	6·2	6·4	·024	
	99·8	100·0		

These results are sufficient to establish the essential composition of the mineral. In view of the fact that the determination of columbium by the Metzger and Taylor method is undoubtedly better than by the first method used, it seems likely that the tantalum content should be a little higher and the columbium content a little lower than here stated, but the higher FeO content, by the first method, 7·5 per cent, probably deserves the greater weight.

The mineral designated "black rutile" by Headden,* which was probably this mineral, was stated by him to consist of TiO_2 90·79 per cent, FeO 8·01, SnO_2 1·35, MnO trace. If the tantalum and columbium oxides determined above are added to the titanium oxide, the result is: Acid earths, 91·2, FeO 7·5, SnO_2 1·3, a striking confirmation of the suspicion, raised by the density, that Headden weighed the tantalum and columbium

* This Journal [3], xli, 249, 1891.

with his titanium. Owing to the unsatisfactory state of the analytical methods applicable to these elements, it seems likely that heretofore small amounts of tantalum or columbium may often have been overlooked in titanium minerals.

The analysis yields no simple formula. Apparently one molecule of FeO is present to one molecule of $(Ta,Cb)_2O_5$, but TiO_2 lies between 6 and 7 molecules. The formula approximates roughly to $Fe(Ta,Cb)_2O_6.6TiO_2$.

Classification of the mineral. (F. L. H. and R. C. W.)

The tetragonal minerals containing titanium, tantalum, columbium and iron evidently form a series with a group at one end to which the name ilmenorutile is given and a group at the other end represented by the mineral described in this paper. Prior and Zambonini's* mineral has a nearly medial composition, but really belongs to the ilmenorutile group. Ilmenorutile, when first described by P. von Eremeyev,† was supposed to be a rutile containing "up to 10 per cent, or more of Fe_2O_3." Brögger,‡ in later analyses under improved conditions, found ilmenorutile to contain from 13·74 to 19·64 per cent of Cb_2O_5, and one specimen showed 0·43 per cent Ta_2O_5. He retains the name ilmenorutile, and it will probably stand for a columbium-iron-rich rutile. Prior§ reviewed Brögger's results and found that the Cb_2O_5 amounted to from 33·02 to 33·50 per cent Cb_2O_5, but found no more Ta_2O_5. In an independent analysis of an ilmenorutile from the Ilmen Mountains, however, he found 21·73 per cent Cb_2O_5 and 14·70 per cent Ta_2O_3 (see table p. 442).

The mineral from Craveggia, Northern Piedmont, is one which was first described by Zambonini‖ as bearing titanium, zirconium, tantalum and columbium, a mistake not unnatural owing to the difficulties of distinguishing in a chemical way between these elements.

After the first publication by Zambonini, further work was done in collaboration with Prior and the mineral was shown to carry¶ no zirconium but to have the composition (mean analysis)** indicated in column I of the table given below, with which are given for comparison an analysis of ilmenorutile (No. II) from the Ilmen Mountains,†† and the mineral from the Black Hills (No. III), the analysis of which has been described.

*Loc. cit.

† Quoted by J. Dana, System of Mineralogy, p. 238.

‡ Brögger, W. C., Die Mineralen der südnorwegischen Granitpegmatitgänge. Pt. 1, Niobate, Tantalate, Titanate and Titanniobate, p. 46.

§ Op. cit. p. 87.

‖ Zambonini, Ferruccio, Strüverite, un nouvo minerale. Rend. R. Accad. Sci. Napoli, 1907, ser. 3, vol. xiii, pp. 35-44.

¶ Op. cit.

** Op. cit. p. 84.

†† Op. cit. p. 87.

	Craveggia. I	Ilmen Mts. II	Black Hills. III
TiO_2	41·20	53·04	49·1
Cb_2O_5	23·48	21·73	6·4
Ta_2O_5	23·48	14·70	35·7
SnO_2	----	----	1·3
FeO	11·38	10·56	7·5
MnO	trace	----	---
CaO	·51	trace	---
MgO	0·17	----	---
	100·22	100·03	100·00
Sp. gr.	5·59	5·14	5·25

Summary.

The occurrence and analysis of a mineral containing titanium, tantalum, iron, columbium and tin is described. Crystallographically it belongs to the rutile group. Chemically it is essentially titanium oxide with iron tantalate and columbate, the tantalate being in excess of the columbate. Tin is an unessential minor constituent. Its formula approximates to $Fe(Ta,Cb)_2O_5.6TiO_2$. It is considered to belong to a group of minerals whose members Prior and Zambonini designated strüverite.

Art. XXXVII.—*Geologic and Petrographic Notes on the Region about Caicara, Venezuela;* by T. A. Bendrat, Turners Falls, Mass.*

In the winter of 1908–09 the writer made some geographic and geologic studies in the interior of Venezuela, his field of investigation being the region immediately west of the El Caura district, at the famous bend of the Orinoco, an area of about 1500 square kilometers, that was hitherto very little known, being mapped.

While the general results of this survey have been summed up elsewhere,† it is to the geologic and especially the petrographic features of the region that this paper relates.

General Geology.

The study of the geology of the region shows an underlying bedrock formation of gneisses and granites and on this the Sabana deposits.

The Gneiss and Granite Basement.

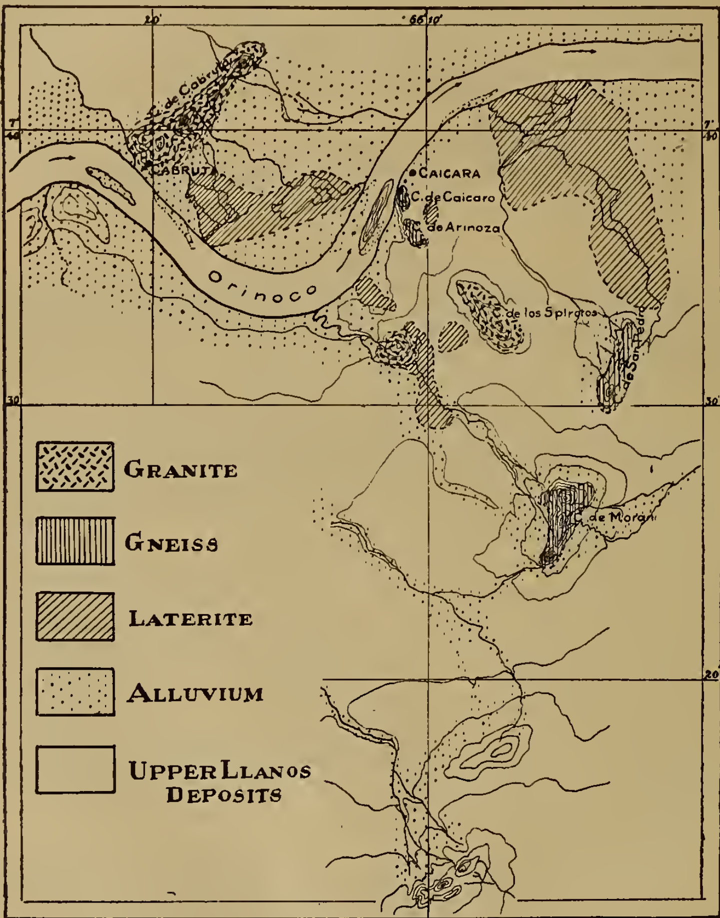
The bed rock consists of a series of granites and gneisses which, wherever they come to the surface, show a prevalence of gneiss over the granite. They rise from the bottom of the Orinoco channel, constituting the foundation of many of the islands; they are exposed in the banks of the river; they appear as cliffs above the water-level during the dry season, they also form the bulk of the so-called Cerros' hills and ridges rising above the plain of the "Sabana," and increasing in height in proportion to their distance from the Orinoco, and which may be regarded as the outliers of the Guyana mountain system in the south. These cerros are portions of the complex of granites and gneisses which have resisted the process of erosion partly because of a number of veins and dikes which traverse them in various directions, but mainly N.–S. E.–W., and N.W.–S.E.

The Isla de Maria Luisa opposite Cabruta was not visited, but examination of the shores of Isla de Caicara, opposite the village of Caicara, showed that its bed-rock is a purple weathering, drab-colored granite with N.–S. and E.–W. cleavage.

* The writer desires to express in this place his high obligations to Prof. B. K. Emerson of Amherst College, who was kind enough to have the petrographic microscopes at Smith College, Northampton, Mass., placed at his disposal.

† Petermann's Geographische Mitteilungen, lvi, No. 5, 1910. Geographen Kalender, 1909, p. 221.

The cliffs along the Caicara side of the Orinoco are evidently continuous with the rocks exposed in the southeastern bank and consist of medium-to fine-grained gneiss with lamination running N.N.E.–S.S.W. or E.N.E.–W.S.W. Small quartz veins cut the gneiss in a general N.W.–S.E. direction.



Scale = 1: 500,000.

On the smooth surface of these rocks, about one kilometer north of Caicara, the writer discovered three grooves about four to five inches long and one-eighth of an inch deep which run perfectly straight, one E. 10° N.E., and the two others E. 10° S.E. They look exactly like glacial striæ the writer has observed in various places in the United States. They may, however, have been produced by man, as in close proximity a series of so-called petroglyphics were found, the grooves of which, however, were considerably deeper and wider.

The distribution of granite and gneiss in the hills and ridges north of Cabruta and south and southeast of Caicara also reveals a prevalence of gneiss over granite. For, with the exception of Cerro de Cabruta north of the Orinoco, and Cerro de los Spiritos, the lower portions of Cerro de Arinoza, and possible the whole of Pan de Azugar,* all the other cerros consist of gneiss. Pan de Azugar could not be visited and the nature of its rock ascertained because of the inaccessibility of the mountain from the land, while a planned ascent from the river side was not carried out because of the departure of the writer. Its outlines, however, are those characteristic of granite hills.

Rising abruptly with its southwestern terminus from the waters of the Orinoco to a height of about 290 meters above sea-level, the Cerro de Cabruta trends for a distance of about twelve kilometers in a northeastern direction and gradually falls off towards the llano-plateau. It is made up of a coarse-grained granite of a tan color weathering purple. Towards the top it becomes more quartzose, and is cut by quartz veins. A dike of felsite traverses the granite in a direction E.–W. on one of the smooth, facette-like cliffs of the cerro near the top. Exfoliation of the granites is strikingly exhibited. A vein of quartz cuts the granite in a direction N.N.W.–S.S.E., and probable determines the direction of the southwestern spur of the cerro in the process of erosion.

The cerros on the east and southeast side of the Orinoco within the area begin with the Cerro de Caicara, which approaches the stream south of the village of Caicara and rises to a height of 127 meters above sea-level. It extends about two kilometers to the south along the stream and consists of a light-colored, fine-grained gneiss. The general strike of the lamination is N.–S. and the dip to the west, as is the case with all the gneisses along the river.

About three kilometers south of Caicara the Cerro de Arinoza attains a height of 146 meters, while its foot is 71 meters above sea-level. Only the lowest levels of this hill consist of a coarse-grained quartzose granite, much the same as that encountered in the Cerro de Cabruta. The structure is at places pegmatite and the joint planes run N.–S. and E.–W. as do quartz and pegmatitic veins of various thickness. Higher up the granite yields to a medium-grained gneiss with lamination E. 70° S.E.; on the southeastern top apparently dipping 27° N.E. On this top occurs a similar coarse-grained and highly quartzose granite, like that found at the foot of the cerro,

*Due south of the former.

which suggests a possible intrusion of the gneissic series by granites from the same magma.

The Cerro de los Spiritos is situated about five kilometers east of Pan de Azugar and nearly eight kilometers S.S.E. of the village of Caicara. About 200 feet high it trends in a general N.W.–S.E. direction for over five kilometers. With the possible exception of Pan de Azugar, as indicated above, it is the only cerro southeast of the Orinoco within the region which is entirely composed of granite. It is of a coarse-grained, feldspathic, rather hornblendic type and exhibits joint planes which run N.–S., E.–W. and N.W.–S.E. The backbone of the hill is a quartz vein from 53 to 54 feet wide. In samples from this vein traces of gold were found by assays by a firm in New York City. Other quartz veins also occur, while near the top a dike of pink felsite, about two feet thick, stands out above the surrounding granite with E.–W. trend.

While the flanks of the cerro exhibit gentle slopes, with only occasional steep cliffs, and are dissected by ravines, for the most part parallel to the main quartz veins, the top is flat and comparatively smooth.

About 26 kilometers S.S.E. of Caicara the Cerro de Morano rises above the plain of the sabana to a height of 375 and 396 meters above sea-level. Its topographic outlines seem to be determined by two quartz veins, a minor one, running almost due E.–W., and a prominent one which constitutes the backbone of the cerro and has apparently determined the N.–S. direction of its longer axis. In approaching the cerro from the north one encounters knobs and cliffs emerging from the sabana which consist of coarse-grained feldspathic granite at places overlaid by limited beds of ferruginous coarse-grained sandstone. The bulk of the cerro is, however, made up of fine to coarse-grained hornblende-gneiss. It contains other quartz veins as well as dikes of amphibolitic gneiss, traversing the cerro in various directions.

The Sabana Deposits.

Dealing with the deposits of the sabana above which rise the isolated cerros just described, one must distinguish between the so-called "Laterite" and what Dr. S. Passarge terms "Upper Llanos" beds.

Laterite.—This very peculiar deposit is apparently composed of a series of more or less fine and soft clays of a light gray color, which have been found by Dr. S. Passarge along the banks of the Cuchivero, as well as the Caura, and, by the writer, overlying the gneisses on the banks of the Orinoco. As long as this clay is under water or still charged with moisture, after the streams have fallen during the dry season, it is exceedingly plastic. But as soon as it becomes dehydrated it turns extremely hard and becomes a clay ironstone, the laterite of the sabana, the river banks and the cerros: the German "zelliger Brauneisenstein." It is, however, not continuous and is often replaced by a hard conglomerate cemented together by iron oxides. This is the case at Caicara, where the lower terrace on which the village is situated consists of the hard conglomerate. Also the level at which the laterite occurs is not uniform, and while at one point it may be seen to rise well above the stream, it disappears at another point below the level of the water.

Not only along the Orinoco, but also inland on the plains of the sabana, wherever the granites or gneisses emerge from the younger deposits, even on the slopes of the cerros at considerable heights, irregular, limited patches of this clay ironstone are found to fill to a greater or less extent the hollows in bedrock.

The general appearance of this laterite deposit in the Llanos of the Orinoco drainage basin, the sabana being only a "floral" form of the Llano, has led Dr. S. Passarge, who saw similar laterite formations in the Kalahari desert in southern Africa, to suggest a possible extended period of laterite formation by weathering from, perhaps, Tertiary time.

This laterite deposit seems to determine the ground-water level in the sabana, carrying ground water over its surface to the sides and slopes of gullies, ravines and streams, as well as to the banks of the Orinoco, or allowing these waters to accumulate in more or less extended and comparatively shallow depressions, thus acting as a hardpan and giving rise to the formation of the "lagunas" which in turn, where partially drained or when drying up, to a certain extent during the dry season, may change into "Potreros," swampy meadows, or into "Morichales," swampy woods, in which the "Mauritia" palm is the characteristic tree. Thus the laterite plays a not unimportant rôle in the shaping of the features of the landscape.

The Upper Llanos Beds.—The Upper Llanos deposits, which, as a rule, unconformably overlie the laterite, wherever they have not been removed by subsequent erosion, or corrasion, or both combined, may be said to consist of the following three members:

A whitish or yellowish clay, rich in iron, which exhibits cell structure.

Loams of various kinds.

Sands of different fineness and color.

Their relations to one another change with the locality and so also does their respective horizon. They constitute the upper portions of the islands, the upper terraces at an elevation of about fifty feet above the average level of the lower terraces, and the sabana itself. They lie between the rocks of the granites and gneisses, wherever these come to the surface, filling in interspaces and fissures. The loam of the sabana becomes exceedingly plastic and soft during the rainy season, allowing turtles to dig furrows and ditches of from half a foot to one foot deep into it, and the torrents to carve deep channels, sometimes down to the underlying laterite. The walls of these ditches and channels become extremely indurated during the dry season, thus rendering traveling across the sabana under such conditions exceedingly difficult and tiresome, especially where there are no roads or paths available.

Petrography.

In describing the granites and gneisses of the cerros petrographically, the writer will describe them in a sequence that is determined by their genetic character, thus taking up the granites first and then the gneisses.

The Granites.—The granites of the region are those of the Cerros de Cabrnta and de los Spiritos and those that form the base of the Cerro de Arinoza.

The microscopical study of thin sections from different places shows that there is essentially the same type of granite in all three cerros. This statement, however, has to be modified in so far that at the two ends of this seemingly elliptic area, the granite shows a tendency to acidity at one and basidity at the other. For, while the Cerro de Cabrnta consists of a granite rich in quartz in its upper levels and its top, the Cerro de los Spiritos has a predominance of the hornblende in the rock of its top.

The petrographic features which characterize this granite are as follows :

In a mass of angular or subangular grains of quartz and feldspar occur phenocrysts of the leading minerals, viz., the quartz orthoclase which is occasionally replaced by microcline as well as soda-lime feldspars, and lastly biotite, which is associated with hornblende, the latter sometimes replacing it entirely.

A number of quartz and feldspar phenocrysts show enlargement by secondary growth, revealed by a faint ring of dark material, or by zonal extinction.

The frequent occurrence of micro-pegmatitic texture suggests conditions in the eutectic magma favoring simultaneous crystallization of quartz and feldspar.

Of the feldspathic minerals the soda-lime group prevails over orthoclase (not so much over the microcline), and is chiefly labradorite.

Biotite occurs in lath-shaped crystals, shreds and flakes: amphibole mostly in prismatic forms.

An intergrowth of biotite and amphibole was observed, the former in the latter, demonstrating conditions in the magma that favored the contemporaneous development of these minerals. Apatite and microlites of titanite occur as inclusions in the biotite, while the amphibole carries needles of apatite and grains of magnetite. Biotite has been observed in feldspar, and also apatite needles, while the quartz has dendrites of magnetite, also apatite and occasionally zircon. Liquid inclusions are sometimes present in the quartz. Titanite also occurs in free crystals.

Secondary minerals are calcite, which might have been derived from the feldspars, and chlorite, from the biotite, and last but not least, garnet, more or less idiomorphic.

Wavy extinction in quartz and feldspar phenocrysts and microscopic grains; bending and breaking, as well as slicing, of feldspars and biotite; granulation in feldspar and quartz, and complete crushing of titanite crystals strongly suggest repeated katamorphism brought about by dynamic stress and shearing.

The occurrence of more or less advanced decomposition and decoloration of considerable part of the biotite indicates the agency of descending waters, while the secondary growth of minerals, involving zonal structure, and the formation of veinlets, where the crystals were broken, tell rather of ascending solutions.

The Gneisses.—The gneisses of the cerros in the sabana of Caicara comprise those of the Cerro de Caicara, Cerro de Arinoza with the exception of its base, and those of the Cerro de Morano.

The study of thin sections prepared from specimens taken from the foot, the top and sides of these cerros shows by the comparison of their composition, structure, texture, and fabric that they are essentially one and the same gneiss, as it was one type in the granites. This is, however, not intended to exclude local phases that represent gradation and variation.

The petrographic description of these gneisses is as follows:

In a groundmass of angular to subangular grains of quartz, with rather fringed and dentated outlines, and of microcline and plagioclase, arranged with their larger diameter either parallel or more or less inclined to the plane of rock cleavage, are imbedded phenocrysts of pegmatite, microcline, and plagioclase, as well as biotite. All these minerals, with the exception of the biotite, exhibit more or less allotriomorphic forms. Microcline seems to replace the orthoclase to a great extent, wherever the latter is not intergrown with quartz, and it is the predominance of microcline, together with that of pegmatite, that constitutes one of the main features of this gneiss. Feldspar is more abundant than quartz.

So far as the ferromagnesian minerals are concerned, biotite occurs in phenocrysts of lath-shaped form, and in flakes. It seems to be almost the only representative of this group, as hornblende is very seldom encountered in allotriomorphic crystals.

Of accessory minerals chlorite is present, most probably as a decomposition product from biotite and hornblende; it is in scaly aggregates. Besides chlorite an occasional crystal of pyroxene is encountered, while magnetite in cubes, though rarely, and dodecahedrons and hematite in flakes, are more frequently met with. Garnets are not uncommon, idiomorphic in form.

As regards inclusions in the minerals, magnetite may be seen in feldspar, with a more or less parallel arrangement to the plane of parting; other inclusions are zircon, chlorite, titanite and tourmaline (?) in quartz, actinolite in the feldspars, very fine glassy particles in the plagioclases, apatite in quartz and in pegmatite, the minute needles, or their fragments, being arranged in trains.

To a greater extent than in the granites we meet in the gneisses with evidence of dynamic metamorphism. The evidences of katamorphism, due to stress and shearing, are: the wavy extinction in a number of quartz and feldspar grains; the bending of lath-shaped biotite; the differential bending and anastomosing of the lamellæ of feldspars; cracks and fractures parallel, or normal, to the plane of parting in biotite; the slicing of crystals of pegmatite and microcline; breaking of crystals of feldspar and biotite, and displacement of the broken parts by miniature faulting; granulation zones about grains of pegmatite.

The gneissoid structure of the rock is also shown in the sections by the direction of the longer axis of a number of grains being parallel, or somewhat inclined, to the plane of schistosity.

The Origin of the Gneiss.—The question arises, whether the gneisses are of igneous or of sedimentary origin.

Evidences in favor of the former are the following: the presence of garnets, which are frequent in the granite of the region; the regularity and fineness of the foliation, and the apparent uniformity of character of the gneiss both macroscopically and microscopically; while as negative evidence in favor of it is the absence of minute variations in the thickness of the laminæ, as well as the absence of minor plications, of widely disseminated graphite and of any ferruginous beds within the gneiss.

In favor of the other view, that the gneiss is sedimentary in origin, seems only the circumstance that the gneiss in all the different cerros is to some, and in that of the Cerro de Caicara to a remarkable, extent impregnated with iron oxides, although no pronounced ferruginous beds have been found.

Consequently we may conclude that the gneiss is of igneous origin. From the pronounced similarity in composition of both granites and gneisses, we may further infer that the gneisses have probably been derived from the granites and might grade into them, although such gradation has not been observed by the writer.

The Veins and Dikes in the Granites and Gneisses.—The writer regrets not to have had time to examine more closely the veins and dikes of the cerros about Caicara, as a more detailed and special study of these would have brought out probably different series of them, so far as strike and dip on the one hand, and composition on the other, are concerned, and the interrelation of these different series might have thrown some light upon the nature and succession of dynamic movements which the gneisses and granites have undergone. As time did not permit this, only specimens were taken and the strike determined of the veins and dikes encountered in ascending the cerros. From notes taken in the field, and from the study of sections prepared from some of the specimens collected, the following may be of interest.

While the writer is far from attaching any special significance to it and deducing any particular law of succession from it, because of the limited material at hand, it is nevertheless a peculiar fact that all of the more prominent quartz veins encountered have a strike magnetic N.–S., while all the pegmatite dikes of the region strike normal to this direction, viz., E.–W. The writer also found near the summit of Cerro de Morano a vein of fine-grained amphibolitic gneiss that varied in thickness from two to three feet. A few feet below the top of Cerro de los Spiritos a felsite dike running E.–W. was met with, about one foot thick and standing out prominently two feet above the surrounding coarse-grained granite, so that from a distance it had the appearance of a wall. Microscopic investigation showed that its main constituents are quartz and plagioclase in nearly equal proportions, with some brown biotite in shreds and flakes. Also in the dike of pegmatite encountered midway between the foot and the summit of Cerro de Morano, and mentioned above, there are scattered through it a few small flakes of decomposing biotite. It might be mentioned in this connection that the dike cuts the foliation of the gneiss at right angles. Microscopical examination of the quartz veins shows that they are made up of small, interlocked grains of quartz with dentated margins; that amphibole of bronze brown to dark-green color occurs in irregular patches; that tourmaline is occasionally met with in radiated aggregates: that garnets also occur and some magnetite. These facts point to the pneumatolytic origin of these veins. The quartz has wavy extinction, which goes to show that after the vein had been formed, together with the enclosing wall rock—in this case the granite, it was subjected to dynamic stress.

In concluding the writer wishes to remark, that it would be of great interest to ascertain the geologic and petrographic nature of other outliers in those waste plains that approach the Orinoco from the south and east, as well as the character of the rocks that make up the mass of the Guiana mountain system, in order to bring out facts that would bear on the relations of those cerros to this area, which is probably Archean.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Researches on Polonium.*—This was the first of the new and strongly radio-active bodies to be discovered, but it has not yet been isolated and characterized as a chemical element. According to the theory of radio-active transformation the relative proportions of the products are equal to the ratio of their mean lives, and since polonium is regarded as a descendant of radium, which has a life about 5300 times as long, a ton of pitchblende containing about 0·2 g. of radium could contain only about ·04 mg. of polonium. Since polonium apparently represents the last unstable body in the series derived from radium, it may be expected that polonium will produce an inactive element, which has been supposed to be lead, and a verification of this transformation would be an important support to the theory. Mdme. Curie and A. Debierne have recently undertaken a chemical research with the view of preparing polonium in a concentrated state. They employed several tons of residues from the uranium mineral, first treating it with warm hydrochloric acid, which dissolved the polonium almost completely. The solution which contained no radium was submitted in a factory to a series of operations, the details of which are reserved for future description, and which yielded about 200 g. of a substance having a mean activity about 3500 times that of uranium, and containing chiefly copper, bismuth, uranium, lead and arsenic. This material was then treated in the laboratory by various chemical methods in order to concentrate the polonium. Precipitation with hydrogen sulphide in acid and alkaline solution and precipitation by stannous chloride were found to be the most trustworthy reactions for the substance. When the product was reduced to a few milligrams it was found by spectrum analysis to contain mercury, silver, tin, gold, palladium, rhodium, platinum, lead, zinc, barium, calcium and aluminium. Great difficulties were encountered in attempting to make a further concentration, but it was found that polonium can be deposited completely by electrolysis from an acid solution, although other metals, such as gold, platinum, mercury, etc., are deposited at the same time. After many experiments the activity was concentrated in about 2 mg. of matter. From the activity of this product it was calculated that it contained about 0·1 mg. of polonium. A portion of it was sacrificed for the study of the spark-spectrum, and several lines were obtained which may be attributed reasonably to polonium. The authors propose to examine the spectrum lines again after the polonium has disappeared, in order to make certain of the lines belonging to it. They hope to see also the spectrum of the element formed at the expense of polonium, which, according to theory, should be

lead ; lead is not entirely absent from the product, but its spectrum is very faint. They observed that the active substance obtained does not give rise to induced radio-activity, nor to any appreciable emission of penetrating rays, but they noticed an extremely minute disengagement of radium emanation. A portion of the solution was utilized for a study of the gases disengaged. Bubbles were observed to come off continuously from the decomposition of water by the α-rays of polonium, and the product given off in 100 days was purified from ordinary gases and found to consist of 1·3 cu. mm. of practically pure helium, an amount which agreed closely with the calculated quantity. This work establishes the production of helium from polonium. A curious effect of the rays was observed. The polonium product was kept dry in a small quartz capsule, and this was found to be cracked in a large number of places under the substance, presumably on account of electric discharges. An abundant disengagement of ozone was noticed in the neighborhood of the substance.—*Comptes Rendus*, cl, 386. H. L. W.

2. *Introduction to General Chemistry ;* by JOHN TAPPAN STODDARD. 12mo, pp. xviii, 432. New York, 1910 (The Macmillan Company).—This is a text book of moderate scope, intended for a first year's work in chemistry. The author has endeavored to give the student a fair idea of the nature of chemical study, of the methods by which our chemical knowledge has been gained, and of the relations which chemistry bears to every-day experiences and to industrial activities. He has aimed to develop the subject in a natural manner, introducing new facts and ideas gradually, and discussing their relations and the theoretical explanations at points where such discussions will be welcomed by the student as summing up and interpreting what has gone before. The quantitative relations of chemistry have been emphasized by frequent reference to a little book dealing with simple quantitative experiments, which the author has recently published. The synthesis of sulphuric acid and the study of its composition is made the basis for the study of other acid substances, thus placing sulphuric acid, in the development of the subject, in a position which it occupies in actual practice, and in general, substances which are most familiar, or from which others are derived, are first described, and the other related substances follow somewhat in the order of their importance.

The book appears to be an excellent one in its clear and interesting presentation of facts and theory. A noticeable feature is the entire absence of pictures and of detailed descriptions of experiments. Their equivalent is expected to be supplied in the lecture-room and the laboratory, or by means of the author's little book, previously referred to. H. L. W.

3. *Die Beziehungen zwischen Farbe und Konstitution bei organischen Verbindungen ;* von DR. H. LEY. 8vo, pp. 364, Leipzig, 1911 (Verlag von S. Hirzel).—This book discusses very fully and satisfactorily the present facts and theories in connection with the

relations between color and constitution in organic compounds. The work will be of interest both to organic and physical chemists, for the chromophore theory, the effect of substituents, ultraviolet absorption, the recent electron theory of absorption, and many other topics are treated. A section at the end of the book deals with practical spectroscopic methods for the study of colored substances. H. L. W.

4. *Rays of Positive Electricity.*—For the past several years Sir J. J. THOMSON has been studying the magnetic and electrostatic deviation of positive rays of electricity by means of the phosphorescence excited in a willemite screen by the impact of the rays. Since this method did not give permanent records it was not very satisfactory to the observer and it was decidedly unsatisfactory, if not confusing, to the reader of the published accounts of the progress of the investigation. Fortunately, Thomson has worked out a photographic process which gives, of course, permanent records of the loci of impact. This process has the additional advantage of requiring a much shorter time of exposure than was possible with a willemite screen, for the reason that ordinary dry plates are much more sensitive to the rays than the phosphorescent screen ; in fact, an exposure of three minutes brings out, on the developed negative, curves which cannot be detected with the screen. In all cases, the photographic plate was placed inside the evacuated chamber and was manipulated by suitable rods which projected outside of the receiver. The ground-glass cones on the rods fitted so well into the complementary cones of the chamber that no leakage and consequent decrease of exhaustion took place. In the final form of apparatus employed, three independent exposures could be made by lowering a long photographic plate in such a manner as to bring three different areas of the plate successively in line with the rays. Fifteen typical negatives are reproduced on the plate accompanying the text.

The rays after passing through the tubular cathode—in a direction away from the anode—were constrained to pass between the poles of a powerful electromagnet and also between two parallel, electrified, metallic plates before they reached the photographic plate. As usual, the directions of the magnetic and electric fields were at right angles to one another. In some cases these fields were coterminous, and in others the center of the electric field was nearer the cathode than the axis of the magnetic field. In the reproductions of the negatives the horizontal and vertical directions uniformly correspond to the electrostatic and magnetic deviations respectively.

For convenience, the curves obtained on any one plate may be divided into two general classes. In one class the parabolic arcs are short, of varying length, and are especially characterized by starting from different points of the same vertical, geometric line. This shows that the minimum electrostatic deflection suffered by the particles which gave rise to the photographic impressions was independent of the nature of the particles. From this fact, the conclusion is drawn that the maximum potential difference through which each set of particles had fallen is the same. These rays are called "primary" rays.

The second type of curve is differentiated by the property of radiating from the point on the negative which is struck by rays which have experienced neither magnetic nor electric deflection. The portions of the curves near this "origin" are straight lines when the magnetic and electric fields are coterminous. If the magnetic field overlaps the electric field on the side nearer the sensitive plate the curves are concave towards the horizontal axis. This fact is interpreted as meaning that the curves represent "secondary" positive rays produced by the passage of primary rays through the gas on the way to the photographic plate, and that the parts of the curve near the origin, which are produced by particles which have suffered only small deflections, were produced by rays which had not traversed the whole of the magnetic and electric fields, but had been *generated* towards the *ends* of these fields. On the other hand, curves which are concave towards the vertical axis correspond to primary rays which, after passing through the cathode, have lost their charges as they were passing through the electric and magnetic fields. In this case, the parts of the curves near the origin would be due to rays which had *lost* their charges near the *beginning* of the electric and magnetic fields.

For sake of brevity Thomson calls the ratio of m/e for any ray to the value of m/e for the atom of hydrogen, the "electric atomic weight" of the particle forming the ray. Primary rays in hydrogen were found to have electric atomic weights 1 and 2; in oxygen, 16 and 32; in carbon dioxide, 12 and 47; in marsh gas, 16 and 28; in cyanogen, 26; etc.

Many interesting and important facts concerning the secondary rays are recorded in the paper, but since an entire page is required for a synoptic table it will not be possible to quote the details in this place. Suffice it to say that the electric atomic weights have the following values: 1, 1·4, 2, 3, 6, 7, 12, 16, 26, 36, 48, 72–78, 96, 100, 200 and 800. The last three numbers pertain to mercury vapor.—*Phil. Mag.* (6), xxi, 225. H. S. U.

5. *Focal Isolation of Long Heat-Waves.*—RUBENS and WOOD first tried to take advantage of the selective refraction of quartz in the manner described in 1899 by Rubens and Aschkinass, which was to employ quartz prisms of small refracting angles in conjunction with a suitable spectrometer. The energy finally emergent in the apparatus was found to be too small a fraction of the incident radiation, and hence the experimenters were led to devise another and more efficient form of apparatus with which they were able to obtain heat waves of greater length than had ever been measured before.

The source of energy, a Welsbach mantle, was placed in line with a circular aperture in a double screen of tin plate. This opening was situated on the optic axis of a double-convex quartz lens and at such a distance from the lens as to cause the ordinary light waves and shorter infra-red radiations—corresponding to refractive indices between 1·43 and 1·55—to form divergent beams after emerging from the lens. On the contrary, the very long heat waves were brought to a relatively sharp focus at a similar aperture in a second screen. By stopping out the central zone of the lens by means of a black paper disc, only the longest waves were allowed to enter the hole in the second screen. A second lens, similarly stopped and placed behind the last screen, completed the purification of the radiation and also brought the waves to a focus on the thermocouple of a radio-micrometer. The wave-lengths and distribution of energy in the isolated radiation were determined by means of a quartz interferometer placed close behind the second aperture.

The mean wave-length was found to be about 108μ and the existence of waves as long as 150μ was established. The longest waves previously recorded had a length of 97μ.

Having determined the mean wave-length of the isolated radiation, the authors studied the absorbing and reflecting powers of various solids, liquids and vapors for this region of the spectrum. Only a few typical results may be mentioned here. Diamond was remarkably transparent, while fused quartz and water-glass were very opaque. Black paper and even black cardboard were partially transparent. A thin lamina of mica densely smoked was exceedingly transparent to waves of length 108μ. As pointed out in the paper, this fact is of importance in the construction of radio-micrometers, etc. The reflecting power of water was found to be comparatively high, which is probably due to the presence of one or more absorption bands in the region under investigation.—*Phil. Mag.* (6), xxi, 249. H. S. U.

6. *A Method of Calibrating Fine Capillary Tubes.*—The usual method for the determination of the mean area of cross-section of the bore of a capillary tube decreases in precision as the radius becomes smaller because of the difficulty of weighing the thread of mercury employed to a sufficiently high degree of accuracy. For example, the mass of a column of mercury 10^{cm} long contained in a capillary tube of $0·1^{mm}$ internal diameter is about 0·01 gram, so that to obtain an accuracy of 1 per cent in the square of the radius the weighing must be correct to 0·1 mg.

A very promising method, which depends primarily upon the determination of the electrical resistance of a thread of mercury, has been devised and tested by T. R. Merton. Each end of the capillary tube is fitted into a rubber stopper, and each stopper enters the shorter arm of a glass tube shaped like the letter L and of relatively large internal diameter. The longer arms of the L-tubes are vertical when the capillary is horizontal. The entire capillary bore and the greater part of the auxiliary end vessels are filled with pure mercury. By using a suitable air pump for evacuation, no difficulty is experienced in forcing the liquid into the capillary. During the determination of the electrical resistance of the thread of mercury in the capillary, the system of tubes is kept within 0·01° C. of a given temperature by means of a water-bath, toluene regulator, etc.

The length of the capillary bore is easily measured by means of a comparator. From the numbers expressing the length of the capillary, the resistance of the thread of mercury, and the specific electrical conductivity of mercury, the square of the mean radius of the capillary bore can be calculated at once. A small correction was added to the length of the bore to allow for the curvature of the stream lines at each end of the capillary tube. The squares of the mean radii of three tubes were found to be respectively $0{\cdot}002304^{mm^2}$, $0{\cdot}004406^{mm^2}$, and $0{\cdot}004192^{mm^2}$, with an error of about $0{\cdot}000002^{mm^2}$. Thus the result obtained for a tube of $0{\cdot}06474^{mm}$ radius is about 20 times as good as for the hypothetical case first cited for a radius of $0{\cdot}05^{mm}$.—*Phil. Mag.* (6), xxi, 386. H. S. U.

7. *An Introduction to Thermodynamics for Engineering Students;* by JOHN MILLS. Pp. viii, 136; 61 figures. New York, 1910 (Ginn & Co.).—This is a text written for the use of classes in engineering, and intended as a preparation for more advanced work in the application of thermodynamics to heat engines. It is divided into five chapters. The first contains a concise summary of the general principles of thermodynamics, and the remaining four the applications to gases, water and saturated vapor, superheated steam, and the flow of steam and gases respectively. At the end of each of these last four chapters is appended a summary of the formulas which have been developed and a considerable number of graded problems with their solutions. This last feature frees the main body of the text from the very necessary but cumbersome explanations of details, and allows the development of the theories involved to be shown in a truer perspective than if such details were interpolated in the exposition. Graphical methods (the temperature-entropy, Boulvin, and other diagrams) are emphasized, but not to the exclusion of the analytical methods. The ground covered is about that customary in first courses in this subject as given in most technical schools in this country. The subject matter is possibly too restricted in scope for a wide field of usefulness, and the discussion of the second law of thermodynamics is marred by a mistaken interpretation of Clausius's statement of it. But on the whole, the end which the author had in mind in writing the book has been successfully attained. L. P. W.

II. GEOLOGY AND MINERALOGY.

1. *Denudation and Erosion in the Southern Appalachian Region;* by L. C. GLENN. Prof. Paper 72, U. S. Geol. Surv., 1911. Pp. 137, 5 plates, 1 figure.—A detailed study of the effects of deforestation, overgrazing, and "agricultural butchery"

upon soil erosion. The paper is of timely interest, first, because of the new law providing for the creation of the Appalachian forest reserves, and, second, because it has recently been suspected in some quarters that the earlier pictures of soil destruction were overdrawn. The author finds about 74 per cent of the total area still forested. Even this amount, however, is considered too small. Under the given conditions of slope gradient, soil texture, rainfall, etc., it is considered unsafe to have more than 18 per cent to 20 per cent of the surface cleared. Clear-cut illustrations of soil erosion are supplied in a variety of situations: (1) on sodded "balds" where over-grazing and trampling by cattle have broken the turf and started landslides that quickly develop into gullies; (2) on all slopes where lumbering has removed the original protective covering and hastened the action of rain-wash; (3) on cleared and abandoned slopes once used for agriculture. In the last-named case the harm has been underestimated in the past. Undercutting and caving, once started in a cleared area, often extend upward into forested tracts, and the debris derived in this manner is washed downward into the forest below. Some porous soils were found to be erosion-resisting but their aggregate area is not relatively great. The allowable limit of steepness for cleared lands, 15°, is almost everywhere exceeded, and in many places greatly exceeded. Terracing is practised on a wholly inadequate scale. There is increased silting on the flood plains and in the stream channels, a conclusion applied to all streams draining catchment areas that have been extensively cleared. One gains from the paper a clear and powerful impression of destructive erosion on exposed mountain soils and of destructive sedimentation on the flood plains. It is with a feeling of great satisfaction that one contemplates the beneficent results that may flow from the recent action of Congress after so conclusive an argument against the further unguarded use of the soil. I. B.

2. *Preliminary Notes on the "Chazy" Formation in the Vicinity of Ottawa;* by PERCY E. RAYMOND. The Ottawa Naturalist, xxiv, Feb. 1911, pp. 189–197.—The following summary is given: "The sections in the vicinity of Ottawa show about 250 feet of strata between the Beekmantown and the base of the Black River. These strata are characterized by two groups of species. The lower 125 to 135 feet contain a small fauna, some of whose species are found in the upper part of the Chazy formation of the Champlain Valley, and this portion is undoubtedly to be correlated with the Upper Chazy . . .

"The upper portion of the section consists of 115 to 125 feet of limestone, sandstone and shale, with fossils more nearly akin to those found in the Black River and lacking the typical Chazy species. . . . This portion of the section . . . is capable of subdivision into two members, the lower of which contains most of the shale and sandstone, and the upper the pure limestone. The lower portion contains an immense number of small ostracods, and, in the middle, great numbers of gastropods and other fossils. This member is from 65 to 75 feet in thickness. [It may be the equivalent of the Pamelia of New York.]

"The upper member is composed mostly of pure limestone, has a larger fauna than either of the other formations, the upper 15 feet being especially fossiliferous. This is the Lowville of the New York section and the thickness is about 50 feet." C. S.

3. *Die Fauna der Spiti-Schiefer des Himalaya, ihr geologisches Alter und ihre Weltstellung;* by VICTOR UHLIG, Denkschr. d. Math-Naturw. Klasse d. Kais. Akademie d. Wiss., Wien, Bd. lxxxv, 1910, pp. 531–609.—There is here presented a summary of the fauna found in the Spiti geode-bearing black shales having a thickness of about 500 feet. There are 218 species of ammonites, 4 belemnites, 35 bivalves and 2 gastropods. Evidently but little of the fauna is bottom mud dwelling as most of it is made up of swimming types. The specimens are as a rule preserved in geodes, or rather concretions, but unfortunately none of them were collected zonally.

This fanna has no direct connection with the Kelloway biota as has been thought; only a few forms point to the Oxfordian, there are certainly some Kimmeridgian species, while the Tithonian and Valangian are best represented. The Spiti shales are, therefore, thought to hold the time of the Upper Jurassic and the early Lower Cretaceous.

The Spiti fauna shows that it had no direct boreal connections, having only a single species each in Aucella and Simbirskites. On the other hand, there is positive faunal affinity with the Alpine region of Tethys.

The author goes into a world-wide study of the Jurassic and Lower Cretaceous faunas that cannot be here detailed. His final conclusions regarding climatic zones are not at all in harmony with those of Neumayr, for the former states, "All of these facts give the impression that the distribution of the marine faunas of the Jurassic and Lower Cretaceous was essentially independent of latitude and climatic zones" (609). C. S.

4. *Beiträge zur Geologie der Bären-Insel, Spitzbergens und des König-Karl-Landes;* by A. G. NATHORST. Bull. Geol. Instit. Upsala, x, pages 261–416 with many illustrations and geological maps, 1910. The author here brings together all that is known regarding the geology and paleontology of these far northern lands, and one is surprised at the great amount of excellent work recorded.

Bären Island is composed of Ordovician, Devonian (Ursa sandstone probably of lagoon origin), three divisions of the Carboniferous separated from one another by discordances, and Triassic. Spitzbergen has in addition to the above Permo-Carboniferous, Permian, Jurassic, Lower Cretaceous and Tertiary (? Miocene). C. S.

5. *Historical-Stratigraphical Review of the Silurian of Sweden;* by JOH. CHR. MOBERG. Årsbok 4, Sveriges Geol.

Unders., No. 229, pages 210 and 1 map, 1910. Here is presented first a general and second a somewhat detailed statement of the Cambrian, Ordovician and Silurian or Gotlandian deposits of all Sweden. There is also a very extensive bibliography. It is one of the guides to the excursions given after the meetings of the Geological Congress at Stockholm last summer. The book is of great value to all students of early Paleozoic stratigraphy.

C. S.

6. *Geologisch-petrographische Studien in der Patagonischen Cordillera;* von P. D. Quensel. Bull. Geol. Inst. Upsala, vol. XI, 1–113, 1910, figs. and geol. map.—The writer during a period of two years, partly by land travel and partly by boat in the fiords, has made a fairly general geological reconnaissance in the chains of the southern Andes, from Cape Horn northward to 41° S., a distance covering 15° of latitude. Availing himself of hitherto published material, which was rather scant, and his own observations, he presents a geological map covering this stretch, and extending from the Pacific on the west to the pampas on the east. Although the work is chiefly devoted to presenting the results of the petrographical investigation of the material collected, these are accompanied by geological observations, which, taken together with a brief résumé of the geology of the area published by him in "Geologische Rundschau" (Band 1, p. 21, 1910), are sufficient to throw much light on the geology of this little known region.

The western, or coast, cordillera, fronting on the Pacific, is composed of an enormous stretch of granular igneous rock, the andendiorite of Stelzner. This immense mass reaches from Cape Horn in nearly 56° S. to 47° S., and is deeply dissected by a remarkable system of fiords, comparable to those of Norway and Alaska. From 47° northward it swings more inland, and is replaced on the coast by islands of metamorphosed older sediments. The author states that it has not the monotonous petrographic character formerly attributed to it, but shows much differentiation into types varying from acid potash granites, and quartz diorites, through syenites and augite-diorites, into gabbros, and is accompanied by systems of aplitic and lamprophyric dikes. Inland it is much covered by glaciers and seas of ice. The author is inclined to place the intrusion at the end of the Mesozoic; unfortunately no direct contacts with fossiliferous strata have been found, and this age is inferred from general considerations. In several places effusive masses of andesite and basalt were found.

In regard to the central and east cordillera the geological formations and structure are very different from the foregoing, and also vary in the long stretch over which reconnaissance was made. Near the strait of Magellan the central chain is a folded range, consisting of sedimentary beds belonging to the Cretaceous, and against which the Tertiary of the pampas is gently inclined; there is probably an unconformity between them. In the northern part of this stretch great masses of quartz-porphyry occur with tuffs and breccias.

North of 50° S. two periods of folding were observed: the first probably Paleozoic, the second Tertiary. This part is also marked by the intrusion of large laccoliths, whose structures and rocks bear a marked resemblance to those of the western United States. North of 47° 30′ the character of the southern Patagonian cordillera, as a folded range, changes, and at the Rio Aysen, where a complete tranverse profile was obtained, the greater part of the central chain consists of granitic igneous rocks, while the eastern chain is composed of masses of porphyries and tuffs. Between the two lies a band of sediments from which Belemnites and other fossils were obtained. On the eastern slopes, down toward the pampas, in several places immense fields of outpoured basalts occur. In the southern portion of the area several large volcanoes were found, a southern continuation of the great series of volcanoes of middle Chile. They are andesitic in character, and their activity continued after the glacial period.

A feature interesting to petrographers is the occurrence, at a number of places in the Andes of southern Patagonia, of alkalic rocks. These consist of intrusive masses of essexite, in stocks, exposed domes, etc. These rocks are composed of purple, pleochroic, titaniferous augite, brown barkevikite, labradorite and analcite, the latter regarded as secondary, perhaps after nephelite. They are accompanied by a series of dikes of bostonite and camptonite with essexite-porphyry, and the author parallels the occurrences with those of Southern Norway, made classic by the researches of Brögger. In other places aegirite-granite-porphyry is found with the essexite, while a trachydolerite is regarded as an effusive equivalent. The occurrence of these alkalic types in the sub-alkalic (alkalicalcic) province of the Andes is both interesting and significant. L. V. P.

7. *Ueber einigige Japanische Vulkane;* von I. FRIEDLAENDER, II Theil. Mitt. d. deutsch. Gesell. f. Nat. u. Völkerk. Ostasiens, xii, 2. Tokio, 1910, with plates and map.—The author continues in this article his description of the Japanese volcanoes, basing his work upon his own observations, and upon those of others. It relates chiefly to the northern part of the island empire, and much of the material, drawn from Japanese sources, is now made available to western people. While it represents chiefly the observations of the geological traveler, and contains no detailed studies, the vulcanologist and geographer will find much to interest them, especially the records of periods of activity for certain volcanoes, which run back in some cases for over 1000 years. The article is accompanied by a number of half-tone plates of the volcanoes described, and by a map which shows their situations. L. V. P.

8. *Geological Survey of Ohio.* J. A. BOWNOCKER, State Geologist. *Fourth Series, Bulletin 11. The Manufacture of Roofing Tiles;* by WOLSEY G. WORCESTER; EDWARD ORTON, Jr., Collaborator and Editor. Pp. viii, 476; 187 illustrations.—The Ohio Survey has undertaken a series of Bulletins on the Clays and Clay Products of the State, and the fact that this industry is so promi-

nently developed in Ohio will give these Bulletins much value. The first report to be completed is that on the Manufacture of Roofing Tiles, an industry which thus far has been somewhat slow to develop in this country, although in the history of the subject we have to go back to 1814 for the time when tiles were first made use of in the state ; this was at Germantown, a village some 30 miles northeast of Cincinnati. Roofing tiles have, aside from the non-permanent wooden roof, various rivals in the slates, corrugated iron, asbestos, and other artificial fabrics, and cement; but the future is likely to see a larger development in the direction which has had so much use in foreign countries. The author of the present work has been engaged in the practical industry for a number of years, and hence is able to discuss the various aspects of the subject with all needed fulness and accuracy.

9. *Elements of Geology ;* by Eliot Blackwelder and Harlan H. Barrows. Pp. 467, 16 plates, 485 figures. New York, 1911 (American Book Company).—No attempt is made in this book to present new material or to discuss controversial matter. It is a text-book pure and simple and the selection of topics as well as the manner of presentation has been determined by that fact. The book shows clearly that its authors are experienced teachers and understand what is and what is not within the intellectual range of students who have not previously studied the subject. The text is rather too brief for use in colleges, but should find a place in institutions where short courses are given to students of elementary science. H. E. G.

10. *A Remarkable Crystal of Beryl ;* by George F. Kunz (from a paper read before the New York Academy of Sciences, April 3d, 1911).—On the 28th of March, 1910, in a pegmatite vein at Marambaya, a village in the vicinity of Arassuahy, on the Jequitinhonha River, in the State of Minas Geraes, Brazil, there was found a crystal of beryl, which was the largest crystal of precious beryl (aquamarine) ever found. In form it was a simple hexagonal prism with slight irregularities due to compression, and terminated with a simple basal plane at both ends. The crystal weighed 110·5 kilograms, was 48·5 centimeters high, and from 40 to 42 centimeters in its different widths. It was so transparent that, looking down into the crystal through its basal termination it could be seen through from end to end. In color it was greenish-blue, absolutely free from included impurities but traversed by a number of fractures.

This crystal was found by a Turk, who mined it in what is known as a primitive mine, at a depth of from five to six meters, and only with the greatest difficulty was it transported by canoe to the coast, by way of the Jequitinhonha River and then shipped to Bahia, where it is said that he realized $25,000 for it. It is estimated that this crystal would furnish at least 200,000 carats of aquamarines of various sizes.

11. *The Mineralogy of Arizona ;* by F. N. Guild. Pp. 99. Easton, Pa., 1910 (The Chemical Publishing Co.)—This is a useful

account of the minerals thus far produced in a region which is unusually rich in variety and number of species, some of them of great rarity elsewhere.

12. *Notes on a recent find of Zincite Crystals;* by A. H. PHILLIPS.—During the past year a small stringer containing well crystallized and separate crystals of zincite was discovered in the Franklin Furnace mine. The vein, one-half inch in average width, was surrounded by the ordinary mixture of franklinite in a matrix of green willemite. Associated with the zincite are crystals of leucophoenicite, pyrochroite,* gageite, calcite and a very soft fibrous asbestos. The best crystals, fourteen of which are in the Princeton collection, the largest measuring $3·5^{cm}$ along its pyramid edge, were imbedded in this fibrous material, though some were broken out of the massive zincite. All the large crystals are apparently flattened, hexagonal pyramids. This apparent distortion is caused by the pyramid faces of one side being very short as compared to those of the opposite side of the crystal. The faces are rough, pitted, and generally crossed by two sets of

FIG. 1.

FIG. 2.

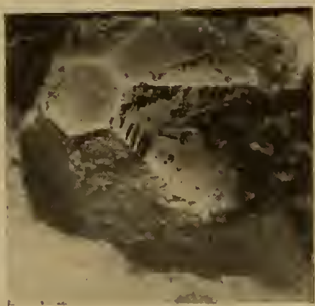


FIG. 1. Zincite crystal showing striations and general termination. Nat. size.

FIG. 2, Crystal in the matrix showing the upper base. Enlarged 6⅔ diameters.

striations; one parallel to the intersection of the pyramid and prism, the other parallel to the pyramid edge and caused by a parallel growth of the pyramid itself. This is so marked in one individual as to obliterate the pyramid edges and the crystal is then rounded and conical.

Forms.—While accurate measurements, owing to the imperfections of the faces, were impossible, they were, however, sufficiently accurate as to identify without doubt the crystal forms. All the

* This pyrochroite is of new habit and it is hoped to publish a note on it in the future.

crystals which lie together in the larger vein gave measurements $(p \wedge p')$ varying from 48° 32′ to 49° 28′; this form thus corresponds to the hexagonal pyramid $(40\bar{4}5)$ described by Grosser.* A single small crystal obtained from a small adjacent vein gave a measurement 55° 10′ for $(p \wedge p')$ and would, therefore, correspond to the pyramid $(50\bar{5}4)$ described by Moses.†

The prism zone is represented by a single face only, the lower end of the crystals being as a rule rounded as shown in the illustration, or terminated by cleavage planes.

Since zincite is dihexagonal polar in type, or hemimorphic, the base is represented by an upper (0001) and a lower $(000\bar{1})$, each of which may occur independently. Both have been described as occurring on artificial zinc oxide crystals.‡ Dana§ figures the lower base on a zincite crystal from this same locality; while the lower base is not represented on any of the above crystals, one crystal, however, illustrated in fig. 2 shows the upper base (0001) very beautifully. This is, therefore, a new form not heretofore observed on zincite. All the other crystals are terminated sharply or are rough and rounded as if they were corroded.

Guyot Hall, Princeton, N. J., Feb. 15, 1911.

III. Miscellaneous Scientific Intelligence.

1. *National Academy of Sciences.*—The annual meeting of the National Academy was held in the new building of the National Museum at Washington on April 18 to 20. President Ira Remsen was in the chair and some forty-five members were present.

The following new members were elected: Edwin E. Barnard, of the Yerkes Observatory; Edward B. Van Vleck, of the University of Wisconsin; John F. Hayford, of Northwestern University; Edwin H. Hall, of Harvard University; James F. Kemp, of Columbia University; Arthur L. Day, of the Geophysical Laboratory of the Carnegie Institution; Julius O. Stieglitz, of the University of Chicago; Bertram B. Boltwood, of Yale University; Robert A. Harper, of the University of Wisconsin. The following foreign associates were also elected: Prof. Ernest Rutherford, of the University of Manchester, England, and Prof. Vito Volterra, of the University of Rome, Italy.

A lecture was delivered on Tuesday evening, under the auspices of the Washington Academy of Sciences and in honor of the National Academy, by Dr. John Murray, on "The Ocean." At the dinner of the Academy, given at the Cosmos Club on Wednesday evening, the Henry Draper medal was presented to Mr. Charles G. Abbot, director of the Smithsonian Astrophysical Observatory, for his researches on the infra-red region of the solar spectrum and his accurate measurements, by improved devices, of the solar constant of radiation.

* Zeitschr. Kryst., xx, 354, 1892. † School Mines, Q., xvi, 226, 1895.
‡ Neues Jahrb. Min., 1884, ii, 164. § This Journal (3), xxxii, 389.

The following is a list of the papers presented at the meeting:

W. W. Campbell: On the motions of the brighter helium stars. Report of progress in spectrographic determinations of stellar motions.

F. R. Moulton: The evolution of periodic solutions of the problem of three bodies.

G. F. Becker: Mechanical quadratures.

W. M. Davis: Corollaries of the theory of isostasy.

Lynde P. Wheeler: Experimental investigation on reflection of light at certain metal-liquid surfaces.

W. J. Humphreys: On the origin of the peaks of maximum pressure in the midst of the permanent tropical oceanic highs.

E. F. Smith: A further study of columbic and tantalic oxides.

J. P. Iddings: The outlook of petrology.

Waldemar Lindgren: The orogenic development of the northern Sierra Nevada.

H. F. Osborn: Biological conclusions drawn from the evolution of the Titanotheres.

W. B. Scott: A new reptile from the Newark beds.

J. M. Clarke: Restorations and ontogeny of the Eurypterids.

Chas. D. Walcott: A geological reconnaissance in the Rocky Mountains of British Columbia.

C. S. Minot: Comparative study of the early stages of vertebrates.

Simon Flexner: Infantile paralysis and its mode of transmission.

E. G. Conklin: Cell-size and nuclear-size.

Jacques Loeb: The cause of death of the unfertilized egg and the cause of the life-saving action of fertilization.

Horatio Wood, Jr.: Studies of the pulmonary circulation.

J. M. Coulter: An American Lepidostrobus.

Theo. Gill: Aristotle's History of Animals.

E. S. Morse: Notes on New England Mollusca.

Franz Boas: Changes in bodily form of descendants of immigrants.

C. Hart Merriam: Classification of Shoshonean tribes. The outside and the inside of the Yosemite Indian.

E. S. Holden: Biographical memoir of W. H. C. Bartlett.

H. L. Abbot: Biographical memoir of C. B. Comstock.

T. B. Osborne: Biographical Memoir of S. W. Johnson.

A. W. Wright: Biographical memoir of Benjamin Silliman, 1816–1885. Biographical memoir of James H. Trumbull.

Wm. H. Dall: Biographical memoir of C. A. White.

H. F. Osborn: Biographical memoir of Joseph Leidy.

2. *Bulletin of the Seismological Society of America.* Publication Committee: J. C. Branner, A. C. Lawson, S. D. Townley. Vol. I, No. 1, pp. 32, Stanford University, 1911.—The opening number of the Bulletin of the Seismological Society, announced a month or two since (see vol. xxxi, 247), has recently appeared, and inaugurates a movement which is sure to be of great importance in the progress of this science in the country. The leading article is by A. C. Lawson, and gives a brief review of the present condition of seismology in the country, with practical suggestions as to means for developing this further. This is followed by a paper on the seismological work on the Pacific coast, by J. C. Branner, and another by A. McAdie on the seismological observations of the future. The earthquakes in Central New Mexico of 1906 and 1907 are discussed at length by H. F. Reid. Other contributions give a list of seismographs in America, and a statement by J. B. Woodworth of the Göttingen nomenclature

of seismological reports furnished by Dr. Klotz of Ottawa. A series of reviews follow. In the following number it is proposed to give a list of earthquake records for a large number of American stations in 1910.

3. *Commercial Geography;* by EDWARD VANDYKE ROBINSON. Pp. xlviii, 455. 252 illustrations, including 100 maps. New York and Chicago, 1910 (Rand, McNally & Co.).—A commercial geography by an economist is a book of unusual interest under any circumstances. In this case the book possesses high distinction as well as interest and for three main reasons. It is very carefully written; it applies economic theory to commercial geography in a skillful and explanatory way and neither ignores nor overdoes the effects of natural environment; it follows the regional method throughout with an evenness of treatment and a skill in the selection of topics that makes every page well-balanced and attractive. As a high-school text the book is far in advance of the older group of commercial geographies. None other has a style at once so vivacious and trenchant. In addition the book goes a long way toward solving a difficult high-school problem. Its combination of the physical, the commercial, and the regional will appeal to school men who wish a broad geography course and not a course in physiography alone or industry or commerce. I. B.

OBITUARY.

SAMUEL FRANKLIN EMMONS, the geologist, died at his home in Washington, D. C., in the morning of March 28th. Although he had not been in good health for some time, his death, from heart failure, was unexpected.

He was born in Boston, Mass., on March 29, 1841; received his education at Harvard University, graduating in 1861; and then went abroad, where he remained for several years as a student at the École des Mines in Paris and the Bergakademie at Freiberg in Saxony.

Returning home in 1867, he joined the staff of the 40th Parallel Survey newly organized by Clarence King. The other members, as assistants to King, were J. D. Hague and Arnold Hague. With the forming of this organization, and with the beginning of its work in the field, it may be said, in a way, that a new epoch in American geology began; the former pioneer period, in which geology was carried on, partly by states and partly individually, by men largely self-trained, was henceforth to be succeeded by one in which such work was to be supplemented, and largely replaced, by national organizations of men who, like Emmons, had been specially trained and fitted as professional geologists. From that time on Emmons remained continuously in the service of the Government with the exception of two years, 1877–9, when he was engaged in managing a cattle ranch in Wyoming. When the present U. S. Geological Survey was organized in 1879, he was appointed as one of the chief geologists in charge of the division of the Rocky Mountains with headquarters at Denver. Although he had joined with Arnold Hague in writing the volume devoted to the descriptive geology of the 40th Parallel Survey, he had given much attention to the study of ore deposits. His bent in this direction had undoubtedly been stimulated by his European training, and by the investigation of several mining districts while assisting J. D. Hague in the volume treating of the mining industry. His instructions, when the National Survey was organized, were to devote himself to a study of the mineral wealth of the Rocky Mountains, and it was chiefly in this task that his life was spent. With the publication of his report on the geology and mining industry of Leadville, Colo., in 1886, a most important step forward was taken in economic geology in this country, in that it was then clearly perceived that the satisfactory economic development of mining regions must in future be based upon a thorough understanding of the geologic structure and the conditions of the ore deposition. From that time Emmons, in the opinion of those qualified to judge, is held to have been the most prominent figure in this country in the development of the economic side of geology, especially as regards the metal mining industry in the west. The stimulus of his work has been felt in an ever increasing degree by the younger men who have succeeded him and who have given this country such a commanding position in this branch of geology. He published many papers in journals, official reports, and the proceedings of scientific societies, and mostly dealing with the particular field he had made his own. His services to science and to mining had been adequately recognized by his election to the National Academy of Science, and to many other scientific and technical societies. His loss will be strongly felt, not only in his especial field of work and by the organization of whose staff he was an honored member, but by a host of personal friends to whom his warm heart and genial character had greatly endeared him. L. V. P.

Samuel Calvin, Professor of Geology in the State University of Iowa and since 1892 State Geologist of Iowa, died on April 17 at the age of seventy-one years.

Professor Jakob Maarten Van Bemmelen, the distinguished chemist of the University of Leyden, died on March 13 in his eighty-first year.

Mrs. Ellen H. Richards, head of the department of social economics at the Massachusetts Institute of Technology, and wife of Prof. Robert H. Richards of the department of mining engineering, died March 30 in Jamaica Plain, Mass. She published a work entitled "First Lessons in Minerals" in 1885.

Edwin E. Howell, mineralogist and maker of relief maps and models, died at his home, in Washington, on April 16, at the age of sixty-six years.

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FOURTH SERIES

VOL. XXXI—[WHOLE NUMBER, CLXXXI.]

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WITH PLATE IV.

NEW HAVEN, CONNECTICUT.

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Fig. 1.

Fig. 2.

Fig. 3.

Fig. 1. *Podokesaurus holyokensis.* ×2/3.
Fig. 2. Pelvic bones. ×3/2.
Fig. 3. Skull bones (?). ×4/3.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XXXVIII.—*Podokesaurus* holyokensis, a New Dinosaur from the Triassic of the Connecticut Valley*;† by Mignon Talbot. (With Plate IV.)

Introduction.

In a bowlder of Triassic sandstone which the glacier carried two or three miles, possibly, and deposited not far from the site of Mount Holyoke College, the writer recently found an excellently preserved skeleton of a small dinosaur the length of whose body is about 18^{cm}. The bowlder was split along the plane in which the fossil lies and part of the bones are in one half and part in the other. These bones are hollow and the whole framework is very light and delicate.

As the fossil lies in the rock, most of the bones are in position, or nearly so, with the exception of the skull and the tail. A detached tail that probably belongs to this specimen lies a few centimeters from the rest of the skeleton and near it are three very thin bones that may belong to the skull (fig. 3, A, B, and C; Pl. IV, fig. 3). Two of these bones are bilaterally symmetrical and one of them is broadly convex with a well-defined median sulcus. They are all more or less embedded in the rock and cannot be described until the rock

* From ποδώκης = swift-footed—an epithet commonly used in speaking of Achilles.

† A paper giving a preliminary description of this fossil was read at the meeting of the Paleontological Society in Pittsburgh, in December, 1910. In that paper the conclusion reached was that the animal was a herbivorous dinosaur: but the work of developing, which is being done at Yale University, has shown that the bone that was then described as the right fibula, displaced, cannot be a fibula, and, notwithstanding its great length, it is described in this paper as the pubis, in position. The bone that was thought then to be two bones, the pubis lying over the ischium, is probably the ischium with a well-developed ridge as is seen in Compsognathus. There would be, therefore, no bone to call the postpubis and the form must be removed from the herbivorous group of dinosaurs.

Fig. 1.

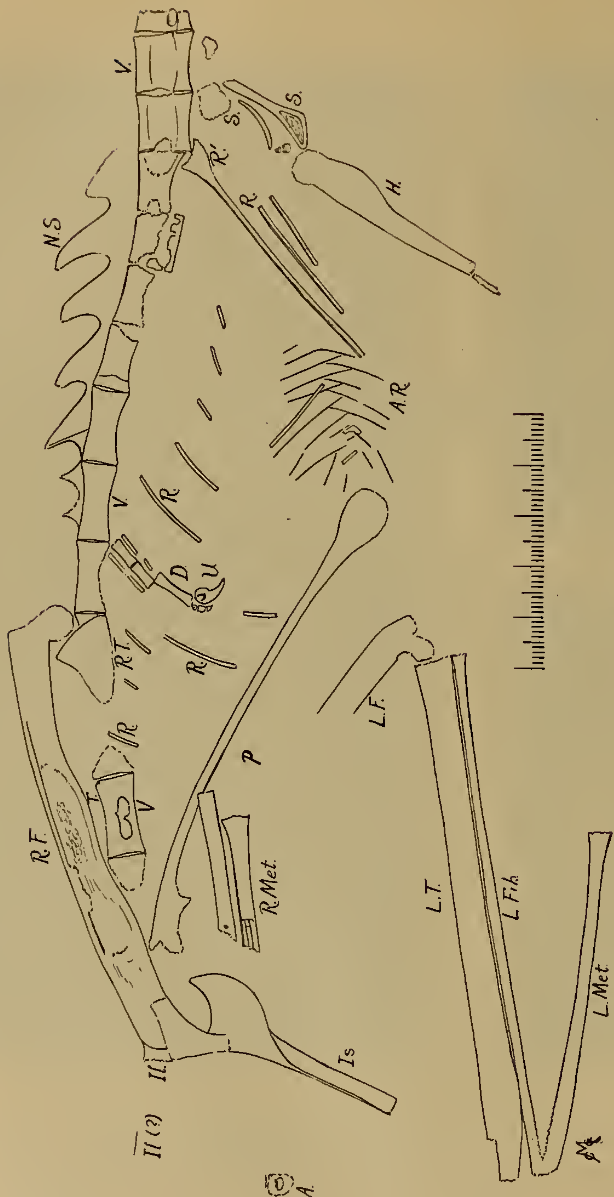

Fig. 1. Outline drawing of the fossil as it lies in the rock. × 2/3.

A. Astragalus (?). *A. R.* Abdominal ribs. *D.* Digit. *H.* Humerus. *Il.* Ilium. *Is.* Ischium. *L. F.* Left femur. *L. Fib.* Left fibula. *L. Met.* Left metatarsals. *L. T.* Left tibia. *N. S.* Neural spine. *P.* Pubis. *R.* Rib. *R. F.* Right femur. *R. Met.* Right metatarsals. *R. T.* Right tibia. *S.* Shoulder elements. *T.* Fourth trochanter. *U.* Ungual. *V.* Vertebra.

is removed. The other bones are better exposed and will be described below.

Description.

In the description which follows these features are to be noted: Light construction—hollow bones; slender, straight femur; position of fourth trochanter; position of fibula, lying close to the tibia; great length of tibia and metatarsals; small humerus; narrow shaft of ischium; great length of pubis; length of vertebræ.

Forelimb.—The humerus (fig. 1, H.)* is a very delicately shaped bone, 42^{mm} long (not quite half the length of the femur), slender and well rounded, with high radial crest. The proximal end shows a slight constriction above the crest and below the bone tapers gradually to a diameter of 3^{mm} at the distal end. Measured through the crest it is 8^{mm}. There is a trace of the impression of the radius or ulna just beyond the distal end.

In the scapular region is a broad, flat bone, lying vertically in the rock, but twisted on its long axis at a right angle, midway of its length (fig. 1, S.). This bone has a length, as shown, of 20^{mm} and a width of at least 3^{mm}. Lying near its proximal end is another flat bone, 8^{mm} long by 5^{mm} wide. These may be three separate bones, more or less firmly united in the living animal. Further development is necessary, however, to bring out their outlines and their relation to each other.

Hindlimb.—The femur (fig. 1, R. F. and L. F.) is slender and nearly straight with thin walls. The bone is expanded on the back side at the distal end. The length is 86^{mm} and the diameter, just distalwards from the fourth trochanter, is $6{\cdot}5^{mm}$. The fourth trochanter (fig. 1, T.) is 18^{mm} long and about 2^{mm} high and is situated just beyond the middle of the shaft, toward the distal end.

Only the proximal end of the right tibia (fig. 1, R. T.) is exposed and there the bone is well rounded. This, however, may be only a small part of the proximal end, as the bone is embedded in the rock. The left tibia (fig. 1, L. T.) is split lengthwise, part of the bone lying in each half of the bowlder. It is an almost straight, narrow shaft with the surface lying uppermost bent slightly at the proximal end, due, probably, to the expansion of the bone. In the position in which it lies, the bone is of nearly the same diameter throughout, about 7^{mm}. Its length is 104^{mm}. Lying close against the tibia and of almost equal length is the extremely thin fibula (fig. 1, L. Fib.).

There is a small, convex bone, 4^{mm} by 6^{mm}, lying where the

* The first four text-figures have been drawn by Miss Clara Gould Mark of Mount Holyoke College. For the privilege of using the restorations of Professor Marsh I am indebted to the editor of this Journal. The photographs were taken by Mr. Asa S. Kinney of Mount Holyoke College.

right tibia and metatarsals should meet, that may be the astragalus (fig. 1, A.). It shows no sign of an ascending process.

Two of the right metatarsals (fig. 1, R. Met.) lie in position. Their diameter is 2·5^{mm} and 3·5^{mm}, respectively, along the shaft, but at the distal end there is an expansion to a diameter of 5^{mm}. In position, at the distal end of the left tibia there is one metatarsal (fig. 1, L. Met.) slightly curved and 65^{mm} long. Alongside are traces of a second. One of the digits (fig. 1, D.), whose divisions are indistinctly shown, lies between two ribs not far from the right metatarsals. It is 20^{mm} long and 1·5^{mm} in diameter and is terminated by an ungual 7^{mm} long. Cross sections of two bones near this one look like unguals.

Pelvis.—The pelvic bones are partly covered by the right femur and their outline is not distinct. What is probably the

Fig. 2.

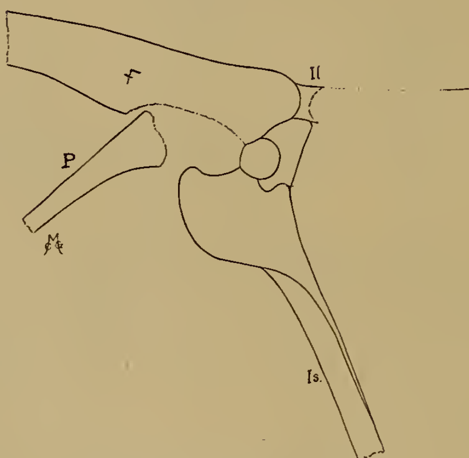

Fig. 2. Pelvic bones. ×1.

F. Femur. *Il.* Ilium. *Is.* Ischium. *P.* Pubis.

pubis (fig. 1 and fig. 2, P.) is a remarkably long, thin bone, 95^{mm} long, expanded at the distal end. The bone seems to be in position and makes an angle of about 40° with the line of the vertebral column. Its length is comparable with that of a new, undescribed form from northern Württemberg.

The ischium (Pl. IV, fig. 2; fig. 1 and fig. 2, Is.) is well rounded, anteriorly, and has a shaft 4^{mm} wide of which a length of 30^{mm} is exposed.* The distal end is embedded in the rock.

* The illustrations seem to indicate the presence of two bones but this may be due to the presence of a ridge on the ischium, as is seen in Compsognathus.

The contact with the ilium and the acetabular edge is obscurely visible.

There is a bone running posteriorly from the head of the right femur which may be the posterior process of the ilium (fig. 1 and fig. 2, Il.), the anterior process being covered by the femur. This posterior extension can be traced indistinctly for 27^{mm} and either points upward or continues the line of the posterior part of the vertebral column.

Vertebræ.—Of the vertebræ there are visible seventeen presacral (fig. 1, V.) and thirteen caudal (fig. 3, V.), all very light

Fig. 3.

Fig. 3. Caudal vertebræ and skull bones (?). $\times \frac{1}{2}$.
A, B, C. Bones of the skull (?). *D, E, F, G, V.* Caudal vertebræ.

and hollow, and some, at least, slightly concave at each end. The presacral vertebræ are slender, the measurements for the sixth presacral being 4^{mm} through the middle of the centrum, 6^{mm} at the ends and 15^{mm} from end to end. A strong, gracefully curved neural spine (fig. 1, N. S.) rises from the vertebræ in the dorsal region, about 10^{mm} high and 12^{mm} long at the base. The first two or three presacrals are a little larger than the others and those at the anterior end of the column, much stronger. One of the latter measures 10^{mm} at the end and the diameter through the middle of the centrum is only a little less. They are not so long, however, measuring only from 12^{mm} to 13^{mm}. One of these vertebræ is shown in cross section at a thin edge of the rock and has a transverse diameter through the cavity of the centrum of 4^{mm} while the height of the cavity is 5·5^{mm} (fig. 4).

The caudal vertebræ are only a little expanded at the ends and are very slender throughout their length. A typical one is 17^{mm} long with a diameter of 4^{mm} at the ends. The neural spines, if such they are (fig. 3, D.–G.), are of different shapes. These caudal vertebræ are so nearly of a size, one with another, that there is no apparent tapering of the series and it is not clear which is the proximal end of the tail nor is it possible, as yet, to estimate its length.

Fig. 4.

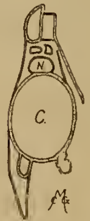

Fig. 4. Cross section of cervical vertebra showing hollow construction. ×2.
C. Cavity of centrum. *N.* Neural canal.

Ribs.—Quite a number of ribs (fig. 1, R.) are visible, all very slender and hollow, but the proximal end is not exposed save in one instance where the bone is so broken that the outline is not distinct. Near this proximal end, however, the bone is somewhat concave and expanded as if it might be bifurcate (fig. 1, R′). The largest rib uncovered is 52^{mm} long and 2^{mm} wide toward the proximal end, while in no place does the thickness seem to be more than 1^{mm}. The most anterior of the cervical vertebræ preserved have long ribs. These are on another piece of the bowlder and are not figured.

Just anterior to the distal end of the pubis there is a small cluster of gently curved abdominal ribs (fig. 1, A. R.), exceedingly slender and dove-tailed as they lie in the rock, the position due, probably, to slipping. This mass of interlacing ribs covers a space of 40^{mm} by 23^{mm}. There are at least eleven of these ribs on each side of the median line, the largest of which is 18^{mm} long and so small in diameter that the bone looks like a mere thread in the rock. Slender as are these ribs, they seem to be hollow.

Sternal element (?).—In the center of this mass of abdominal ribs is a small body that responds to dilute hydrochloric acid, as do all of the bones. The part exposed measures 5^{mm} by 3^{mm}. This may be one of the sternal elements displaced.

Gastrolith.—Lying 10^{mm} away, and still among these ribs, is a small piece of quartz, a flat, well-rounded pebble, 1^{mm} thick and 10^{mm} long. The width exposed is 4^{mm}, but more of the pebble is embedded in the rock. There are no other pieces of quartz larger than a grain of sand visible in the bowlder, and considering this fact, considering, also, its smooth, polished surface* and its position, the writer concludes that this must

* Dinosaurian Gastroliths, G. R. Wieland, Science N. S., xxiii, pp. 819–821.

be a gastrolith. This would seemingly be the first record of gastroliths found with carnivorous dinosaurian remains.

Comparison with other forms.

Herbivorous dinosaurs.—Compared with *Nanosaurus agilis* Marsh, the oldest known predentate dinosaur, the following points may be noted :* *Points of similarity*—The femur is shorter than the tibia, the ribs are very delicate, and the posterior extension of the ilium seems to have the same position. *Points of dissimilarity*—In this form the femur is more slender and is nearly straight, while in *Nanosaurus* it is distinctly curved. In this form, too, the fourth trochanter is much nearer the distal end of the femur, the metatarsals are more slender and probably longer, the humerus is relatively much smaller, the shaft of the ischium is narrower, the pubis has a long anterior extension, and there is no postpubis.

In *Laosaurus consors* Marsh,† from the Jurassic, the femur is much curved and is more nearly equal in length to the tibia, while the fourth trochanter is far up toward the proximal end; the fibula is more bent, curving away from the tibia; the metatarsals are very much shorter; the prepubis is short and pointed; and a postpubis is present. *Laosaurus* has a short humerus as this form has but the shape is not the same.

Hypsilophodon foxii Huxley (fig. 5), of the Wealden, England. Here we notice that the main points of difference are in the length and position of the pubis, and the presence of a postpubis in *Hypsilophodon*. In *Hypsilophodon* the femur is curved, but the fourth trochanter is situated more nearly as this one is, toward the distal end; the humerus is stouter and larger in every way with the radial crest much farther from the proximal end; the metatarsals are much shorter; the ribs are very much stronger; the neural spines are of an entirely different shape.

Carnivorous dinosaurs.—*Anchisaurus colurus* Marsh,‡ a very slender, long-limbed carnivore from the same Connecticut valley Triassic, with which this form seems to compare quite closely in general outline, shows the following differences. There is a decided difference in the relative lengths of the femur and tibia, the femur of the large form being much longer than the tibia. Marsh points out that the long femur is found in the larger animals of both carnivorous and herbivorous types, while the smaller birdlike forms of both types have the tibia longer than the femur.§ This small form certainly

* Neubeschreibung des Originals von Nanosaurus agilis Marsh, F. von Huene and R. S. Lull, fig. 1, p. 135.

† Dinosaurs of North America, O. C. Marsh, pl. LVII.

‡ Ibid., pl. IV.

§ Ibid., p. 201.

FIG. 5.

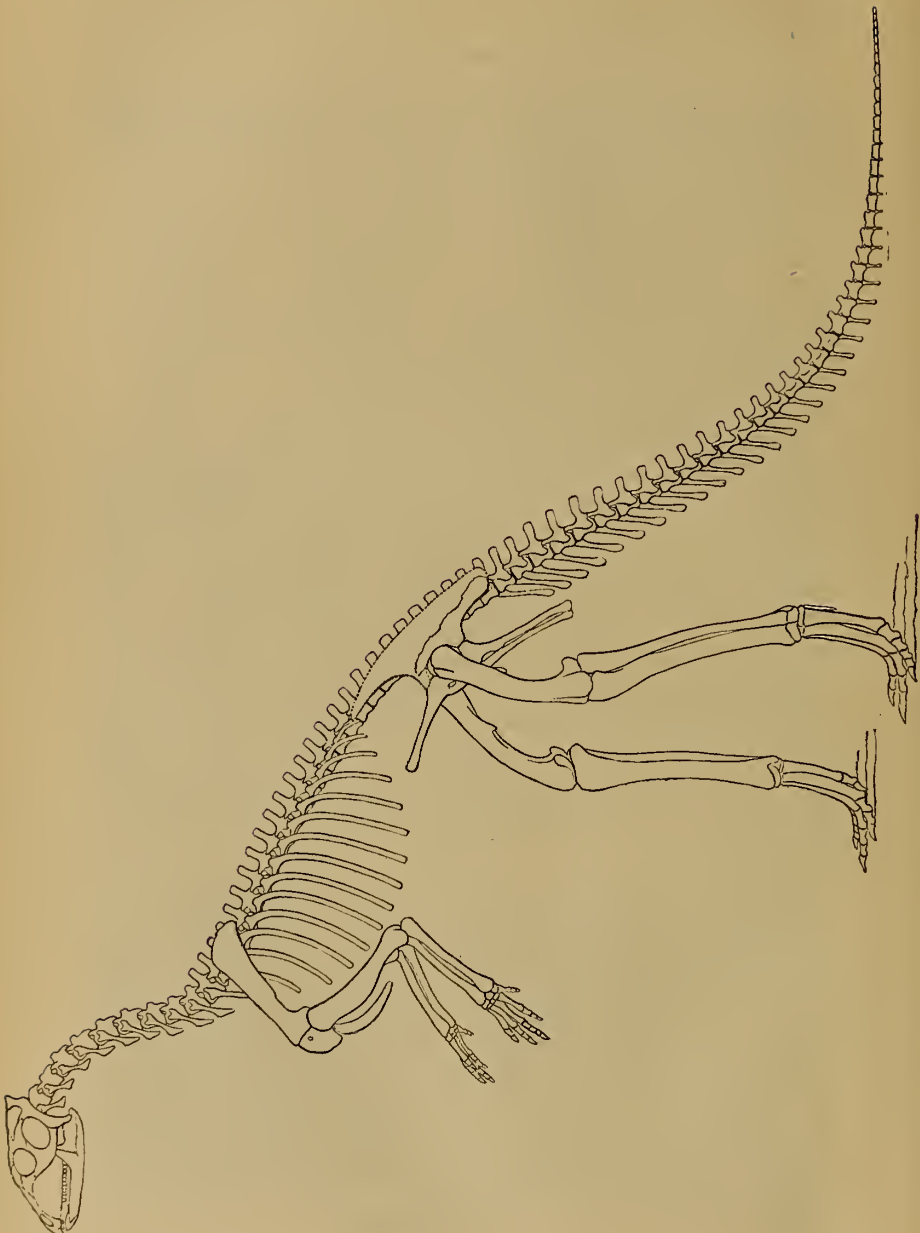

FIG. 5. Restoration of *Hypsilophodon foxii* Huxley, after Marsh. ×1/8 natural size.

helps to confirm his observation. In *Anchisaurus*, the femur is much bent and the fourth trochanter is high up toward the proximal end ; and all the limb bones are much stronger. The pubis of *Anchisaurus* is shorter, and runs at almost a right angle to the vertebral column ; nor is it expanded at its distal end, as it is in this form. On the other hand, there is a general similarity in the size of the corresponding vertebræ, though those of the caudal region of *Anchisaurus* are not quite so long and slender.

Compsognathus longipes Wagner (fig. 6), from the Jurassic of Bavaria, corresponds quite closely with this form in length and general proportions of the limbs, in the shape of some of the neural spines, especially those just anterior to the scapular region, and in the general shape of the ischium. The pubis of *Compsognathus* is much shorter, proportionally, however, makes a larger angle with the vertebral column, and is much more expanded at its distal end. The shaft of the ischium is not so slender nor so uniform in width.

Classification.

No attempt at a definite placing of this fossil will be made in this paper, but certain conclusions reached by the foregoing study will be stated. The fossil is interpreted as that of a carnivorous dinosaur because of the length, shape, and position of the pubis and the absence of a postpubis. Since no jaw has been found and there is no proof of the presence or absence of an ascending process from the astragalus, the determination of its position among the dinosaurs depends on the character of the pubis and the presence or absence of a postpubis. The position and length of the pubis are more nearly like those of the carnivores than those of the herbivores, and there seems to be no postpubis. The ischium is shaped somewhat like the bone in *Scelidosaurus harrisoni* Owen, that von Huene describes as the ischium, with a query, however, stating that it may be the pubis, but not accepting that interpretation because he can find no obturator foramen.*

The short, slender humerus and the long, straight hind-limb bones, together with the well-developed fourth trochanter, are indicative of bipedalism. The length of the tibia, much greater than that of the femur, the extreme length of the metatarsals, over half that of the tibia, and the very light construction of the skeleton, indicate rapid locomotion, which Lull uses as an indication of adaptation to climatic conditions, arguing that this animal must have been able to travel fast and

* Ueber die Dinosaurier der Aussereuropæischen Trias, F. von Huene, p. 57.

FIG. 6.

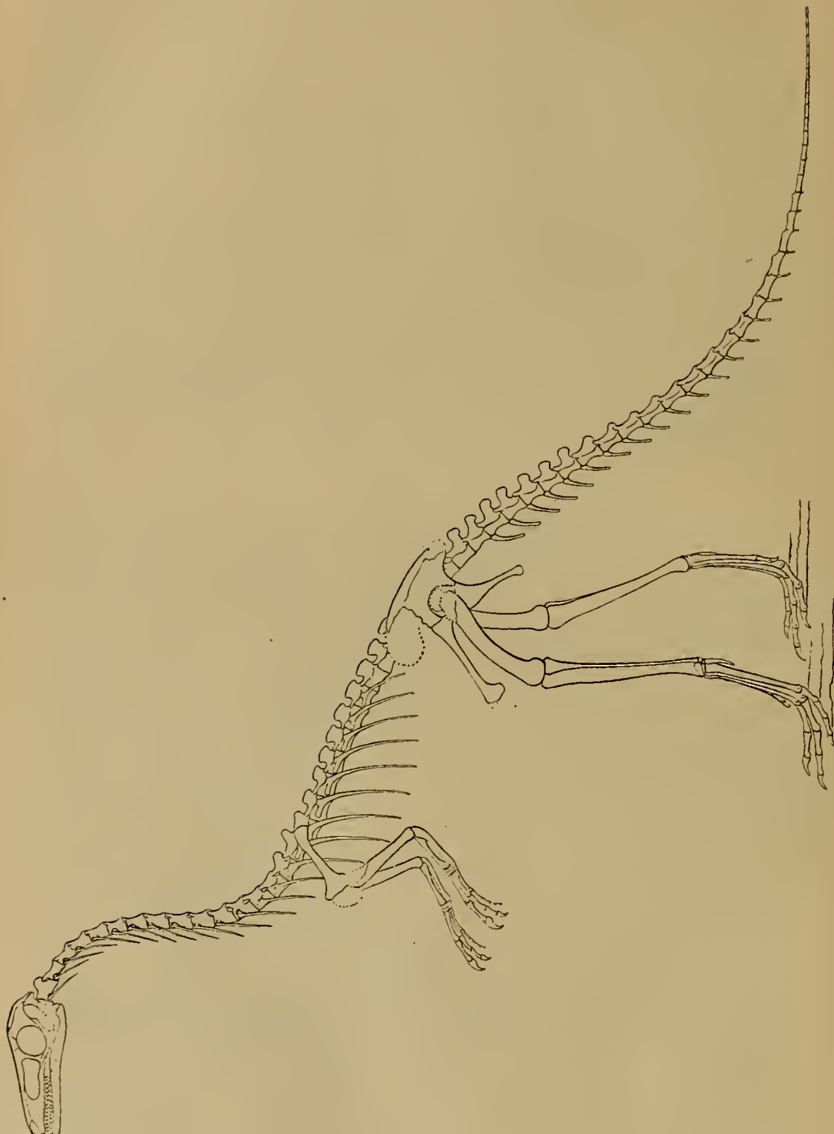

FIG. 6. Restoration of *Compsognathus longipes* Wagner, after Marsh. × 1/4 natural size.

far for water in a semi-arid climate. In support of this interpretation, also, may be added Barrell's suggestion that the rock in which the fossil is embedded indicates deposition on a flood-plain in a semi-arid region. It is significant that many of these Connecticut valley sandstones that have dinosaur footprints have also raindrop impressions.

Through the courtesy of Professor Schuchert the specimen has been sent to the Peabody Museum of Yale University for development, where further study will be given it by Professor Lull, to whom my thanks are due for many suggestions in regard to the interpretation of this fossil.

Mount Holyoke College, April, 1911.

Art. XXXIX.—*The Minerals Associated with Diamonds and Carbonados in the State of Bahia, Brazil;* by J. C. Branner.

Several persons have already studied and written upon the minerals associated with diamonds in Brazil.* Most of the papers, however, have been based upon the concentrates found in washing for diamonds in the Diamantina district in the state of Minas Geraes. Comparatively little has been said of the general geology of the Brazilian diamond region, and that little has not always helped to clear up the questions that arise in connection with the origin of the diamonds. Indeed the geology of the diamond district of Minas Geraes is far from being simple, and no reconnaissance has yet been made that shows the general structure and relations of the rocks and minerals. The diamond district of Bahia is north and a little east of Diamantina and about 650 kilometers distant on an air line.

The paper published by Damour in 1853, two by Gorceix published in 1884, and one by Hussak published in 1899, deal with the minerals found with the diamonds in Bahia, but none of these papers contains anything on the stratigraphy of that district. Indeed, up to the year 1905 practically nothing was known in regard to the general geology of the Bahia diamond region. In that year Professor Derby made a trip into the region for the state of Bahia, and prepared a short report to the government on its geology. That paper was published in Portuguese at Bahia, and, on account of its importance, it was translated into English and republished in *Economic Geology* (vol. I, pp. 134-142, Dec., 1905), and again in the Smithsonian Report for 1906 (pp. 215 to 221).

The paper by Derby represents our knowledge of the geology and mineralogy of the diamond regions of Bahia up to 1907, when I visited and traveled through that region for some months.

General geology of the diamond regions of Bahia.—I have already published brief sketches of the geology of the Chapada Diamantina of Bahia,† and only enough will be repeated in this place to give an idea of its broad features.

* Boué, Bovet, Brongniart, Damour, Derby, Dufrenoy, Eschwege, Gorceix, Hussak, Moissan, and others.

† The economic geology of the diamond-bearing highlands of the interior of the state of Bahia, Brazil. Engineering and Mining Journal, lxxxvii, 981, 1031. May, 1909.

Outline of the geology of the black diamond region of Bahia, Brazil. Australasian Assoc. for Adv. Sci. 1908, 324-328. Brisbane, 1909.

The table following shows the order of the rocks, their approximate thickness, and ages, in so far as the ages are now known. In the adjoining state of Sergipe, Cretaceous fossils have been found in abundance, and some have been found in the vicinity of the city of Bahia, but below the Cretaceous nothing has thus far been discovered that makes it possible to determine the ages of the beds with certainty.* The divisions mentioned in this paper are based solely upon stratigraphic and lithologic characters and physical breaks, and must therefore be regarded as tentative until something more trustworthy can be found. It should be added, however, that these divisions when put to the test in the field appear to be legitimate, and, for the most part, widespread.

TABLE OF GEOLOGIC FORMATIONS IN THE INTERIOR OF BAHIA.

Names	Thickness in meters	Ages
Alagôas series	?	Tertiary
Sergipe series	?	Cretaceous
Salitre limestones	350	Jura ?
Estancia red beds	350	Trias ?
Lavras series (diamond bearing)	700	Carboniferous
Cambão quartzites	100	(possibly part of the Lavras).
Caboclo shales (Paraguassú of Derby ?)	500	Devonian ?
Jacuipe flints	100	(possibly part of the Caboclo).
Tombador sandstones	400	Silurian ?
Minas (or Jacobina) series	1000	Cambrian ?
Crystalline complex	—	Pre-Cambrian in part ?

The Cambão quartzites and the Jacuipe flints appear to be local deposits that may belong to the larger divisions either above or below them.

Attention is directed to the fact that the diamonds and carbonados are found in the Lavras series, and to the further fact that the rocks of that series are everywhere of sedimentary origin, strongly false-bedded, and for the most part gently folded. The demarcation between the Lavras series and the rocks above and below is clear and well defined, with the possible exception of places where the Cambão quartzites occur.

Eruptives have been reported to me as occurring in the rocks of the Lavras series only in the region south of the Serra do Assuruá about Fundão, and Guaríba. These rocks I did not see personally, but they are reported by H. E. Williams, assistant of the Serviço Geologico do Brasil, who, as my assistant, examined portions of the diamond regions. Mr. Williams says

*It is reported that Carboniferous fossils were found in the interior of Pernambuco in 1910 by Dr. José Bach, but I have not been able thus far to get direct confirmation of the discovery.

these eruptives are dikes of diabase and that they break through the Lavras quartzites.

It should be noted in this connection that the principal diamond deposits extend over a wide area in the interior of Bahia, and that nowhere have eruptive rocks been found cutting the diamond-bearing sediments except at the places reported by Mr. Williams.

In the crystalline complex, however, that underlies all of the sedimentary beds of the interior of Bahia, there are many kinds of eruptive rocks. So far as observed, the eruptives in the crystalline series are all old; at least they have not been found to pass up into the sedimentary beds in which the diamonds are found, with only the exception just mentioned.

Of the sedimentary rocks the Minas (or Jacobina) series, as shown in the Serra de Jacobina, has its beds generally standing at a very high angle. Whether the position of these beds is due to folding or to faulting is not yet entirely clear, though the weight of evidence seems to be in favor of the theory of faulting.*

The Lavras quartzites.—Of the overlying Paleozoic beds the diamond-bearing Lavras series was most studied. The beds are usually more or less folded. The folds vary greatly: in some places they are so gentle as to be almost imperceptible, while in others they are highly distorted. In the mountains west of Gruna the beds are much contorted, broken, and faulted. Over most of the area, however, the folds are not closely pressed, the dips varying from ten to forty degrees. This structure in connection with the sharp separation of the Lavras series from the underlying and overlying beds, makes the working out of the distribution of the diamond-bearing beds comparatively easy.

The rocks of the Lavras series are nearly all pinkish quartzitic sandstones and conglomerates. The pink color appears to be characteristic of the series everywhere except in places where weathering has permitted the leaching out of the coloring matter.

Analysis of the Lavras Quartzite

Collected by J. C. Branner near Andarahý, State of Bahia.
L. R. Lenox, analyst.

Silica (SiO_2)	97·94%
Oxides of iron and alumina (Fe_2O_3 and Al_2O_3)	1·98
Lime (CaO)	none
Magnesia (MgO)	trace
	99·92%

* This Journal, xxx, 390-391, Dec. 1910.

The composition of the quartzite as shown by the analysis is about what might have been expected. The pink color is evidently due to the small percentage of iron present in a high state of oxidation.

It has already been said that the beds are almost everywhere strongly false-bedded. It is a striking fact that the false dips are not variable in direction as we are accustomed to see them in such rocks, but they are remarkably constant. In the northern and eastern parts of the diamond district these false dips are almost invariably toward the north. So nearly universal is this rule that I venture to say that, in the region north and east of Morro do Chapeo, fully ninety-nine per cent of the false dips is toward the north. About Lençoes and south of there south dips are much more common.

Occurrence of the diamonds.—Most of the diamond washings in Bahia are in stream beds, either actual or abandoned. In other words, the diamonds are found chiefly in alluvial deposits. The position of these deposits, however, shows clearly that the diamonds come directly from the Lavras series. In a great many places the diamonds and carbonados are found in alluvial deposits along streams that flow over the Lavras beds only. Such is the case at and south of Morro do Chapeo and at Campinas. In some of the most productive areas the alluvial deposits have been long exhausted, and the miners now obtain the stones directly from the disintegrating Lavras quartzites themselves. Between Lençoes and Andarahý the quartzites have been found so productive that the miners have removed the disintegrated rock down to where it is so hard that it cannot be removed with the hoes, mattocks, and *almocafres* used to scrape it away.

At Ventura the diamonds and carbonados are found in gravels that rest upon the Caboclo shales, but the valley is very narrow and the Lavras quartzites cap the hills to the north and west, while the stream itself rises in and flows for many kilometers over the Lavras beds, so that there seems to be no reasonable doubt that they have the same origin at Ventura as they do at Campinas, a few kilometers to the north, where they are taken directly from the disintegrated quartzites.

Personally I have never seen a diamond or a carbonado in the original quartzite, but it seems to be a matter of common information that they have been so found. Professor Derby tells me that he himself has seen one such specimen. The evidence, therefore, all points to the Lavras sedimentary series as the immediate source of the diamonds and carbonados in the state of Bahia.

The minerals associated with the diamonds and carbonados.—The question naturally arises whether the diamond originated in the Lavras quartzites, or whether they originated elsewhere and were washed out of their original matrix and deposited along with the other sediments in the Lavras beds. Perhaps this question might be readily answered under ordinary circumstances, but in this case it is not so simple.

It was hoped that a study of the minerals associated with the diamonds might settle the question definitely; and it was in this hope that the present examination was undertaken.

In order to study the mineralogical association of diamonds and carbonados in the diamond region of Bahia, I have obtained thirty-five samples of the concentrates from different parts of the Bahia fields, and have had the minerals in them separated and identified.

Some of the samples were collected by myself, but most of them were obtained for me through the kindness of my Brazilian friends, Dr. Alencar Lima of Bahia, Col. Dias Coelho of Morro do Chapeo, and of Mr. Arthur R. Turney of Lençoes. The samples consist of the fine heavy materials left in the bottom of the wooden bateas at the final "clean-up" in washing for diamonds at various places in the state of Bahia. The different minerals were separated by the use of Thoulet heavy solutions, and the percentages were determined by weighing before and after the separation. The weights are not altogether precise owing to slight losses, one of which came from the solubility of the gold in the solutions used.

Notes on the minerals.—The table shows that the minerals are unevenly distributed, some of them being very abundant in one locality and lacking at another.

As was to have been expected, quartz is by far the most abundant at all localities. The quartz grains nearly all have secondary enlargement; that is, the cementing material of the diamond-bearing quartzites is partly quartz in optical continuity with the original sand grains.

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* Samples 1 to 5, inclusive, are from Mosquitos near Lençoes, and were given me by Mr. Arthur R. Turney of Lençoes, Estado da Bahia.

† Samples 6 to 14, inclusive, were obtained for me by Col. Dias Coelho of Morro do Chapeo. The precise localities are not stated, but it is understood that they are from washings about Morro do Chapeo, Campinas, and Ventura.

‡ 15, from Col. Dias Coelho, is marked Tres Moitas, Jacobina Nova, which is on the west side of the Salitre Valley about 130 kilometers west of Villa Nova.

§ 16, from Col. Dias Coelho, is marked Rio Cambão, Jacobina Nova. The locality is within the Salitre drainage west of the Serra de Angico and 160 kilometers west of Villa Nova.

‖ 17, from Col. Dias Coelho, has no locality label.

¶ Nos. 18 to 35, inclusive, were sent me by Dr. Alencar Lima of Bahia. The exact localities are given in the table. The Chique-Chique mentioned is near Mucugé and should not be confused with a city of the same name on the Rio São Francisco.

TABLE OF MINERALS ASSOCIATED WITH DIAMONDS AND CARBONADOS IN THE STATE OF BAHIA, BRAZIL.—*Percentage of Minerals Found.*

Sample.	Locality.	Weight grams.	Quartz.	Hematite.	Rutile.	Ilmenite.	Tourmaline.	Martite.	Nigrine.	Zircon.	Cyanite.	Magnetite.	Garnet.	"Favas."	Monazite.	Staurolite.	Pyrite.	Brookite.	Octahedrite.	Topaz.	Gold.	Diamond.	Beryl.	Corundum.	Titanite.	Carbonado.
*1	Mosquitos, near Lençoes	9·66	93·7		1·86			1·42		0·49				1·66							x					
2	Mosquitos, near Lençoes	19·21	85·7		8·75			0·75						4·95		x		x								
3	Mosquitos, near Lençoes	5·34	29·7					13·47		27·0				30·5												
4	Mosquitos, near Lençoes	3·81	56·7		5·25			0·25		14·7				23·4		x										
5	Mosquitos, near Lençoes	2·85	8·78		22·4			4·12						64·6		x										
†6	Vicinity of Morro do Chapeo, Campinas and Ventura	25·75	64·2		2·48					0·47	0·43			28·7		1·25					x	x		x		
7	Vicinity of Morro do Chapeo, Campinas and Ventura	234·35	98·2	0·49			0·55	0·80								x										
8	Vicinity of Morro do Chapeo, Campinas and Ventura	175·67	96·80		0·75		0·40	0·19		0·59				1·30												
9	Vicinity of Morro do Chapeo, Campinas and Ventura	254·19	68·0					31·65				0·37														
10	Vicinity of Morro do Chapeo, Campinas and Ventura	330·	100·				x																			
11	Vicinity of Morro do Chapeo, Campinas and Ventura	94·42	97·5	·04	1·04		·06			0·55	x			0·87		x										
12	Vicinity of Morro do Chapeo, Campinas and Ventura	203·5	100·																			x				x
13	Vicinity of Morro do Chapeo, Campinas and Ventura	229·12	100·					x		x																
14	Morro do Chapeo		88·9		2·6		4·1				x		4·4				x									
‡15	Tres Moitas, Jacobina Nova		95·9		4·1																					
§16	Rio Cambão, Fazenda Ingazeira, Jacobina Nova		96·8		2·4		x			x	x			0·8												
‖17	Vicinity of Morro do Chapeo		21·2		51·6		x			x				x	27·2					x						
¶18	Garimpo Cousa Boa, Chique-Chique		100·		x																					
19	Grupiara do Chique-Chique		100·																							
20	Cousa Boa, Chique-Chique		98·	1·7			0·3																			
21	Cousa Boa, Chique-Chique		100·		x																					
22	Cousa Boa, Chique-Chique		100·																							
23	Bom Será de Baixo, Chique-Chique		65·	21·6	10·8		x	2·1						x												
24	Canal de Fumaça, Chique-Chique		38·2		40·2	x	10·1	0·5					11·4	0·4												
25	Capão de Baixo, Chique-Chique		94·2		·4	1·8	x	3·6			x													x		
26	Caetano Martins, Chique-Chique		30·8	14·8	30·7		2·4	13·4		6·3	x	x		1·0												
27	Luiz dos Santos		30·3		35·4	31·8		0·8		1·7	x															
28	Siberia, Paraguassú, Chique-Chique		46·2				40·8		3·1	1·1				8·8												
29	Bom Será, Chique-Chique		89·0	x	2·2		2·4		6·1	0·7				x									x			
30	Reginaldo, Chique-Chique		29·8	4·1	56.0	x	2·6	0·1		6·8				0·6							x					
31	Cousa Boa, Chique-Chique		39·8	10·5	23·7	x	7·5	13·6	3·9	1·5																
32	Bom Será de Cima, Chique-Chique		60·8	3·2	31·2			0·2		5·1			x	x					x		x					
33	Siberia, Chique-Chique		22·1		8·5	8·1	6·4	4·2	45·8	5·4	x														x	
34	Larangeiras, Chique-Chique		91·3		7·8			0·9			x			x												
35	Corrego dos Pombos		86·2					2·4	6·4		5·3			x							x			x		

The corundum reported is of the ruby and sapphire varieties, and is of a pale gray color.

The magnetite is sometimes found partly altered to hematite and the large amount of hematite and martite found with the diamonds is to be referred to this source.

Metallic copper was found in several of the samples, but as the pieces are very small, and invariably curled up like filings, it is supposed that they came from the pieces of sheet copper often nailed in the bottom of the bateas to mend holes, and that these small fragments have been scratched off by the gravels while the washing was going on.

Dr. A. F. Rogers gives me the following note upon the *favas* and diamonds found in these concentrates:

"The phosphate '*favas*' are rounded grains with faint greasy luster and pitted surfaces. The colors are quite variable, faint yellow, bluish gray, and dark brown. Under the microscope fragments are almost opaque, with a faint action on polarized light and have an aggregate structure. The index of refraction is about 1·62 and the hardness about 5. In composition the 'favas' are hydrous phosphates of aluminum. They probably vary in composition as they do in specific gravity, some being a little greater than 3·3, and some a little less.

"Diamonds were found in two samples,—a single smoky cleavage in one sand, and thirty-five crystals and cleavages in another sample. These crystals are colorless, yellowish, greenish, and pale wine-colored. The crystals are the common isometric forms, usually octahedral in habit, the faces being the octahedron, the dodecahedron, and the trisoctahedron. Some crystals are fairly sharp octahedrons with plane faces and grooved edges, but most of them have curved faces in oscillatory combination with each other. Several spinel twins of triangular shape were noticed. The crystals vary in size from 1 to 2^{mm} in diameter. One carbonado was found in this sample."

Four microscopic slides have been made from the diamond-bearing quartzites collected south of Lençoes for the purpose of ascertaining whether any of the minerals that are so characteristic of the metamorphic rocks occur in them in such manner as to show that they originated in the quartzites themselves.

Unfortunately the only minerals thus far found in the microscopic slides are quartz, chalcedony, and tourmaline: quartz forms the mass of the rock, the cementing material is partly quartz but largely chalcedony, while the tourmaline appears to have been carried in solution into small irregular cavities and there crystallized out. The dark greenish bands made by the tourmaline are quite visible to the naked eye in hand specimens. This particular microscopic examination does not, therefore, throw any positive light on the subject. But in view of the scarcity of the diagnostic minerals, no other result was to have been expected from the examination of so few slides.

One other mineral which is not mentioned in the table is found in the diamond-bearing beds in Bahia. This mineral is a jet black, opaque, hydrocarbon having a lustrous conchoidal fracture, a hardness of 2·2, specific gravity of 1·51, and is related to asphaltum, but is not certainly identifiable with any known form. It was thought at first that this mineral might be especially interesting on account of its association with the diamonds and carbonados, but it occurs in large lumps and seems to have no apparent relation to them.

Comparison of the minerals of Bahia and Minas.—In order to compare the minerals found in different districts I have brought together here the Bahia lists published by Damour, Gorceix, and Hussak,* and I have made up from various sources a list of all minerals reported from the diamond washings of Minas Geraes.

In comparing the minerals from the Minas diamond washings with those at Bahia, it should be kept in mind that in Minas the diamonds are found for the most part in river beds, either actual or abandoned, and that the minerals associated with them are the result of a long and high degree of concentration. In one instance to my own knowledge the Minas diamonds were obtained from a metamorphosed rock that was broken up by weathering. In the Bahia region this long and complete concentration has occurred in some instances, but in others there has been practically no natural concentration since the minerals were set free from the quartzite matrix.

Conclusion regarding the relations of the Bahia and Minas districts.—Taking the Bahia list of minerals as a whole and comparing it with the Minas list, we must conclude that the only difference between them that seems worthy of note is the presence of the carbonado in Bahia and its absence from Minas. The other differences, such as the finding of ilmenite, monazite, topaz, and spinel in the Bahia deposits, and the occurrence of tantalite, euclase, fibrolite, titanite, chrysoberyl, chromite, and klaprothine in the Minas gravels I regard as purely accidental, and liable to disappear with further search for those minerals in the regions from which they have not yet been reported. The talc and graphite in the Minas deposits may be regarded as purely local, as is that of asphaltum in the Bahia deposits.

The diagnostic minerals.—A study of this table at once shows that most of the minerals mentioned have no diagnostic value. Quartz, for example, may occur in rocks of any age, and in sedimentary, eruptive, deepseated, or metamorphic rocks, in pegmatites, or in ordinary veins. It cannot therefore be re-

* Eugen Hussak.—Ein Beitrag zur Kenntnis der sogenannten "Favas" der brasilianischen Diamantsande. Tschermak's Min. u. Petr. Mitteilungen, xviii, 334–359, Vienna, 1899.

Minerals associated with Diamonds and Carbonados in the States of Bahia and Minas Geraes, Brazil.

	Bahia, by various authors.	Bahia, by Branner.	Minas Geraes, by various authors.
1. Beryl	o	o	
2. Brookite	o	o	o
3. Carbonado	o	o	o
4. Cassiterite	o		
5. Chalcedony		o	
6. Chlorite	o		
7. Chromite			o
8. Chrysoberyl			o
9. Cinnebar	o		
10. Columbite	o		
11. Corundum	o		o
12. Cyanite	o	o	o
13. Diamond	o	o	o
14. Diaspore	o		
15. Euclase	o		o
16. "Favas"	o	o	o
17. Fibrolite	o		o
18. Garnet	o	o	o
19. Gold	o	o	o
20. Hematite		o	o
21. Ilmenite	o	o	
22. Klaprothine			o
23. Limonite	o	o	o
24. Magnetite	o	o	o
25. Martite	o	o	o
26. Monazite	o	o	
27. Nigrine		o	
28. Octahedrite	o	o	o
29. Perovskite			o
30. Pyrite	o	o	o
31. Quartz	o	o	o
32. Rutile	o	o	o
33. Spinel	o	o	
34. Staurolite	o	o	
35. Tantalite	o		o
36. Titanite	o	o	o
37. Topaz		o	o
38. Tourmaline	o	o	o
39. Xenotime	o		o
40. Zircon	o	o	o
Minerals found in the rocks, but not generally in the concentrates.			
41. Asphaltum		o	
42. Calcite		o	
43. Feldspar	o	o	o
44. Graphite			o
45. Kaolin	o	o	
46. Mica	o	o	o
47. Psilomelane	o	o	o
48. Pyrolusite		o	
49. Talc			o

garded as helpful in determining the Brazilian association of diamonds.

Omitting from the list all minerals of common or wide occurrence, I have made up the following table of those which I regard as diagnostic in the state of Bahia, and the columns indicate their genetic rock associations :

Table of Diagnostic Minerals associated with Diamonds and Carbondos in Bahia.

	Eruptives	Deep-seated granites	Metamorphics	Pegmatites
Beryl	--	--	x	x
Brookite	x	x	--	--
Cassiterite	--	--	--	x
Columbite	--	--	--	x
Corundum	--	x	x	--
Cyanite	--	--	x	--
Diaspore	--	--	x	--
Monazite	--	x	x	--
Octahedrite	--	--	x	--
Staurolite	--	x?	x	--
Tantalite	--	--	--	x
Titanite	--	x	x	--
Xenotime	--	x	--	x
Zircon	--	x	x	--

This table brings out the fact that the genetic relations of these minerals are plainly with deep-seated granites, metamorphics, and pegmatites rather than with eruptives.

In view of the widespread occurrence of diamonds in the Lavras quartzites in Bahia, and in view of the absence of eruptives from the vicinity of the diamond washings, one of the following conclusions seems to be warranted :

First, either the Bahia diamonds or carbonados originated in the old granites and metamorphics that underlie the Paleozoic beds in Bahia and have passed down mechanically to their present position, or

Second, they are one of the results of metamorphism of the quartzites themselves and have originated where we now find them.

Possible origin of the diagnostic minerals.—If the diamonds and their associated diagnostic minerals were derived from older metamorphic or eruptive rocks, where did they come from ? East, west, and south of the diamond regions of Bahia are extensive areas of the crystalline rocks mentioned at the beginning of this article, consisting of old, probably Archean, granites, gneisses, schists, and eruptives of many kinds, and similar to those upon which subsequent deposits have been laid down. If, therefore, such a source is assumed for the diamonds and their associated minerals, there is no great geographic difficulty in accounting for them.

But if they originated in the ancient rocks and passed down with their associates through ages to the Lavras series, the hardness of the minerals must have been a factor of considerable importance in their history.

The associated diagnostic minerals, including the diamonds, are arranged with reference to hardness in the following tables:

Table showing the Hardness of the Minerals associated with Diamonds in Bahia.

Minerals	Hardness
1. Diamonds, carbonados	10
2. Corundum	9
3. Beryl, spinel	8
4. Zircon	7·5
5. Cyanite, staurolite, cassiterite, diaspore	7
6. Tantalite	6·5
7. Brookite, columbite	6
8. Monazite, octahedrite, titanite, "favas"	5·5
9. Xenotime	5

The hardness of the diamond (and carbonado) is a strong point in favor of the theory of the possibility of its having been passed down through several geologic ages, but the chances of the survival of a mineral having a hardness below 6· seems rather small though not at all impossible. The value of this evidence, therefore, seems to be doubtful.

Conclusion.—It is fully realized that the results of this study are mostly negative. There is no evidence, however, that the Brazilian diamonds are of eruptive origin. And they certainly were not brought into their present position in the Lavras quartzites by eruptive action of any kind.

I am strongly inclined to believe that the diamonds of Bahia have their origin in the quartzites where they have been occasionally found in place, and that they are associated with minerals characteristic of metamorphic rocks for the reason that those minerals also originated in the quartzites under the same conditions as the diamonds themselves.*

*The occurrence of diamonds in place in South Africa and in Arkansas, and associated in both instances with peridotites, appears to have thrown the burden of proof upon any geologist who ventured to suggest any other than an igneous origin for diamonds in other parts of the world. But even this stronghold of the believers in the igneous origin of diamonds is seriously shaken by two important facts:—

First, that diamonds are found in only a small percentage of the South African eruptive pipes.

Second, that diamonds have been found in the garnets of the eclogites brought up into the diamond-bearing pipes by the eruptives. So that after all, a metamorphic rather than an eruptive origin of even the South African diamonds seems to be a possibility, if not a probability.

[A. L. du Toit.—The diamond-bearing blue-ground and allied rocks of South Africa, Trans. Edin. Geol. Soc., lx, 361-362, Edinburgh.]

Art. XL.—*An Engelhardtia from the American Eocene;* by Edward W. Berry.

The walnut family (Juglandaceæ), which in the popular mind is fully rounded out by the enumeration of the walnut, butternut, hickory and pignut, consists of six or seven genera and about forty species scattered throughout the warmer parts of the north temperate zone and penetrating some distance south of the equator along the Andes in South America and in the East Indies. The Juglandaceæ are of considerable interest for a variety of reasons, chief among which, aside from their great economic importance, are their line of ancestors reaching back to the mid-Cretaceous, and because of the much discussed question as to whether their morphological characters shall be interpreted as primitive or as mere simplifications of a more highly organized stock.

All of the genera have not adopted the same methods of dissemination and certain tropical and sub-tropical genera have kept the seed part of their fruits comparatively small and light, thus enabling them to produce large numbers of seeds with the same expenditure of energy required for a single walnut. Furthermore, instead of depending upon chance for the distribution of their latent progeny, the bracts which are normally present throughout the family have developed enormously and serve as wings. This is especially true of the genus Engelhardtia, a recent addition to which is the occasion for the present brief note.

The genus Engelhardtia was described by Leschen in 1825 and contains about ten species of the southeastern Asiatic region. These range from the northwestern Himalayas through farther India and Burma to Java and the Philippines. The pistillate flowers are small and are grouped in paniculate spikes. They develop into small drupe-like fruits, each of which is connate at the base to a large expanded tri-alate involucre.

A single little known species rarely represented in even the larger herbaria occurs in Central America and is the type and only species of the genus Oreomunnea of Oersted. This is much more restricted in its range than are its kin beyond the Pacific. Oreomunnea is very close to Engelhardtia, and for the purposes of the paleobotanist the two may be considered as identical since they represent the but slightly modified descendants of a common ancestry which was of cosmopolitan distribution during the early Tertiary. The present isolation of Oreomunnea furnishes a striking illustration of the enormous changes which have taken place in the flora of the world in the relatively short time, geologically speaking, which has elapsed since the close of the Cretaceous.

The principle has frequently been ennunciated that when closely related forms are found in the existing flora of the world, restricted in range and isolated from their nearest relatives, or when the existing genera are monotypic, it is quite safe to predict an interesting and extended geological history. Engelhardtia proves to be another illustration of this principle, for its peculiar three-winged fruits have been known in the fossil state for almost a century. They were long unrecognized, however, and the earlier students who described them compared them with the somewhat similar winged fruits of the genus Carpinus (Betulaceæ). With the botanical exploration of distant lands in the early part of the 19th century, specimens of Engelhardtia began to be represented in the larger European herbaria, and Baron Ettingshausen,* that most sagacious of paleobotanists, as long ago as 1851 pointed out that certain supposed species of Carpinus were really fruits of Engelhardtia. He returned to the subject in 1858† without, however, actually changing the names of any of the supposed species of Carpinus nor does he seem to have been aware of the existence of a living species of Engelhardtia in Central America.

Since Ettingshausen's announcement a dozen or more fossil species have been described. The oldest known occurs in the upper Eocene or lower Oligocene (Ligurien) of France and the species become increasingly abundant throughout southern Europe especially toward the close of the Oligocene and the dawn of the Miocene, Saporta stating that the slabs from the leaf-beds at Armissan in southeastern France are thickly strewn with their peculiar fruits. Fossil forms continue in Europe throughout the Miocene and Pliocene and specimens of late Miocene or early Pliocene age are recorded from Spain, France, Italy, Croatia and Hungary.

The accompanying sketch map of the world (fig. 1) shows the existing distribution of Engelhardtia and Oreomunnea somewhat generalized and exaggerated in order to be seen on so small a scale map. The Tertiary occurrences of Engelhardtia are indicated by stars, a single star covering all of the records in a single area, as for example, southeastern France, from which one Ligurien, three Tongrien, five Aquitanien and one Pontien occurrences have been recorded. No fossil American species have been previously known with any degree of certainty. Lesquereux‡ in 1883 recorded *Engelhardtia oxyptera*

* Ettingshausen, Die Tert. Fl. von Wien, Abhandl. k.k. geol. Reichsanstalt, Wien, xi (3), p. 2, 1851.

† Ettingshausen, Beiter. z. Kennt. foss. Fl. von Sotzka, Sitzungsb. k. Akad. Wiss. Wien, xxviii, 1858, p. 12, pl. iv, fig. 4; pl. v, figs. 1-3.

‡ Lesquereux, Cret. and Tert. Fl., U. S. Geol. Surv. Terr., vol. viii, p. 192, 1883.

Saporta* from the Miocene of Florissant, Colorado. I have been unable to get track of this specimen and as no specimens of Engelhardtia have been detected in Professor Cockerell's recent and extensive collections from this locality and as Carpinus is not at all uncommon, it seems probable that Lesquereux's determination was based upon material of the latter genus, particularly as the Florissant plant beds are considerably younger than the type locality for *Engelhardtia oxyptera*,

Fig. 1.

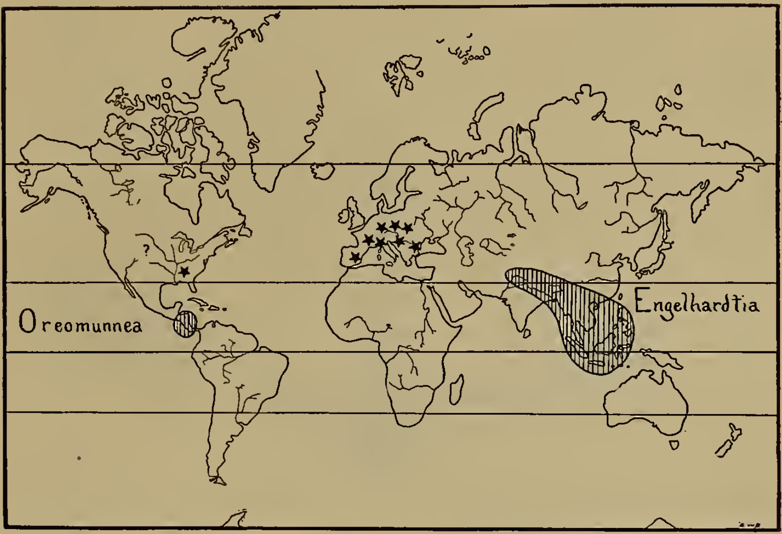


Fig. 1. Sketch map showing the existing geographical distribution of Engelhardtia (vertical lining) and fossil occurrences (stars).

which was Armissan, France. In any event the Florissant material differs markedly from the present species from Mississippi, having a different venation and being only half the size of the latter.

With these introductory remarks we may proceed to the description of an unmistakable species of Engelhardtia recently recognized from the Eocene deposits of northern Mississippi. The single specimen of the fruit shown in the accompanying text figure was collected in 1889 by W. J. McGee while engaged in his studies of the so-called Lafayette formation and has lain unstudied in the collections of the U. S. National Museum since that date.

*Saporta, Études sur la Végét. du sud-est de la France à l'époque Tertiaire, xi, p. 344, pl. xii, fig. 2, 1866.

The writer has collected leaves of Engelhardtia in these deposits, but since their exact relationship with the fruit is unsettled they will not be considered at the present time. The species, which is new, may be called

Engelhardtia (*Oreomunnea*) *mississippiensis* sp. nov.

Description.—Involucre large, trilobate, somewhat reflexed. Alæ widely spreading, the angle between the median and

Fig. 2.

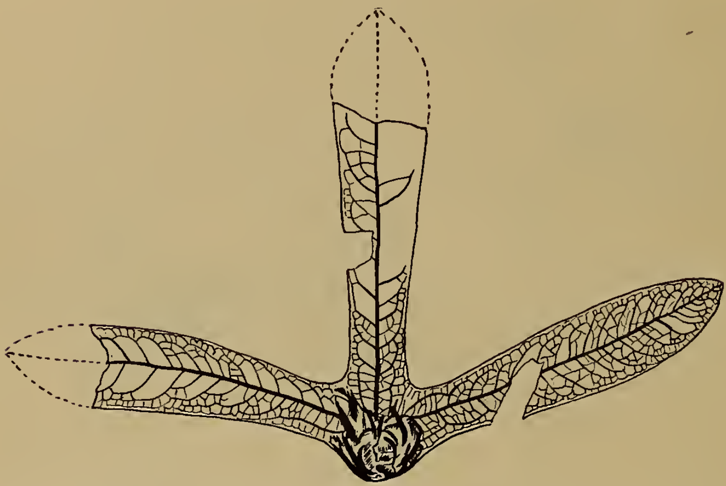


Fig. 2. *Engelhardtia* (*Oreomunnea*) *mississippiensis*, sp. nov. from the Eocene of Mississippi (nat. size).

lateral wings being 70° to 80°. Sinuses correspondingly open, rather straight-sided, rounded at the angle, which is 1·5^{cm} from the extreme base of the specimen. The median wing is the longest of the three and is equilateral, spatulate or oblanceolate in outline, expanding gradually distad from a basal width of 8^{mm} to a width of 13^{mm}, where the distal portion is broken off, 5^{cm} above the base. Since this apical part is missing the total length is estimated at 6·5^{cm}, which is a minimum rather than a maximum estimate. Lateral wings slightly inequilateral, the outer part of the lamina being a trifle wider than the inner. Apex rounded. Length 5^{cm}. Greatest width, which is above the middle, 11^{mm}. Least width proximad, 7^{mm}. Primaries three in number, one median primary being present in each wing. The primaries are relatively very stout and continue with but slight attenuation to the tips of the wings. No subordinate primaries or discordantly directed secondaries are present as in some of the European Tertiary species.

Secondaries numerous, thin, more or less parallel, about twelve to fifteen pairs to each wing, alternate. The secondaries branch from the midvein at a wide angle which becomes progressively less distad, where they are placed at more frequent intervals and are more regularly curved, camptodrome throughout. Tertiaries extremely fine, forming small arches just inside the margin and more or less rectangular meshes within the spaces bounded by the secondaries.

Margins strictly entire throughout. The essential portion of the fruit is poorly preserved and partially broken away, as is usually the case in the fossil species of this genus. It appears to have been of considerable consistency, and the whole fruit having fallen face downward the reflexed wings raised the peduncular portion, which either rotted away before fossilization or, what is more probable, was broken off when the specimen was collected.

Among previously described Tertiary forms the present species is most similar to *Engelhardtia Brongniarti* Saporta, a species recorded from Spain, France, Italy, Germany, and Austria-Hungary and supposed to range from the Oligocene to the Pliocene. The American species is somewhat larger than the usual size of *Engelhardtia Brongniarti*, although Unger has figured forms of the latter which do not differ much in size from Sotzka in Styria. The wings are more spreading and the outlines are much more elegant. In the European form the wings are rounded apically as in the American species but they are approximately the same width throughout and do not taper downward as they do in *Engelhardtia mississippiensis*. The secondaries, instead of being regular and camptdodrome as in the latter, are less numerous and more irregular in position, several in each wing ascending from the base for considerable distances approximately parallel with the midvein.

Among the existing species with which it has been compared *Engelhardtia mississippiensis* is very similar to most of the described oriental forms, perhaps resembling *Engelhardtia spicata* Blume more closely than the others. The latter ranges from the northwestern Himalayan region through Burma to Java and other East Indian islands. Comparative material of Oreomunnea is very scarce. A single fruit in the National Herbarium is closer to the fossil than are any of the Asiatic species, but in the absence of more material the limits of variation in Oreomunnea are unknown.

In a general way Engelhardtia fruits are not unlike those of Carpinus, as has already been mentioned. There seems to be little occasion for confusion, however, even in poorly preserved fossil material. The fruit proper is decidedly different, although this is seldom well enough preserved in fossils to be decisive. The involucre is also markedly different in the two genera. Carpinus involucres are usually smaller with the median wing much wider and longer than the lateral wings and with somewhat different venation.

The margins are also toothed while in Engelhardtia they are always entire. I have examined fruits of all of the existing species of Carpinus and experience no difficulty in readily distinguishing them from those of Engelhardtia, the American species of the former being especially different in appearance from those of Engelhardtia. I have seen involucres of the old world *Carpinus betulus* from trees cultivated in this country in which the wings had entire or nearly entire margins, but the aspect of the specimens as a whole, because of their different proportions and venation, was markedly unlike Engelhardtia, and if they had been found as fossils no competent paleobotanist would have been at a loss regarding their botanical affinity for a single instant.

Engelhardtia mississippiensis was collected from a locality about one mile southeast of Early Grove in northeastern Marshall County, Mississippi, a few miles from the Tennessee border. The age of the beds is Wilcox Eocene, as indicated by the large flora associated with the present species.

Johns Hopkins University, Baltimore.

Art. XLI.—*The Use of Sodium Paratungstate in the Determination of Carbon Dioxide in Carbonates and Nitrogen Pentoxide in Nitrates by Loss on Ignition;* by F. A. Gooch and S. B. Kuzirian.

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

From certain carbonates, like those of magnesium, zinc and cadmium, carbon dioxide may be expelled by simple ignition at a moderate temperature, leaving an oxide in definite and weighable condition. In the case of calcium carbonate, this process of decomposition is completed only at the high heat of the blast lamp, and the reaction, being easily reversible in the atmosphere containing carbon dioxide evolved in the ignition or produced in the source of heat, may leave the oxide not quite pure. Strontium carbonate and barium carbonate are not entirely broken up by simple ignition under the conditions ordinarily available in analysis; nor are the alkali carbonates. For the decomposition of refractory carbonates it is customary to make use of a suitable flux which, by combining with the oxide, will aid in the expulsion of the carbon dioxide. Anhydrous borax,* silicon dioxide,† potassium dichromate,‡ and recently, sodium metaphosphate§ have been thus used in the analysis of carbonates, and they are applicable similarly to the determination of nitrogen pentoxide in nitrates which leave definite oxides on ignition. Such fluxes, moreover, serve the very essential end of conserving the residual oxides in definite and stable form for weighing under the ordinary atmospheric condition of the balance room. Of those mentioned the first two, borax and silicon dioxide, require prolonged ignition to bring them to constant weight before making use of them to react with the carbonate or nitrate; and generally they yield in the fusion process a pasty magma, so that prolonged heat at a high temperature is necessary to the complete expulsion of the gaseous product. Sodium metaphosphate, though more fluid in fusion, also demands prolonged care in the preparation. Potassium dichromate is too easily decomposed with loss of oxygen to be employed in exact processes demanding long continued fusion or heating to temperatures much above its fusing point.

These are points which have been sufficiently emphasized in the work to which reference has been made.

* Fresenius: Zeitschr. anal. Chem., i, 181.

† Rose: Ann. Phys., cxvi, 635. Fresenius: Zeitschr. anal. Chem., i, 184. Richards and Archibald, Proc. Am. Acad., xxxviii, 443.

‡ Rose: Ann. Phys., cxvi, 131. Fresenius: Zeitschr. anal. Chem., i, 183.

§ Lutz and Tschischikof: Chem. Zentralblatt, 1905, i, 564. Böttger: Zeitschr. anal Chem., xlix, 487.

In sodium paratungstate of composition corresponding approximately to the formulæ $5Na_2O.12WO_3$, or $Na_{10}W_{12}O_{41}$, we have material very easily prepared, stable in fusion, and well suited for use as a flux in the rapid determination of the loss of carbonates and nitrates on ignition. For the following experiments the sodium paratungstate was prepared by dehydrating and fusing over the blast-lamp a known weight of normal sodium tungstate, $Na_2WO_4.2H_2O$, adding an equal weight of tungsten trioxide, WO_3 (previously ignited with care to remove all ammonia and to insure complete oxidation), and heating to clear fusion. The cooled mass, which is very easily pulverized, was ground in a mortar and bottled. From this material kept in a desiccator over sulphuric acid (though not more than ordinarily hygroscopic), portions were weighed for the analytical determinations. Approximately half the weight of the paratungstate is tungsten trioxide (molecular weight 232) and this should be capable of expelling carbon dioxide (molecular weight 44) to the amount of one-fifth its own weight, and of nitrogen pentoxide (molecular weight 108·02) to an amount one-half its own weight. The weights of paratungstate used were, therefore, always in excess of ten times the weight of carbon dioxide and four times the weight of nitrogen pentoxide to be expelled. In the following determinations it was the practice to weigh a platinum crucible, introduce the dried carbonate and weigh again, add a suitable amount of the prepared sodium paratungstate, stir carefully with a platinum wire with care to avoid mechanical loss, and weigh again. The crucible was heated over a bunsen burner, first at very low heat and then to fusion of the mixture for five minutes, cooled in a desiccator over sulphuric acid, weighed, and re-ignited to test the constancy of weight. The constant weight was usually got in the first ignition. In Table I are given the results of the estimation of carbon dioxide in calcite.

TABLE I.

Analysis of Calcium Carbonate (Calcite).

$CaCO_3$ taken grm.	$Na_{10}W_{12}O_{41}$ taken grm.	Loss on ignition grm.	Theory for CO_2 grm.	Error grm.
0·5000	2·5	0·2195	0·2198	−0·0003
0·5000	2·5	0·2206	0·2198	−0·0008
0·5000	2·5	0·2200	0·2198	−0·0002
0·5000	2·5	0·2203	0·2198	−0·0005
0·5000	2·5	0·2200	0·2198	−0·0002
0·5000	2·5	0·2204	0·2198	−0·0006
0·5000	2·5	0·2190	0·2198	−0·0002
0·5000	2·5	0·2200	0·2198	−0·0002

The strontium carbonate used in the experiments given below was prepared with great care. Strontium chloride, C. P., was partially precipitated by strong hydrochloric acid, washed with hydrochloric acid, dissolved in water and added in dilute solution drop by drop from a stoppered funnel to a saturated solution of ammonium carbonate heated to the point of decomposition. The precipitated carbonate was carefully washed, dried, washed again with ammonium carbonate and then with boiling water, and dried below red heat. In Table II are the results obtained with this preparation of strontium carbonate.

Table II.

Analysis of Specially Precipitated Strontium Carbonate.

$SrCO_3$ taken grm.	$Na_{10}W_{12}O_{41}$ taken (approx.) grm.	Loss on ignition grm.	Theory for CO_2 grm.	Error grm.
0·5000	2·5	0·1488	0·1490	−0·0002
0·5000	2·5	0·1494	0·1490	+0·0004
0·5000	2·5	0·1494	0·1490	+0·0004
0·5000	2·5	0·1490	0·1490	0·0000
0·5000	2·5	0·1496	0·1490	+0·0006
0·5000	2·5	0·1486	0·1490	−0·0004

With barium carbonate prepared from the chloride by partial precipitation with strong hydrochloric acid, solution of the precipitated chloride in water, gradual addition of the solution with constant stirring to a hot solution of ammonium carbonate, careful washing, and drying, the following results were obtained:

Table III.

Analysis of Specially Precipitated Barium Carbonates.

$BaCO_3$ taken grm.	$Na_{10}W_{12}O_{41}$ taken (approx.) grm.	Loss on ignition grm.	Theory for CO_2 grm.	Error grm.
0·5000	2·5	0·1120	0·1115	+0·0005
0·5000	2·5	0·1125	0·1115	+0·0010
0·5000	2·5	0·1109	0·1115	−0·0004
0·5000	2·5	0·1113	0·1115	−0·0002
0·5000	2·5	0·1123	0·1115	−0·0008

The similar use of sodium paratungstate for the determination of the nitrogen pentoxide in nitrates is shown in the following table:

TABLE IV.

Analysis of C. P. Nitrates of Commerce, after Drying.

Nitrate taken grm.	$Na_{10}W_{12}O_{41}$ taken grm.	Loss on ignition grm.	Theory for N_2O_5 grm.	Error grm.
KNO_3				
0·5000	1.5	0·2668	0·2670	−0·0002
0·5000	1·5	0·2678	0·2670	+0·0008
0·5000	1·5	0·2674	0·2670	+0·0004
0·5000	1·5	0·2672	0·2670	+0·0002
0·5000	1·5	0·2675	0·2670	+0·0005
$Sr(NO_3)_2$				
0·5000	2	0·2544	0·2543	+0·0001
0·5000	3	0·2546	0·2543	+0·0003
$Ba(NO_3)_2$				
0·5000	3	0·2073	0·2067	+0·0006
0·5000	3	0·2076	0·2067	+0·0009

From the results of the experiments described above it is obvious that sodium paratungstate, easily prepared and stable, makes an excellent flux for use in the rapid determination of carbon dioxide and of nitrogen pentoxide by loss on ignition.

ART. XLII.—*The Influence of Pressure on the Melting Points of Certain Metals;* by JOHN JOHNSTON and L. H. ADAMS.

THE authors have been engaged in developing methods and apparatus by means of which it will be possible to investigate the effect of high temperatures and pressures on certain systems and reactions, and especially those in which water plays an important part. The work has progressed until now we are able to introduce into the bomb current leads and thermoelement wires in such a manner that the wires are all thoroughly insulated electrically, and the joint remains absolutely pressure tight. Thus, it is possible to heat a substance to somewhat over 400°,* under pressures up to 2000 atmospheres;† and to measure both temperature and pressure with precision. Moreover, the whole system, by reason of the special methods of construction adopted, is absolutely free from pressure leaks, even when the bomb is repeatedly closed and opened, disconnected from, and reconnected with, the remainder of the high pressure system. For instance, on one occasion heating was continued for 30 hours continuously at a pressure of 1800 atmospheres, without sensible loss of pressure in the whole interval.

Before proceeding further in the main purpose of the work, it seemed desirable to make a rigorous test of the precision of temperature measurements under these conditions. For this purpose, determinations of metal melting points are suitable by reason of their definiteness. Accordingly it was resolved to investigate the effect of pressure upon the melting point of tin, bismuth, lead and cadmium, the four metals which lie within our present range of temperature. The results are eminently satisfactory, for, as we shall see, a precision in the temperature measurements of about 0·02° was reached, using a thermocouple of copper-constantan, for which an electromotive force of one microvolt corresponds to about 0·02°. It may here be said that the results of this investigation are in entire accord with what was to be expected from the magnitude and direction of the heat change and volume change which accompany the process of melting; and that the small discrepancies between the observed and the calculated values are to be ascribed mainly or entirely to uncertainty in the experimental determinations of the latent heat of fusion and of the change of density on melting.

* The highest temperature the oil will stand without serious charring.
† The limit of the present compression pump.

Briefly, the method pursued in this investigation is as follows: A charge of the metal to be investigated was placed in a suitable apparatus for heating it under pressure; its freezing point or melting point was then determined, at constant pressure, using the Frankenheim method. A small electric resistance furnace supplied the heat; a thermocouple was used to measure the temperature of the metal; and a high boiling paraffin oil served to transmit the pressure.

Description of the Apparatus.

The essential parts of the apparatus are: the bomb, in which the substance to be heated under pressure is placed; the pump, with which to supply the pressure; and a gage for measuring it. In fig. 1 is shown the arrangement of these parts, together with the accessory apparatus consisting of valves, pressure-line connections, oil-reservoir, thermocouple, heating current wires, etc. In this diagram the bomb is drawn to scale but the remainder of the apparatus only approximately so. The bomb itself (the interior of which is shown in greater detail in fig. 3) was built up of a cylinder of machine steel *KK*, on to which were shrunk a ring of nickel steel *RR* and a number of thinner rings of boiler-plate separated from one another by a space of about 4^{mm}. Water enters at W_1, circulates between the rings and around the central cylinder *KK*, and leaves at W_2.* The bomb is closed by means of two hardened steel plugs, *G* and *H*, held in place by a 500 ton hydraulic press, the platens of which are shown at *PP*. On the shoulder (*LL*, fig. 3), of either plug is turned a V-shaped ridge, and on the adjacent shoulder of the bomb a groove to correspond. Between the groove and ridge lies a ring or "washer" of thick sheet copper; by maintaining with the press a force of about 20 tons in excess of that exerted on the inside surface of the plug by the internal pressure, the bomb is effectively and easily closed. Opening the bomb again—after it has been removed from the press—is effected with the aid of a large nut which fits the heavy screw thread cut on *G*.

Experience has shown that without some device for centering the bomb and plugs with respect to the press platens, good and certain closure of the bomb is not possible, time after time. The arrangement used for this purpose is worthy of mention; it is very simple and consists merely of the curved surfaces of *A* and *G* on the one end, and of *A* and *B* on the other. By this arrangement practically perfect alignment is

*This water-cooling device leaves nothing to be desired as regards efficiency, but is somewhat difficult to construct and to make water-tight. It is not of our own design. the bomb having been reconstructed from one which had been designed and built by Dr. A. Ludwig, secured automatically, and a pressure-tight closure of the bomb thereby insured.

FIG. 1.

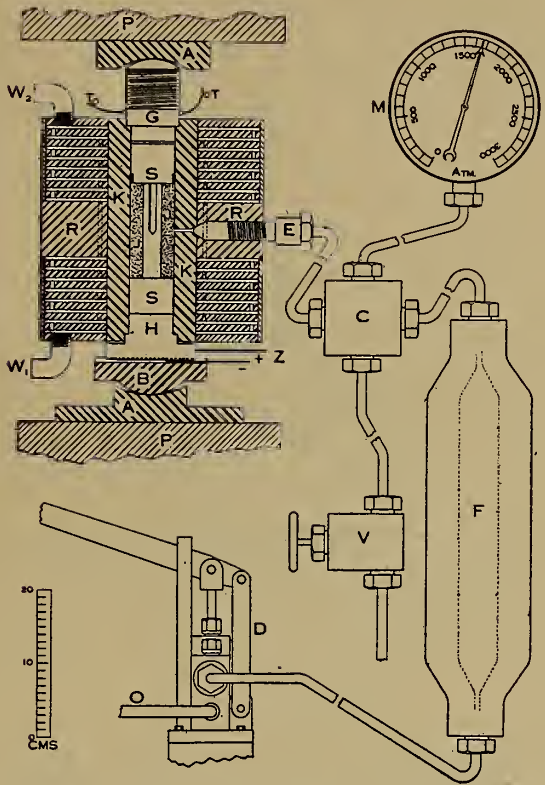


FIG. 1. General arrangement of apparatus. The bomb is drawn to scale; the rest of the apparatus only approximately so. Pressure is supplied by the pump *D*, and transmitted through the system by means of a paraffin oil which has at the same time a high boiling point and low viscosity. *F* is a steel bottle of about one liter capacity; it serves to increase the volume of the system. The valve *V* (shown in detail in fig. 2), is used to lower the pressure in the system. *M* is a Bourdon gage graduated to 3000 atm. in divisions of 50. The connection block *C* affords a 4-way connection between pump, valve, gage, and bomb. The latter consists essentially of a ring of nickel-steel *RR*, and a number of rings of boiler plate shrunk on to a cylinder of steel *KK*. On the outside of the rings is shrunk a thin cylinder. The cooling water enters at W_1 and leaves at W_2. The bomb is closed by means of the steel plugs *G* and *H*, which are held in place by a hydraulic press the platens of which are shown at *PP*. The curved surfaces of *A* and *B* on one end and of *A* and *G* on the other constitute the essential parts of the device used for securing alignment of bomb and plugs. *JJ* is the electric furnace (for details see fig. 3), and *SS* soapstone blocks for thermal insulation at the ends. Thermocouple wires are shown at *TT*, and heating current wires at *Z*.

The electric furnace, depicted at *JJ*, and the arrangement of the interior of the bomb, will be described later on.

The pressure in the system may be raised by means of the pump *D* (fig. 1). It has a plunger 8^{mm} in diameter, and is of the type ordinarily used with hydraulic presses. With this pump we have obtained without difficulty pressures up to 2000 atmospheres. It communicates through the pipe *O* with the oil-supply tank (not shown in the diagram) and forces oil out through the steel bottle *F* and the connection block *C* into the bomb. The bottle *F*, which has a capacity of about one liter, serves to increase the volume of the system, which otherwise would be less than 100^{cc}, and thus makes for greater constancy of pressure during heating and cooling and during changes such as occur when the material under investigation melts or solidifies.

The connection block *C* affords a 4 way connection between the pump, the bomb, the gage, and the release valve *V*. The gage *M*, of the Bourdon type, is a new one manufactured by Schæffer and Budenberg, and was calibrated by them. It is 8 in. in diameter and is graduated up to 3000 atmospheres in divisions of 50. The indications of Bourdon gages, as is well known, are subject to a hysteresis effect; that is, the reading corresponding to a certain pressure may vary slightly, depending on whether the pressure is rising or falling. From various considerations, however, the writers are led to believe that the discrepancy in the present instance is small and that the readings of the gage are subject to a probable error no greater than ± 5 atmospheres,—an accuracy quite sufficient for the present purpose.*

The valve *V* serves to lower the pressure in the system or to release it entirely; it is shown in greater detail in fig. 2, which is drawn exactly to scale. The valve-stem, which ends in a cone fitting into a conical depression in the valve block, is kept in place by the nut *m*. The packing consists of three layers of leather surmounted by a steel disk. The pitch of the screw between stem and nut is identical with that between nut and block; by this means the valve is not jammed down into its seat, when the nut *m* is tightened.

Fig. 2 serves also to illustrate the type of high pressure connection which has proved uniformly satisfactory for making all the connections necessary in work, such as the present, where high pressures are employed. On account of its sim-

* We have under construction an absolute gage, of the piston type described by P. W. Bridgman (Proc. Am. Acad., xliv, 119-251, 1909), by means of which we shall be able to measure pressures with an accuracy of 0·1 per cent. In the present work its use was unnecessary by reason of the comparatively small influence of pressure on the melting points which we have investigated.

plicity of construction and certainty of operation, it seems desirable to describe it more fully.

The end of the pipe *p* is turned off at an angle of 60°; a small round nut is put on, using a left-handed thread, and the whole is held in place by means of the larger nut *n*, which is undercut to receive the smaller nut. The end of the pipe fits into a conical hole also turned accurately at an angle of 60°. An essential part of the procedure is that before the joint is

FIG. 2.

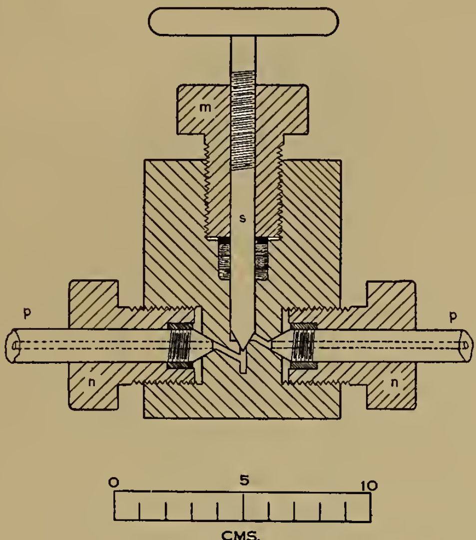


FIG. 2. Details of high pressure valve and connections, drawn to scale. The main body of the valve is of best quality nickel steel. The conical lower end of the valve spindle *s* fits into a conical depression. The leather packing around the spindle is held down by the nut *m*. On either side of valve is shown the type of high pressure connection which has been used for joining various parts of pressure apparatus. The end of the pressure pipe *p* is turned off at 60° and fits pressure-tight into a conical depression. A small round nut is screwed onto the end of the pipe and the whole is held down tight by means of the larger nut *n*.

assembled for the first time, the pointed end of the pipe should be given a blow with a hammer squarely on its end. This treatment enlarges the tip slightly and has the effect of making certain that when the end of the pipe is forced into its seat by screwing up the nut *m* it is the extreme tip that binds on the surrounding metal. This type of joint may occasionally leak when pressure is applied for the first time; increase of pressure, however, makes the joint tight by expanding the tip of the tube against its seat, and when this has once happened, it remains tight indefinitely. Joints such as this have been subjected to pressure up to 8,000 atmospheres, with both liquids and gases; when properly made, they show not the slightest leak whatever. This type of connection possesses the following distinct advantages over other types which have been used for high pressure work; (1) it may be taken apart and put together again *repeatedly* without impairing its efficiency; (2) the joint is tight *every time* and thus there are avoided the troublesome delays so common in high pressure work;* (3) the danger of the whole joint blowing out at high pressure—which may easily happen with ordinary butt joints—is practically obviated, because of the smallness of the bearing surface under all conditions.

The tubing which has been used for all connections is of mild steel, cold-drawn, 12^{mm} in outside diameter and 2^{mm} inside diameter. It stands without rupture pressures of at least 8,000 atmospheres and can easily be bent or twisted if heated to redness.

We shall now proceed to describe the disposition of the interior of the bomb, comprising the arrangements for heating, and for measuring the temperature of, the charge of metal; the details are shown in fig. 3, which is drawn to scale.

The electric furnace *JJ* (fig. 3) was made by wrapping a thin sheet of asbestos paper around a copper tube 25^{mm} in diameter, and winding on this "nichrome" wire (B and S No. 16; 1·3^{mm} in diameter), so that a coil 10^{cms} long with 5 turns per cm. was formed. The whole was inserted in a cylinder of soapstone and the intervening space filled with "magnesite" mixture. Soapstone cylinders, *SS*, afford heat insulation at the ends of the furnace and also serve to fill up the space. One terminal of the heating coil is "grounded" onto the bomb through the brass ring *I*; the other end is led through the lower soapstone plug *S*, the steel plug *H*, and out along a slot cut in the top of the base plate *B*. The thermocouple wires *TT* pass out through the top plug *G*.

There are several ways in which good electrical connection may be made between the inside and the outside of the bomb. The method adopted in the present instance is as follows: a hole about 12^{mm} in diameter is bored in the steel part through which the wire is to pass and a cylinder of soapstone is turned to fit this hole. Through the soapstone is drilled a hole of the same diameter as the wire, which is then threaded through this hole. The soapstone cylinder is inserted in the steel, and

* In this connection we desire to express our indebtedness to Mr. Geo. F. Nelson, to whom is principally due the success of this high-pressure joint, and without whose mechanical skill and ingenuity our work would not have been so far advanced.

rammed firmly into position by applying a force of twenty or thirty tons; this force is communicated through a small steel cylinder of the same diameter, which is properly drilled or grooved so as not to injure or interfere with the wire or wires. In order to prevent the wires being actually squirted out through the holes in the stone, two procedures may be followed.

FIG. 3.

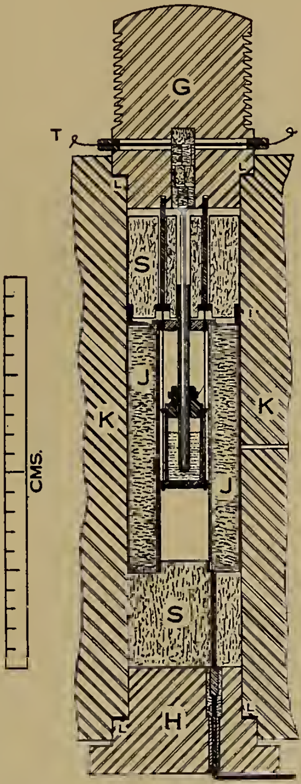


FIG. 3. Electric furnace and interior of bomb, drawn to scale. *JJ* is the furnace, *SS* soapstone blocks for thermal insulation of the ends, and *G* and *H*, the plugs which close the bomb. Freedom from leaks is insured by the use of the rings or "washers" of sheet copper shown at *LL*. Thermocouple wires *TT* are led into the bomb through the upper steel plug *G*. One terminal of the heating circuit is grounded onto the bomb at *I;* the other passes out insulated through *H*. The graphite crucible with thermocouple tube in place is shown suspended from the upper plug.

The soapstone cylinder may be made in two or more parts and the holes for the wires staggered; or the internal part of the wire may be made somewhat larger than the outer part.* The latter method has been adopted in the case of large wires, such as those of the heating circuit. The former method was used for the thermocouple and other small wires. The thermocouple wires are insulated in the horizontal portion of their path through the plug *G* by sections of glass tube, which are kept in place by short plugs of fibre. The heating current wire, after it has passed out through the soapstone, is likewise insulated from the steel plug *H* by the insertion of a thin cylinder of fibre.

The material to be investigated is contained in a graphite crucible of the form depicted in fig. 3. The crucible is held rigidly in position by small steel rods, which screw into the ends of larger steel rods, attached firmly to the plug *G*. The crucible lid, also of graphite, is held in place by means of a small screw-clip (not shown in the figure) fastened to one of the supporting wires. To the crucible lid is fastened by two steel pins the thermoelement jacket which is a porcelain tube, 7^{mm} in diameter. The thermocouple wires are separated from one another, as usual, by means of a small porcelain tube slipped over one of them.

By these methods of construction, motion of the thermoelement, or of its jacket, with respect to the charge, is absolutely prevented, so that we could always be sure that the junction was in the proper position with respect to the crucible, viz., located axially and about 6^{mm} from the bottom of the charge.

Temperature Measurement.

To determine the temperatures, thermoelements of copper-constantan were employed. Three lengths were cut off a reel of No. 30 (B and S) constantan wire ($0{\cdot}25^{mm}$) and were joined separately to lengths of copper wire of the same diameter. Two of these elements were preserved as standards, and gave readings at all temperatures not more than 2 microvolts apart; the third element was fixed in the plunger *G* in the way already described. The differences between this element and the standards amounted to 20–30 microvolts, probably owing to strains set up in it while it was being made pressure tight through *G*.

Before proceeding to the measurements, it was, however, necessary to calibrate the standard elements, since so far as we are aware, no satisfactory calibration of such elements over the temperature range 0° to 400° has yet been made. For this

* An equivalent method which may be used with some wires is to tie a knot which shall be too large to pass through the small hole drilled in the soapstone block.

purpose, we determined, on the standard element, the electromotive force corresponding to the boiling points of water, naphthalene, benzophenone, and the melting point of zinc; while for the temperatures below 100° we compared it with a four-junction element belonging to Dr. W. P. White, the calibration of which is known with an accuracy of a few thousandths of a degree.* The values assigned to the standard temperatures are as follows:†

Naphthalene b.p.	$217{\cdot}7° + 0{\cdot}057\ (p - 760)$
Benzophenone‡ (Merck) b.p.	$305{\cdot}6° + 0{\cdot}063\ (p - 760)$
Zinc, m.p.	418·2°

All temperatures given in the present paper are referred to the above fixed points; we also give the actual electromotive forces observed, so that the temperature may be easily corrected, if a change in the above reference points be rendered necessary by future work.

In all the measurements, the cold junction was immersed in an ice-bath at 0°, and the electromotive force was measured by means of the usual potentiometric arrangement. By this means, an accuracy of 1 microvolt, corresponding to 0·02°, could be easily attained. The results thus obtained for the calibration of the standard element are:

t	*e* (microvolts)	*t*°	*e* (microvolts)
0	0	100·0	4227
24·92	975·7	217·7	10119
50·00	2012	305·6	15007
75·00	3096	418·2	21755

Attempts were made to obtain a single equation which should pass through all the points; but without success. Accordingly, two cubic equations of the form $e = A + Bt + Ct^2 + Dt^3$ were used to calculate the electromotive force corresponding to any given temperature; *e* was computed for every 10° from 10° to 430°; the slight irregularities were evened out by adjustment of the successive differences. From the

* See Phys. Rev., xxxi, 159. Its calibration curve is $e = 155{\cdot}311\ t + 0{\cdot}183\ t^2 - 0{\cdot}00014\ t^3$.

† Cf. Sosman, this Journal, xxx, 6. 1910; Day and Sosman, *ibid*, xxix, 93, 1910. It is to be noted that up to the present there have been only *two* gas thermometer determinations of the boiling points of naphthalene and of benzophenone—one by Crafts (Bull. soc. chim., xxxix, 277-89, 1883) and one by Jacquerod and Wassmer; the former does not claim an accuracy better than 1°, so that the only accurate data at present available are those of Jacquerod and Wassmer.

‡ The b.p. of benzophenone (Merck), according to Waidner and Burgess (Bull. Bureau of Standards, vii, 6), is 0·2° higher than that of benzophenone (Kahlbaum); the b.p. of the latter is 305·4, according to Jacquerod and Wassmer.

table thus obtained, giving e in terms of t, another and more convenient table was constructed, giving t for each even 100 microvolts.

This table is presented in abridged form—for every 500 microvolts—in Table I, in which are also included the E.M.F.'s corresponding to the fixed reference points. Incidentally it may be noticed (1) that a quadratic equation will not express the relation between t and e with sufficient accuracy; for such an equation when passed through the steam, benzophenone, and zinc points misses the naphthalene point by 1·5°; (2) that the cubic equation of the above form fits the data with much greater accuracy than the inverse form of function, $t = Ae + Be^2 + Ce^3$.

TABLE I.

Abridged Standard Curve for Copper-constantan Elements.

Microvolts	t	Diff.	Microvolts	t	Diff.
0	0		11500	243·19	
500	12·94	1294	12000	252·28	909
1000	25·53	1259	500	261·30	902
500	37·77	1224	13000	270·25	895
2000	49·72	1195	500	279·14	889
500	61·40	1168	14000	287·97	883
3000	72·83	1143	500	296·75	878
500	84·05	1122	*14995*	*305·4*	
4000	95·07	1102	15000	305·48	873
4227	*100·00*		500	314·15	867
500	105·88	1081	16000	322·76	861
5000	116·52	1064	500	331·31	855
500	127·00	1048	17000	339·80	849
6000	137·32	1032	500	348·24	844
500	147·50	1018	18000	356·62	838
7000	157·55	1005	500	364·95	833
500	167·48	993	19000	373·24	829
8000	177·29	981	500	381·49	825
500	186·99	970	20000	389·70	821
9000	196·58	959	500	397·87	817
500	206·07	949	21000	406·00	813
10000	215·47	940	500	414·09	809
10119	*217·7*		*21755*	*418·2*	
500	224·79	932	22000	422·14	805
11000	234·03	924	500	430·15	801
500	243·19	916	23000	438·12	797

This table may be used for any element with the aid of its deviation curve, which is obtained by plotting at two or more known temperatures the differences between the readings of the element in question and the standard curve. Its use thus saves much calculation and recalculation of thermoelement curves.* The uncertainty in the temperatures deduced in this way from the above table should, we believe, not exceed 0·1° on the temperature scale we have chosen; and is much smaller than the present uncertainty in the absolute value of the temperature scale—an uncertainty which is about 1° at 450°. The readings may be immediately referred to any other scale of temperature by including in the deviation curve the differences between the two scales. Temperature differences, however, over a small range are probably accurate at least to 0·02°, regardless of slight discrepancies in the temperature scale, and of possible errors in the interpolation formula. For this reason the values of temperatures and differences in Table I are given to hundredths of degrees.

Melting Point Determination.

Briefly, the method pursued in the determination of the melting points of the various metals under pressure was as follows: A charge of the proper amount of metal having been placed in the graphite crucible, the whole was heated somewhat above the melting point of the metal (a thin layer of oil on the surface of the metal prevented oxidation). The porcelain tube which serves to protect the thermocouple from the surrounding metal, attached to the crucible lid, was fitted into position. Crucible, steel plug (*G*, fig. 3), soapstone cylinder, etc., were then assembled and placed in the bomb, which was thereupon set in position on the lower platen of the press, and connected with the high pressure line (at *E*, fig. 1). The upper press platen was forced down until the upper plug (*G*) slipped into place and centered itself; the electrical connections were made, the cooling water† turned on, and all was in readiness for the actual measurements.

The pressure *inside* the bomb was increased by means of the pump *D*, while simultaneously excess pressure in gradually increasing amount,‡ was applied by means of the press, on the plugs *G* and *H*. When the desired pressure was attained, the freezing point of the metal was determined as usual by the Frankenheim method.

No account was taken of the effect of pressure on the thermoelectric E.M.F. This influence is very slight in those

* This matter is more fully treated in Sosman, *loc. cit.*, *q. v.*

† A supply of both hot and cold water was available; for most of our experiments hot water was used to "cool" the bomb. By the use of hot water in this connection a smaller heating current is required; in addition, this plan makes for more uniform temperature distribution within the bomb.

‡ When the pressure was decreased again by releasing the valve *V*, a corresponding diminution in the external pressure exerted by the press was effected by suitable manipulation of the proper valves.

cases which have been investigated: namely, for couples composed of platinum or other metals with mercury the difference of reading produced by a change of pressure of 1000 atmospheres is only about 0·2 microvolts.* It is therefore practically certain that the error introduced by neglecting this variation does not exceed one or two microvolts, i. e., it is less, and probably much less, than 0·05°.

It may be stated that we were able to get very sharp points; it is obvious that the temperature did not stay long at the melting point, on account of the smallness of the charge and of the rapid rate of cooling, but the break in the curve was perfectly definite and reproducible. This is shown by the results, which have been brought together in chronological order in Table II, for the four metals investigated, namely, tin, lead, cadmium, and bismuth.

In the second column is given the pressure in the system in atmospheres at the instant of freezing. The third column shows the observed reading of the thermoelectric E.M.F. at the freezing point; while in the last column these latter values are converted into degrees (uncorrected, that is, taken directly from Table I). Freezing points rather than melting points were taken since the former were with our apparatus much the sharper. Melting points were taken in a few cases, however, and found to agree well with the freezing point under the same pressure.

A study of the results in Table II shows conclusively (1) that the melting point of a given metal under a given pressure is reproducible, since measurements made on different days, with different charges are in good agreement; and (2) that since the same results were obtained with increasing and decreasing pressure, the hysteresis effect of the gage was not large enough to interfere seriously with the accuracy of the measurements.

Relation Between Melting Points and Pressures.

It was expected that the change in melting point, Δt, would be a linear function of the pressure P. Accordingly, the straight line, $t = a + bP$, which best fits the data, was calculated by the method of least squares, from the observations with each of the four metals used. The results of these calculations are shown in Table III. In the first column of each table is given the pressure arranged in ascending order of magnitude. Columns 2 and 3 show respectively the observed change of melting point and that calculated from the least square curve. The differences between observed and

* E. Wagner, Ann. d. Physik., xxvii, 955, 1908; Hörig, *ibid.*, xxviii, 371, 1909.

Table II.

Direct Experimental Results.

Date	Pressure in atmospheres P	Freezing point in microvolts	Freezing point in degrees* (uncorrected) t'
	Tin		
Jan. 3	1000	10995	233·89
	750	10952	233·09
	2000	11174	237·18
	1490	11081	235·47
	1000	10994	233·87
	500	10904	232·20
	2000	11174	237·18
Jan. 16	500	10907	232·26
	1000	10999	233·96
	1995	11170	237·11
	Lead		
Jan. 10	500	16399	329·26
	1000	16641	333·38
	1490	16876	337·35
	2000	17114	341·38
	770	16536	331·59
	505	16409	329·43
	350	16332	328·12
	250	16293	327·46
	150	16238	326·53
	Cadmium		
Jan. 14	1500	16331	328·11
	1500	16333	328·14
	2000	16524	331·39
	2000	16526	331·42
Jan. 16	1515	16352	328·47
	1010	16162	325 24
	512	15976	322·06
	350	15912	320·97
	Bismuth		
Jan. 21	500	12860	267·71
	1000	12746	265·67
	998	12748	265·71
	1550	12655	264·04
	2010	12551	262·18
	1480	12662	264·17

* These temperatures were read directly from the standard curve, no account being taken of the differences in electromotive force of the element actually used and the standard element. Since, however, these differences were always small and correspond to less than 1·0°, and since the standard curve changes in curvature very slowly, no error is introduced thereby into the change of melting point caused by pressure, the quantity in which we are chiefly interested.

TABLE III.

Change of Melting Points with Pressure.

Pressure in atmospheres	Change of melting point: observed	Change of melting point: calculated	Difference
		TIN	
P	$\Delta t = t' - 230{\cdot}61°$	$\delta t = 0{\cdot}003275\ P$	$\Delta t - \delta t$
500	1·59	1·64	— 0·05
500	1·65	1·64	+ 01
750	2·48	2·46	+ 02
1000	3·26	3·28	— 02
1000	3·28	3·28	00
1000	3·35	3·28	+ 07
1490	4·86	4·88	— 02
1995	6·50	6·54	— 04
2000	6·57	6·55	+ 02
2000	6·57	6·55	+ 02
		BISMUTH	
	$\Delta t = 269{\cdot}37 - t'$	$\delta t = 0{\cdot}003548\ P$	
500	1·66	1·77	— 0·11
998	3·66	3·54	+ 12
1000	3·70	3·55	+ 15
1480	5·20	5·25	— 05
1550	5·33	5·50	— 17
2010	7·19	7·12	+ 07
		CADMIUM	
	$\Delta t = t' - 318{\cdot}81$	$\delta t = 0{\cdot}006288\ P$	
350	2·16	2·20	— 0·04
512	3·25	3·22	+ 03
1010	6·43	6·35	+ 08
1500	9·30	9·43	— 13
1500	9·33	9·43	— 10
1515	9·66	9·53	+ 13
2000	12·58	12·58	00
2000	12·61	12·58	+ 03
		LEAD	
	$\Delta t = t' - 325{\cdot}35$	$\delta t = 0{\cdot}008026\ P$	
150	1·18	1·20	— 0·02
250	2·11	2·01	+ 10
350	2·77	2·81	— 04
500	3·91	4·01	— 10
505	4·08	4·05	+ 03
770	6·24	6·18	+ 06
1000	8·03	8·03	00
1490	12·00	11·96	+ 04
2000	16·03	16·05	— 02

calculated values, as may be seen by referring to the fourth column, are on the whole quite small; indeed the deviation of the results from a straight line is no greater than the probable error of the observations. In other words, no indication of a tendency of the pressure-temperature curve to bend toward the pressure axis can be observed. This is confirmed by inspection of the graphs reproduced in fig. 4, which were obtained by plotting t or Δt against P for each metal.

FIG. 4.

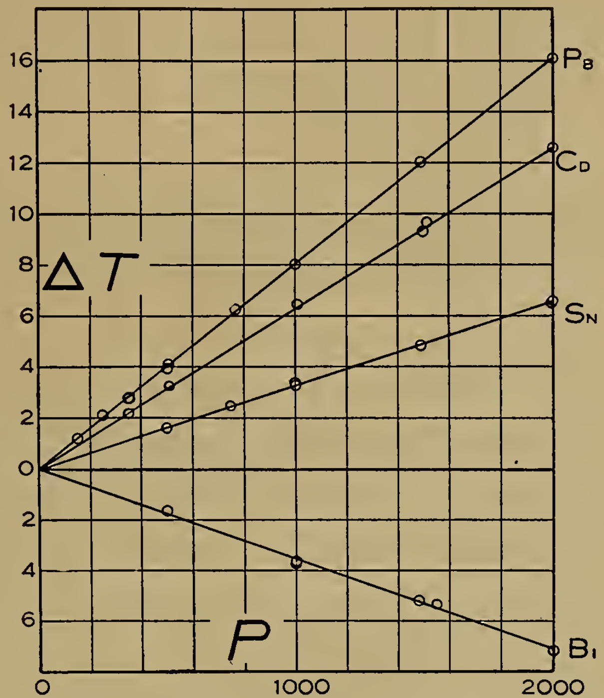


FIG. 4. Diagram showing the relation of the change of melting point ΔT to the pressure P (in atmospheres) for each of the four metals studied. The relations between ΔT and P, it will be noted, are represented with great exactness by straight lines. The melting point of bismuth decreases with pressure while that of the other metals increases.

It was thought that it would be of interest in this connection to calculate from the Clausius-Clapeyron equation the change of melting point with pressure. We may write the equation

$$T\frac{dp}{dT} = \frac{Q}{dV} \quad \text{or} \quad dt = \frac{T(V_l - V_s)\,dp}{42720\,q}$$

where dt is the change in melting point for the change in pressure dp, T is the absolute temperature of melting, V_l

and V_s are the volumes of 1 gram of the metal at the melting point in the liquid and solid states respectively, and q is the latent heat of melting in calories per gram.

A number of measurements not agreeing among themselves are recorded in the literature on the latent heat and volume change on melting of Cd, Pb, Bi, and Sn. We have made use of the data of Person* for the latent heat of melting, and of Vicentini and Omodei† for the change of volume at the melting point, to calculate by means of the formula, the change of melting point per 1000 atmospheres for each of the four metals. These data were chosen for the sake of uniformity and because we believed them to be the best available. The results of the calculation follow :

	I	II	III	IV	V
Metal	Latent heat: cal. per gram. q	Vol. change on melting cc per gram. $V_l - V_s$	δt per 1000 atm. calc. from vol. change and latent heat	δt‡ per 1000 atm. calc. from obs. change of m. p. with pressure	Probable error§ of coefficient in col. IV
Sn	14·25	0·003894	+ 3·34	+ 3·28	± 0·02
Cd	13·7	0·00564	+ 5·91	+ 6·29	± 0·04
Pb	5·37	0·003076	+ 8·32	+ 8·03	± 0·03
Bi	12·6	0·00342	− 3·56	− 3·55	± 0·08

The agreement between the values given in columns III and IV is close—in fact, closer than might be expected when we consider the uncertainty in the latent heat and volume change of the metals involved.

The change of melting point with pressure of tin and bismuth has been measured by Tammann.‖ He found for dt/dp per 1000 kg/cm², 2·2 for tin and 3·9 for bismuth. His calculated values (by the Clausius-Clapeyron equation and using, as it happens, the same data for latent heat and volume change as those we have employed) are 3·3 and 3·3 for tin and bismuth respectively.¶ It is worth while noting that Tammann made his temperature measurements with a thermoelement of Pt—Pt Rh and a direct-reading galvanometer. This fact is sufficient to explain the discrepancy between his results for tin and bismuth and ours for the same metals.

* Ann. Physik, lxxv, 462; lxxvi, 432, 596, 597.

† Beibl. Ann. Physik, xii, 176.

‡ These coefficients, are, of course, the δt (× 1000) of the third column of Table III.

§ For calculation of probable error of the coefficient *cf.* Merriman, Method of Least Squares, 6th ed., Chapter on the Precision of Observations.

‖ Zs. anorg. Chem., xl, 54, 1904.

¶ 3·3° per 1000 kg/cm² is equivalent to 3·4° per 1000 atm. Apparently, Tammann's calculated value for bismuth is in error by about 2 units in the second significant figure.

Melting Point of the Metals at Atmospheric Pressure.

The melting points of the samples of metals used in this investigation were determined with both copper-constantan and Pt—Pt Rh elements which were calibrated, as stated above, in steam, at the boiling points of naphthalene and benzophenone, and at the melting point of zinc.*

Metal	Source	Melting point*
Sn	Baker's	231·0
Bi	"	270·7
Cd	Kahlbaum's	320·4
Pb	Baker's	326·7

These melting points are in very close agreement with those published by the Bureau of Standards, when the difference in temperature scale is taken into account. Incidentally, the melting points of Kahlbaum's tin and lead were measured. The result for tin was 230·5° and for lead, 326·7°.

Summary.

1. There has been designed and built an apparatus suitable for studying chemical and physical reactions at temperatures up to 400° and under pressures up to 2000 atmospheres. Both temperature and pressure in the reaction zone may be measured with fair accuracy.

2. The change with pressure of the melting point of tin, bismuth, lead, and cadmium has been measured; it was found to be a linear function of the pressure within the limits of experimental error.

3. By substitution in the Clausius-Clapeyron equation of the data of Vicentini and Omodei on the volume change at the melting point, and of Person on the latent heat of fusion, dt / dp was calculated for each of the four metals. The calculated values show satisfactory agreement with those observed.

4. Incidentally, the melting points of tin, bismuth, cadmium, and lead were determined, and a standard curve for the calibration of copper-constantan elements at temperature from 0° to 425° is given.

Geophysical Laboratory,
Carnegie Institution of Washington,
March 25, 1911.

* The values assumed for napht. bp., benzo. bp., Zn, mp. being 217·7, 305·4 and 418·2 respectively. Cf. *ante* p. 509, foot-note.

ART. XLIII.—*A New Occurrence of Pearceite*; by FRANK R. VAN HORN and C. W. COOK.

Introduction.

IN the summer of 1908, Mr. R. B. Cochran, formerly superintendent of the Compania Metalurgica Mexicana at Sierra Mojada, Coahuila, Mexico, presented the Department of Geology and Mineralogy at Case School of Applied Science with several specimens of silver, copper and lead minerals from the Veta Rica mine at the locality mentioned above. We wish to take this opportunity of thanking Mr. Cochran, both for specimens and much useful information concerning the district.* One of the minerals was recognized as polybasite, but blowpipe tests showed that it contained chiefly arsenic with little if any antimony, and must, therefore, be pearceite. This in itself was interesting, since the mineral has been found previously only at four other localities, namely: Schemnitz, Hungary in 1833,† Arqueros, Chile, in 1879,‡ Aspen, Colorado, in 1892,§ and Marysville, Montana, in 1896.‖ The pearceite also occurred in well-defined crystal aggregates, and likewise appeared to be twinned, so that the specimens were sent to the University of Michigan, where their crystallographic properties were investigated by the junior author.

Geography and Local Geology.

Sierra Mojada is the name of a town as well as that of a range of mountains which perhaps more properly might be called hills. The region is situated in the extreme western part of the State of Coahuila, Mexico. It is reached from Escalon on the Mexican Central railroad, a distance of 494 miles south of El Paso, Texas. From Escalon, the Mexican Northern railroad runs 78 miles northeast, and terminates at Sierra Mojada, which lies in a valley about three miles wide. This valley is bounded on the south by the range of hills called Sierra Mojada, and on the north by other hills called Sierra Planchada. Ore was first discovered in 1878, and is found for a distance of about three miles along near the base of Cretaceous limestone cliffs

* A complete description of this region and geological occurrence of the ores was given at the Pittsburg meeting of the Geological Society of America, Dec. 29, 1910, in the paper entitled "The Occurrence of Silver, Copper and Lead Ores at the Veta Rica Mine, Sierra Mojada, Coahuila, Mexico," by Frank R. Van Horn.

† H. Rose, Pogg. Ann., xxxiii, 158, 1833.

‡ Domeyko, Min. 393, 1879.

§ Penfield-Pearce, this Journal, xliv, 17, 1892.

‖ Penfield, ibid., ii, 18, 1896.

which constitute the Sierra. The ore occurs at or near the contact of the limestone with a rock which is locally called conglomerate, although others have named it a porphyritic breccia.* However, the rock seems to be either a decomposed rhyolite or a rhyolite tuff, since it consists chiefly of fine-grained quartz and orthoclase, much decomposed. Along the contact of the two rocks there are many indications of faulting, such as breccias, slickensides, and clay selvages. It seems not improbable that the valley was made by faulting, which has left the cliffs as a fault scarp. There are about 19 mines in the district, which, even in 1900, produced about 200,000 metric tons of ore. Up to 1893, it was a silver-lead camp in which the predominant ore was argentiferous cerussite with small amounts of galena. In 1893, however, in the western part of the region, large bodies of silver-copper ore were found in the San Jose mine in addition to the silver-lead ore bodies. Similar silver-copper ores were afterward found on adjoining properties, of which the Veta Rica mine is one. The latter has proven to be the richest if not quite the largest mine in the camp.

Ores and Minerals Found at Veta Rica Mine.

Although Sierra Mojada is still predominantly a silver-lead camp, nevertheless the chief output of the Veta Rica, which is one of the largest mines in the district, is known as a siliceous silver lime containing workable amounts of copper. The chief ore is either a red or dark gray magnesian limestone, impregnated with quartz, cerargyrite, native silver, and sometimes barite. In the specimens of this type which were subjected to investigation, no well-defined copper minerals were observed, although it is said to contain from 0·6 up to 2 per cent of copper.

In another part of the mine, along a fissure in the limestone, copper minerals containing silver are found. A rather interesting fact is that on the same level along this fissure are two ore bodies of this type, but one consists of sulphides while the other is entirely oxidized. Specimens from the former presented by Mr. Cochran consist of massive chalcocite, chalcopyrite, and a little covellite. Also small amounts of galena and sphalerite are said to occur at this point. About 120 meters west of this ore body, but at the same horizon and on the same fissure, is the oxidized body, which consists of native copper, cuprite, azurite, and malachite associated with gypsum. The water channel which caused the oxidation of this body has evidently been prevented in some manner from reaching the sulphides.

* The Sierra Mojada, Coahuila, Mexico, and Its Ore Deposits, by James W. Malcolmson, Trans. Amer. Inst. of Min. Eng., xxxii, 105, 1902.

Occurrence of the Pearceite.

In 1906, while working along the northern part of the silver-copper siliceous lime ore body, a fault was encountered having a displacement of about 40 feet. Following along the fault plane, silver-copper ores of great richness were discovered, along with considerable barite as gangue mineral. Minerals observed from this point were native silver, argentite, proustite, pearceite, and erythrite. The latter occurrence is rather peculiar, since it is the only oxidation product, if native silver is excepted. Furthermore, there have been no other cobalt minerals noted either from this mine or the district as a whole, although it would seem as if some cobalt arsenides should be present. There were said to be about 200 pounds of pearceite crystals found, but on account of the heavier government tax on high grade ores, practically the entire amount was ground up and distributed through poorer grades. However, eight specimens were presented by Mr. Cochran, while a ninth aggregate was very kindly loaned to us by Senor Felipe Borrego, formerly with the Veta Rica mine, but at present foreman of the Guadalupe mine at Cerro de San Pedro, San Luis Potosi, Mexico.

Crystallography.

The crystallography of pearceite was studied first, in 1896, by Penfield,* who worked on crystals from the Drumlummon mine, Lewis and Clark County, Marysville, Montana. At this time he proposed the name pearceite for polybasites in which arsenic was in excess of antimony. He states that it crystallizes in the monoclinic system and possesses a rhombohedral symmetry, due, in all probability, to twinning similar to that of the micas. On account of this rhombohedral symmetry, which was likewise exhibited by all the material under investigation, as well as the similarity on angles for several forms, and the imperfection of the crystals, definite orientation was found to be impossible. Also, an attempt to obtain etching figures, using nitric acid as the solvent, met with failure. Therefore, although several undoubtedly new forms are present, it is thought best to limit the present crystallographic report to a discussion of a new twinning law.

The pearceite occurs in aggregates of twin crystals, more or less perfectly developed, which show striations and vicinal planes. The individual crystals are tabular in habit with the basal pinacoid as the predominating form; the pyramids and domes occurring as very narrow faces. Unfortunately most of the edges of the crystals were broken off, as the mineral is very brittle. The basal pinacoid is characterized by the presence of

* S. L. Penfield, this Journal, ii, 19, 1896.

triangular figures. According to Hintze* the sides of these, figures are parallel to the faces (111), ($1\bar{1}1$), and ($\bar{1}01$).

The new twinning plane, which is practically present on all of the specimens, is likewise parallel to one of the sides on the triangle. It must, therefore, lie in either the unit prism-basal pinacoid zone or the ortho-basal pinacoid zone and the twinning plane must be either a pyramid or an orthodome.

The examination of the twinning planes of a large number of monoclinic minerals shows that twinning in the ortho-basal pinacoid zone is very common, whereas the pyramids function but rarely as twinning planes. The new twinning plane on pearceite has, therefore, been tentatively assumed to be parallel to the orthodome (702) on the basis of the twinning angle, which is 34° 42′. The average of the measurements, made on a number of different crystals, gives for the angle between the basal pinacoid (100) and the orthodome (702) a value which agrees quite closely with the calculated value, as may be seen from the following :

	Observed	Calculated
(100) : (702)	72° 39′	72° 53′

Fig. 1 shows the general character of the crystal aggregates as well as the presence of reëntrant angles. The triangular striations on the basal pinacoid are seen on numbers 1, 2, and 3. Parts of the best crystal measured are shown under 8, 9, and 10, but unfortunately the original was broken while determining the specific gravity. Nevertheless the reëntrant angles are still visible on all three fragments. Number 7 is an aggregate of small thin plates and closely resembles some specular hematites in micaceous appearance.

Chemical Composition.

The empirical formula which was proposed in 1896 by Penfield,† and was accepted, is $(Ag,Cu)_9(As, Sb) S_6$ or $9(Ag,Cu)_2S.(As, Sb)_2S_3$. This is analogous to the formula for polybasite, $(Ag,Cu)_9(Sb,As) S_6$, which was proposed by Heinrich Rose in 1829.‡ A portion of one of the Sierra Mojada crystals which seemed free from all impurities was analyzed by Dr. N. A. Dubois of the Chemical Department of Case School of Applied Science with the following results:

* C. Hintze, Handbuch der Mineralogie, 1904, p. 1167.
† Op. cit., page 18.
‡ H. Rose, Pogg. Ann., xv, 575, 1829.

	Percentage found	Atomic weights	Combining weights	Ratio	Proportion found	Propor'n taken
S	17·46 ÷	32·07	= ·5444	=·5444÷·1008 =5·400×2=	10·80=	11
As	7·56	74·96	= ·1008	=·1008÷·1008 =1·000×2=	2·00=	2
Sb	0·00					
Ag	59·22÷	(107·88×2)=	·2744 }	=·3975÷·1008 =3·943×2=	7·886=	8
Cu	15·65	(63·57×2)=	·1231 }			
	99·89					

The International Atomic Weights for 1911 were employed in the calculations, and twice the atomic weights of silver and copper were used on the basis that these elements are isomorphous

Fig. 1.

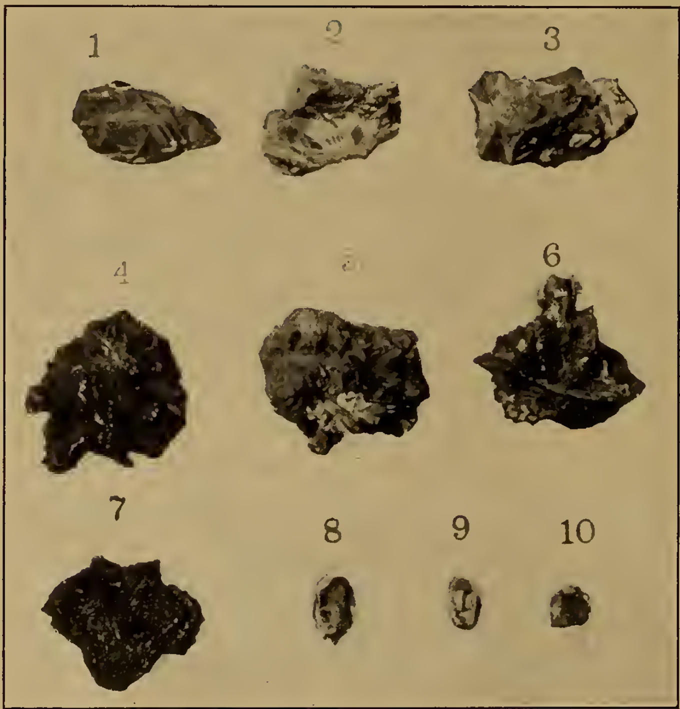


Fig. 1. Pearceite crystals from Veta Rica Mine, Sierra Mojada, Mexico.

in the compound $(Ag,Cu)_2S$. No antimony was found, so that evidently the pure pearceite molecule is present, as was also the case with the Montana occurrence mentioned at the beginning of this article. At the three other localities cited a small amount of antimony was determined. Although iron was present in small amounts in three of the previous occurrences, and zinc in one of them, neither of these elements was observed in the Veta Rica pearceite. A glance at the proportion of combining weights found in this analysis shows an extremely close approximation to the formula $(Ag_2Cu_2)_8As_2S_{11}$ rather than to that of the accepted one, $(Ag_2Cu_2)_9As_2S_{12}$. The theoretical composition of the Sierra Mojada pearceite was calculated for the latter formula on the basis that the ratio of silver to copper was 2744 : 1231, as follows:

Atomic weights		Molecular weights	Theoretical perc'tage	Percentage found	Difference	Theo. percent. of Ag_9AsS_6
S = 32·07	S_{12}	= 384·84	17·27	17·46	+·19..	15·54
As = 74·96	As_2	= 149·92	6·73	7·56	+·83..	6·05
Ag = 107·88	$Ag \frac{2744}{3975}$ of 107·88 × 18	= 1339·92	60·12	59·22	−·90..	78·41
Cu = 63·57	$Cu \frac{1231}{3975}$ of 63·57 × 18	= 353·88	15·88	15·65	−·23..	
		2228·56	100·00	99·89		100·00

It is seen that the differences between the theoretical composition and that which was actually found are quite considerable, so that the theoretical composition required by the formula $(Ag_2Cu_2)_8As_2S_{11}$ was likewise calculated, using the proportion of silver to copper as above, with the following results:

	Molecular weights	Theoretical percentage	Percentage found	Difference	Theoretical percentage of $Ag_{16}As_2S_{11}$
S_{11} =	352·77	17·56	17·46	—·10	15·84
As_2 =	149·92	7·46	7·56	+·10	6·72
Ag_{16} =	1191·92	59·32	59·22	—·10	77·44
Cu_{16} =	314·56	15·66	15·65	—·01	-----
	2009·17	100·00	99·89		100·00

A comparison of the results obtained above shows that the analysis of Sierra Mojada pearceite conforms much more closely in all respects to the formula $(Ag_2Cu_2)_8As_2S_{11}$ or $(AgCu)_{16}As_2S_{11}$ than to $(Ag_2Cu_2)_9As_2S_{12}$ or $(AgCu)_{18}As_2S_{12}$. A comparison of other analyses of pearceite and polybasite will follow this article, at a later date, in another paper by the senior author.

Physical Properties and Pyrognostics.

The physical properties of the pearceite from the Veta Rica mine are very similar to those from the Drumlummon mine, Marysville, Montana, described by Penfield.* The mineral is black, and has a splendent metallic luster. It has a very pronounced conchoidal fracture, and is exceedingly brittle, which accounts for the fact that not enough crystal faces remained in the pyramid and prism zones to properly orientate the mineral and accurately determine the new twinning law. A specific gravity of 6·067 was obtained from the average of four determinations on two different crystals, in which the separate results were 6·01, 6·10, 6·02, and 6·14. A fifth result obtained was 6·33, which the writer feels is not accurate. However, if the average of all five were taken, the maximum specific gravity possible would be 6·12.

Although the streak is black, and the mineral is practically opaque, nevertheless if very small pieces are observed with a high power objective in convergent light, a brownish green color is apparent on the edges. No change of color is perceptible if the mineral is rotated between crossed nicol prisms.

In a closed tube in the flame of a spirit lamp, the mineral decrepitates, fuses easily to a black globule, and deposits a white crystalline sublimate consisting of octahedrons of As_2O_3. The globule when heated with the blowpipe gives a yellow sublimate of As_2S_3. In the open tube it gives a sulphurous odor, and a white crystalline coating of As_2O_3. On charcoal, the mineral gives a faint white coating of As_2O_3 and the odor of SO_2. After continued blowing, a malleable bead is obtained. If this is treated with borax on platinum wire, it alloys with the wire but gives a bead which is green while hot but blue when cold, indicating copper. Continued fusion of the alloyed wire gave a bead which was dark green when cold.

Geological-Mineralogical Laboratory,
Case School of Applied Science, Cleveland, Ohio, February, 1911.

* Op. cit., page 23.

ART. XLIV.—*Mollugo verticillata* L.; by THEO. HOLM. (With nine figures drawn by the author.)

IN several respects our common Carpet-weed, *Mollugo verticillata* L. is quite an interesting plant, and there are several points in its structure, external as well as internal, which have not been studied so far; as a matter of fact, a number of our commonest plants are actually but little known, and it so happens that *Mollugo* illustrates an excellent example of anisophylly, beside that the internal structure, of the leaf especially, is somewhat anomalous when we compare the other members of the *Ficoideæ*, to which the genus is now generally referred. For several reasons, which will be shown in the subsequent pages, *Mollugo* is somewhat out of place in this family, which contains so distinct and utterly different types as *Tetragonia*, *Aizoon* and *Mesembryanthemum*; moreover, Jussieu,* who established the family *Ficoideæ*, did not include *Mollugo*.

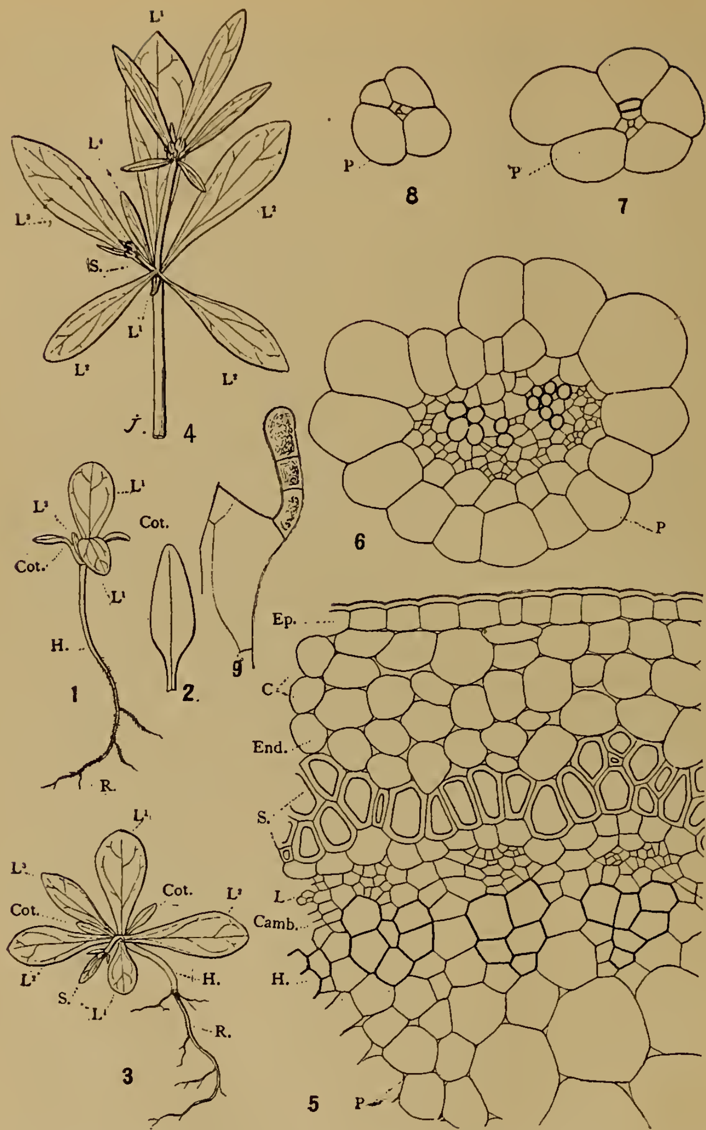
Now in regard to anisophylly, which is illustrated so very plainly in this species of *Mollugo*, the term was first proposed by Wiesner, and expresses the unequal size of leaves of plagiotropic shoots in accordance with their position on the upper or lower face of the shoot; more frequently the leaves of the upper face are of a smaller size than those of the lower, but the opposite case is known also. Anisophylly occurs in very many plants, cryptogamous as well as phænogamous, herbs as well as trees; it may be characteristic of certain genera, or only of certain species within the same genus.† It is readily appreciated that light must be one of the factors to produce anisophylly, especially when we consider the branches of a tree where the peripheral leaves are usually much larger than the inner ones, on account of their fuller exposure to the sunlight. However, this is not always the case, and, as stated by Goebel (l. c.) there may be several other factors, beside light and position to horizon, that produces anisophylly. Already in the buds of *Aesculus* anisophylly may be observed, thus a long time before they open, and etiolated specimens of *Goldfussia* and *Elatostemma* exhibited the same degree of anisophylly as other specimens grown under normal conditions.

Now in regard to *Mollugo*, the foliage is in the Synoptical Flora of North America‡ described as "pseudo-verticillate," a term on linguistic grounds inadmissible; moreover the leaves are opposite, and very plainly so. The leaf-arrangement, as

* Genera plantarum, Paris, 1789, p. 315.

† Compare Goebel: Organographie der Pflanzen, Jena, 1898, p. 85 *seq.*, where several cases are described, and the most important literature cited.

‡ 1895–1897, p. 257.



well as the anisophylly, may be observed already at the seedling-stage. Our figure 1 illustrates a seedling, in which we notice the primary root (R.), the erect hypocotyl (H.), the cotyledons (Cot.), and the first leaves proper. These leaves are represented by two pairs, the first (L^{1}) being almost fully developed, while only one (L^2) is as yet visible of the second pair. It is now interesting to notice that the first two leaves (L^1) are of unequal size, the posterior being the larger, thus demonstrating the fact that, in this case, the anisophylly is not produced by any difference in exposure to light; the little shoot is erect, and the leaves are equally exposed to the effect of the sunlight. Nevertheless, as shown in figure 3, three distinct pairs of leaves develop in this way, with a remarkable tendency to attain a larger size on one side of the shoot than on the other. This plant (fig. 3) is, also, a young seedling with the cotyledons (Cot.) plainly visible, and we notice, furthermore, a very distinct, central internode which bears a few flowers and green leaves. At this stage the hypocotyl (H.) has become bent down toward the ground by the weight of the leafy rosette; thus we have before us an indication of the future habit of the plant already illustrated by this very young specimen, viz.: a basal rosette of crowded, opposite leaves of unequal size, and a terminal shoot which begins with a stretched, plagiotropic internode terminated by an inflorescence, which is preceded by a few pairs of leaves. There is, thus, an alternation of short and of long internodes, while the foliage shows the same anisophylly throughout, the leaves upon, or nearest, the upper face being distinctly smaller than those of the lower face of the shoot. No stipules are developed, but the leaves, the large as well as the small, bear pluricellular, glandular hairs (fig. 9) at the base, near the margin and along the dorsal face of the midrib. Very minute leaves occur, also, at the base of some of the flower-stalks and represent fore-leaves, as described by Eichler.* The apical portion of a branch from a mature specimen is represented in figure 4. We notice in this branch the long internode *J*, which bears four pairs of leaves, of which the first pair (L^1) contains the smallest and largest of all the leaves developed, the inner pair (L^4) show the gradual decrease in size when compared with the outer (L^2–L^3), and one of these is frequently completely suppressed. Furthermore is to be noticed that the lateral shoot (S.) is developed from the axil of a large leaf (L^3) on the outer face of the mother-shoot.

The anisophylly illustrated by *Mollugo* thus shows the much farther development of the leaves of the lower face of the stem, than of those of the upper. Furthermore, the ramification of the stem shows us, that the strongest lateral branches constantly develop from the axils of the largest leaves, rendering the complete growth of the plant horizontal, and more or less closely appressed to the ground. As already mentioned, this

* Blüthendiagramme, vol. ii, Leipzig, 1878, p. 119.

particular habit of the species with the unequal development of the foliage and with the plagiotropic shoots, is noticeable at a very early stage of the plant, beside that it occurs in small, depauperate specimens where only two or three branches may be developed; in other words, the species shows a typical example of what Goebel has designated as "habituelle Anisophyllie" (l. c. p. 93). This peculiar deviation in the development of foliage is not, however, characteristic of all herbs with prostrate stems; it does not, for instance, occur in such plants as *Euphorbia maculata*, nor in *Stellaria media*, *Callitriche Austinii* and many others. It seems to be restricted to certain genera of widely different plants, as stated above, and we might mention at this place, that it is exceedingly well represented by *Abronia fragrans* Nutt. In this plant the stems are prostrate with the leaves opposite, and the ramification is plainly sympodial. Each shoot is terminated by an inflorescence, and the size of the leaves in each pair is very unequal. Furthermore, it is from the axil of the larger leaf that the long shoot becomes developed, which repeatedly terminates into an inflorescence and so on. From the axil of the smaller leaf, on the other hand, only a very short branch becomes developed, resulting in a very unequal structure of the whole shoot, a succession of branches, alternately to the right and left side of the main axis. *Abronia micrantha* Torr. shows exactly the same structure, but it is a smaller plant, thus the anisophylly and the sympodial ramification is less plainly to be observed. In the near ally Oxybaphus of much the same habit, the anisophylly is not to be observed, not even in the species with the leaves broad, although the ramification is the same, sympoidal.

Another peculiarity possessed by *Mollugo verticillata* is the alternation of long and short internodes, as shown in figure 4; this type of structure is not very common, but represented by several monocotyledonous and dicotyledonous genera, viz: *Munroa*,* *Eriochloa*, *Cynodon*, *Androsace*, *Chimaphila*,† *Erigeron* (*flagellaris* Gr.), etc. In regard to the inflorescence, this is in the Synoptical Flora (l. c.), only described as "flowers 2–5 from each node, slender-pedicelled, subtended by foliaceous bracts"; it is, however, cymose, and represents a dichasium. The floral structure is rather peculiar, there being five free sepals, no petals, mostly three stamens, alternating with the three carpels; the fruit is a membranaceous, loculicidal capsule with several estrophiolate, rugose seeds.

Now in respect to the internal structure of the vegetative organs very little seems to be known about *Mollugo verticillata* judging from the treatment of the *Ficoideæ* in Solereder's

* Bot. Gazette, vol. xxxix, 1905, p. 123.
† Merck's Report, vol. xviii, p. 143. New York, 1909.

Systematische Anatomie der Dicotyledonen.* A brief description of the stem is given by Karl Christ.† In speaking of the roots of the *Ficoideæ* Solereder (l. c.) states that the anomalous structure of the stem generally recurs in the root-system; however, the stem-structure of our *Mollugo* is anything but anomalous, and the root-structure is indeed very simple. At the seedling-stage the primary root has a hairy epidermis, and a thinwalled cortex of only two strata. Endodermis is, also, thinwalled, and the pericambium consists of a single layer of thinwalled cells; the stele is diarch with a diametric ray of vessels, and with two strands of leptome. Increase in thickness commences early, but only within the stele so long as the individual has not reached the flowering stage. In mature specimens the primary root is a little thicker, but relatively short, and sparingly branched; epidermis and cortex with part of endodermis are now replaced by several strata of thinwalled cork developed from the pericambium, and the stele consists now of a dense mass of collateral mestome-strands. In other words, the structure agrees with that, which is the most common in roots of dicotyledonous plants.

In passing to describe the stem we might begin with the hypocotyl. This stem-portion shows, also, an early increase in thickness by the formation of pericyclic cork, and by the development of secondary mestome-strands between the primordial, while the individual is a mere seedling bearing only the cotyledons and a minute vegetative shoot. At this stage epidermis is thinwalled, and the cortex is composed of only two layers of very large cells surrounding a typical, thinwalled endodermis. Inside the cork is a continuous band of leptome, and hadrome of wide vessels extending to the center, and with thickwalled parenchyma between these. If we compare this structure with that of the hypocotyl of a mature specimen, we notice no difference except that it contains a little more cork, but even so, all the peripheral tissues from epidermis to endodermis are still present.

In regard to the stem proper, and especially the stretched, prostrate internodes, these exhibit the structure as follows: They are cylindric, glabrous and perfectly smooth, covered with a very thin cuticle; the outer cell-walls of epidermis are slightly thickened, and the cortex is compact, but consists only of three strata with a little chlorophyll, beside that many of the cells contain styloids of calcium oxalate. There is a distinct endodermis, which contains starch, and pericycle representing a closed sheath of stereome (S in fig. 5) in one to two layers,

* Stuttgart, 1899, p. 468.

† Beiträge zur vergleich. Anat. d. Laubstengels der Caryophyllinen. Thesis, Marburg, 1887.

beside a single stratum of thinwalled parenchyma bordering on the leptome (L. in fig. 5). We find in the stele about twenty, distinct, collateral mestome-strands separated from each other by narrow rays of thinwalled parenchyma, and enclosing a solid pith, which is not excentric; it is only in very thick stems that some of the internodes (but not all) may show an excentric structure so far as concerns the stele, but not the cortex. The structure of the fruiting pedicel agrees with that of the internode described above, but we notice here the presence of small, obtuse hairs (fig. 9) filled with a greenish brown, granular substance; moreover the stele contains only four mestome-strands.

Before leaving the stem we might mention that in vigorous specimens the basal nodes are frequently swollen, and distinctly so; this is, however, not due to the presence of collenchyma, as was expected, but simply to an increase of strata in the cortex.—While thus the structure of root and stem is very simple, we observe in the leaf several points which are quite interesting. It is, for instance, strange that the leaves, although being held in a horizontal position, possess stomata on both faces, and, at the same time, the chlorenchyma illustrates a typical dorsiventral structure with palisade-cells on the ventral, and with a pneumatic tissue on the dorsal.

The cuticle is thin, and the lumen of the thinwalled epidermis is wider on the ventral than on the dorsal face, but there are no papillæ; viewed in superficial sections, the lateral walls of epidermis are undulate on the dorsal, but less so on the ventral. Stomata abound on both faces of the blade; they are level with epidermis, and lack subsidiary cells. Hairs like those observed on the pedicels (fig. 9) occur along the midrib on the dorsal face, and at the base of the leaf-blade. There are two strata of typical palisade-cells with single, quite large, rhombic crystals of calcium oxalate, besides styloids; spheric crystals were observed in material preserved in alcohol, and they were located beneath the stomata. No collenchyma and no stereome is developed, but the veins have large-celled parenchyma-sheaths (P. in figs. 6–8); the midrib is the broadest of these (fig. 6); it is arch-shaped in cross-sections, and the hadrome contains several narrow spiral-vessels; the lateral veins are much thinner (figs. 7–8) and consist only of a few leptome-cells and a single spiral-vessel, or of leptome alone as shown in figure 8, which represents the marginal mestome-strand. The water-storage tissue is very poorly developed as a few strata above the midrib, between the palisades and the parenchyma-sheath.

From an anatomical point of view *Mollugo verticillata* is very distinct from the "other" members of *Ficoideæ* as described by Solereder (l. c.): *Mesembryanthemum*, *Tetra-*

gonia, *Aizoon*, *Sesuvium*, *Galenia*, etc., with their centric leaf-structure, abundance of water-storage-tissue, and papillose epidermis, not speaking of the frequent anomalous stem-structure possessed by these, mostly xerophilous genera; in some of the other genera, the herbaceous *Adenogramma*, *Gisekia*, *Limeum* and *Psammotropha*, the stem-structure is normal, and, as stated by Solereder, these genera are now generally referred to other families, viz. *Portulaceæ* and *Phytolaccaceæ*. Our *Mollugo* does not, from an anatomical viewpoint, show any relation to the *Portulaceæ*, but to the *Caryophyllaceæ;* in respect to the habit, it resembles the *Alsineæ*, but the floral structure, and especially the fruit, is different.

Let us now examine the various views that have been expressed in regard to the classification of *Mollugo* based solely upon the floral characters.

As stated in the preceding, Jussieu did not include *Mollugo* in the *Ficoideæ*, but referred it to the *Caryophylleæ*; in accordance with him, the *Ficoideæ* consisted of *Sesuvium*, *Aizoon*, *Glinus*, *Orygia*, *Mesembryanthemum*, *Tetragonia*, beside two other genera, *Reaumuria* and *Nitraria*, which are now referred to *Tamariscineæ* and *Xygophylleæ*. With Bentham and Hooker, the family *Ficoideæ* is divided into three tribes: *Mesembryeæ*, *Aizoideæ* and *Mollugineæ*; in the last of these we find *Mollugo* with *Orygia*, *Pharnaceum*, *Gisekia*, and a few others. A similar classification is proposed by Pax,* who calls the family *Aizoaceæ*, with two tribes, *Molluginoideæ* and *Ficoideæ*, the latter including, of course, *Mollugo*, *Glinus*, *Pharnaceum*, while *Mesembryanthemum*, *Sesuvium* and *Tetragonia* are referred to the former. In other words, the extremely different habit, the floral structure: calyx, stamens and pistil free (*Mollugo*), or calyx and stamens united, the pistil free (*Aizoon*), or finally, calyx, stamens and pistil united (*Mesembryanthemum* and *Tetragonia*), not speaking of the fruit, which varies from a capsule with loculicidal dehiscence (*Mollugo*), or, at the same time, loculicidal and septicidal (*Mesembryanthemum*) to a pyxidium (*Sesuvium*) or a drupe (*Tetragonia*), these very prominent characters are now considered of no sufficient importance for arranging these genera into more than one single natural family. A different classification was, however, suggested by Fenzl,† who at first placed *Tetragonia* and *Aizoon* as members of the family *Ficoideæ*, removing *Mesembryanthemum* from these, establishing the family *Mesembryanthemeæ*, and referring *Mollugo* with its

* Engler und Prantl, Natürliche Planzenfamilien, vol. iii, p. 38, Leipzig, 1889.

† Monographie der Mollugineen and Steudelieen (Ann. Wien Mus., vol. i, p. 337, 1835).

nearest allies to the *Portulaceæ:* sectio *Mollugineæ.* But later on* Fenzl changed his views and transferred *Tetragonia*, *Aizoon* and *Galenia* to the *Portulaceæ*, tribes *Tetragonieæ* and *Aizoideæ*, leaving *Mesembryanthemeæ* intact. The segregation of *Mesembryanthemum* evidently rests on good foundation, but it seems unfortunate that the other genera should be considered allies of the *Portulaceæ*; it also seems more natural to keep *Tetragonia* and *Aizoon* in a family distinct from *Mollugo*, as was first proposed by Fenzl. According to Rohrbach these genera might be referred to two families: *Molluginaceæ* and *Ficoidaceæ*,† and he considered them as being somewhat related to the *Portulaceæ* and *Caryophylleæ*, beside the *Phytolaccaceæ*. As pointed out by Eichler,‡ this relationship is much more natural than that supposed by Bentham and Hooker,§ who place them all as *Ficoideæ* between *Cacteæ* and *Umbelliferæ*, widely separated from the *Caryophyllaceæ* and *Portulaceæ*. It seems altogether as if the position of *Mollugo* is very difficult to define in the natural system; it surely does not belong to the same family as *Tetragonia* and *Mesembryanthemum*, and especially not if we compare the internal structure. It represents evidently a little family of its own, allied in some respects to the *Caryophylleæ*, but by no means to the *Cacteæ*.

Brookland, D. C., Feb. 1911.

EXPLANATION OF FIGURES (p. 526).

FIGURE 1. Seedling of *Mollugo verticillata* L., showing the primary root (R.), the hypocotyl (H.), the two cotyledons (Cot.), and three normal leaves L^1–L^2, of which L^1 and L^1 are opposite, while the other leaf opposite L^2 is not visible; magnified four times.

FIGURE 2. One of the cotyledons; × 6.

FIGURE 3. A young plant with the cotyledons still attached, seen from above, showing three pairs of opposite leaves (L^1–L^3), but of which the one corresponding to L^3 is not visible; S is the first branch with a stretched internode and a few leaves; the other letters as above; × 4.

FIGURE 4. Part of a floral shoot; for explanation see the text; magnified about three times.

FIGURE 5. Cross-section of the stem. Ep.=epidermis; C.=cortex; End.=endodermis; S.=stereomatic pericycle; L.=leptome; Camb.=cambium; H.=hadrome; P.=pith; × 320.

FIGURE 6. Cross-section of midrib of leaf, showing the large-celled parenchyma-sheath (P.), the leptome and the hadrome; × 320.

FIGURE 7–8. Two lateral veins of the leaf, of which fig. 8 is from the marginal; P. =parenchyma-sheath; × 320.

FIGURE 9. Hair from the leaf; × 320.

* Ibidem, vol. ii, p. 279, 1839.
† Martius Flora Brasil, Fasc. 56, 1872.
‡ Blüthendiagramme, p. 119, Leipzig, 1878.
§ Genera plantarum, vol. i, p. 51, London, 1862–1867.

ART. XLV.—*The Chemical Composition and Crystallization of Parisite and a New Occurrence of it in the Granite-Pegmatites at Quincy, Mass., U. S. A. With Notes, on Microcline, Riebeckite, Aegirite, Ilmenite, Octahedrite, Fluorite and Wulfenite from the same Locality;* by CHARLES PALACHE and CHARLES H. WARREN.

Parisite.—The rare fluo-carbonate of calcium and the cerium earths, parisite, was first discovered in 1835 at the emerald mines of Muso valley, U. S. of Columbia, by J. J. Paris, after whom it was named. It was first described by Bunsen in 1845.* Its crystallization was described by Des Cloizeaux,† who also gives the indices of refraction as determined by Senarmont. A paper relating to its crystallization was published by Vrba in 1886.‡ The mineral was again described by Penfield and Warren,§ with chemical analyses, from a new locality in Ravalli Co., Montana, U. S. A., where it occurred in the form of embedded crystals in what appeared to be a decomposed rhyolite. Crystals from Muso valley were also analyzed by them, and the chemical composition was shown to correspond to the formula $(R'''F)_2Ca(CO_3)_3$. In 1894 A. Nordenskiöld‖ described as parisite a mineral from Narsarsuk, Greenland. Later G. Flink¶ re-examined this mineral and showed that it differed from parisite in its rhombohedral crystallization, in the relative proportions of its constituents and in its indices of refraction as previously determined. Flink gave it the name synchisite and determined the formula to be $(R'''F)_2Ca_2(CO_3)_4$. It occurred on the surfaces of feldspar or aegirite crystals, or in cavities in alkali granite pegmatite, and with it also occurred the barium-parisite, cordylite, described by Flink and later by Bœggild.** The new occurrence of parisite at Quincy, Mass., at first thought to be synchisite from a preliminary crystallographic examination and so announced,†† is also in an aegerite-bearing-rock. Murgoci,‡‡ in a paper discussing the origin of riebeckite and riebeckite rocks, notes the presence of rare earth carbonates (parisite?) with the riebeckite and aegirite. Tacconi also notes the presence of parisite in

* Bunsen, Lieb. Ann., liii, 147, 1845.
† Min., ii, 162, 1874.
‡ Ber. Bœhm. Ges., 647, 1886, and Zs. Kr., xv, 210, 1888.
§ This Journal, viii, 21, 1899, and Zs. Kr., xxxii, 1, 1899.
‖ G. För. Förh., xvi, 338, 1894.
¶ Bull. G. Inst. Upsala, v, 81, 1901; see also Bœggild, Medd. om. Groenland, xxiv, 29, 1901.
** Medd. om Groenland, xiv, 236, 1898; xxiv, 42, 1901; xxxiii, 101, 1906.
†† This Journal, xxviii, 450, 1909. ‡‡ This Journal, xxx, 137, 1905.

connection* with the riebeckite granite at Montorfano, N. Italy. It forms there thin hexagonal crystals several millimeters long, generally embedded in a chloritic mass which is encrusted with stilbite and chabazite, and is associated with fluorite, pyrite and quartz. G. Tschernik† also describes the mineral from a Manchurian locality where it occurred in an erratic granite bowlder rich in pyrite and with accessory fluorite and zircon. He gives chemical analyses of three different phases of the mineral as found there, with an elaborate discussion of the same.

It thus appears quite certain that parisite, or the closely related mineral synchisite and cordylite, are characteristic *pneumatolitic minerals* of the *riebeckite-aegirite* rocks.

The parisite to be described in the present article, as well as the other minerals, occurs in one part or another of the pegmatite-pipes of the Quincy granite located in the quarry of Fallon Brothers and the Ballou quarry, North Common Hill, Quincy, Mass. The granite, as is well known, is a riebeckite-aegirite-bearing rock high in silica, ferrous and ferric oxides and the alkalies, but very low in lime and magnesia. The feldspar is almost wholly a microcline-microperthite. These pegmatites have been described in a preliminary way in a short article which appeared in this Journal in November, 1909, and are also described in considerable detail in a paper which will appear shortly in the proceedings of the American Academy of Arts and Sciences. The last paper will contain also a somewhat fuller description of the minerals of the pegmatites (with the exception of the parisite) than will be given here, and to this paper the reader is referred for further details.

In the larger Fallon-quarry pegmatite the parisite is relatively abundant in all parts where open spaces are present, implanted on the surfaces of the microcline and aegirite crystals. It was particularly abundant along the immediate lining (consisting almost entirely of microcline and aegirite crystals) of the large central pocket, and was found to some extent on the surfaces of the many pegmatite fragments found in the open space of the pocket. In a similar pipe, but without any central pocket, in the nearby Ballou quarry, it has been observed only as grains in the massive rock. It may also be noted that occasional grains have been identified in the Quincy granite in other parts of the area, but seem to be confined to such parts of the granite as show other undoubted evidences of pneumatolitic activity. In one instance it has been noted in close association with minute crystallizations of astrophyllite.‡

* Rend. Acc. Linc., xiv, 2, 88, 1905.

† Verh. Min. Ges. St. Petersburg, xliv, 1906, pp. 507–545. Reviewed in N. Jahrb. f. Min., etc., Band ii, p. 336, 1909.

‡ On the Occurrence of Astrophyllite in the Quincy Granite, see Pirsson, this Journal, xxix, p. 215, March, 1910.

Crystallography.—Crystallographic data concerning parisite are but scanty, and for that reason a rather full account of our observations on the Quincy crystals is here presented.

Parisite was determined to be hexagonal by Des Cloizeaux* in 1874, and he found on the type crystals from Muso valley series of pyramids of both orders, the base and a prism. The value of $\dot{c}$ calculated from his measurements was 3·2891. His crystals were doubtless the large and rather rough ones first found there and he describes them as badly striated. He suggests a rhombohedral interpretation of the crystals, but with no reason for its adoption.

Vrba† in 1888 measured three crystals from Muso valley which gave good readings for the form *o* from which he calculated the element $c = 3{\cdot}3646$.

Penfield and Warren‡ in 1899 described a new occurrence of parisite from Montana, but the crystals were too badly striated to give reliable measurements.

Cesàro,§ in 1907, gave the results of measuring minute but brilliant crystals of parisite attached to quartz. The locality is Muso, but apparently from a deposit different from that which yielded the original crystals. He derives the value $c = 3{\cdot}405$, but makes no statement as to the number of crystals or faces measured. His crystals showed distinct rhombohedral development and Cesàro adopts a rhombohedral position with the pyramid *f* $(11\bar{2}4)$ as the positive unit suggesting, however, a possible preference for the choice as unit of the steeper pyramid *g* $(11\bar{2}3)$. The latter choice was independently arrived at by the study of the much more complex crystals of parisite from Quincy as shown below.

Tschernik‖ found on crystals from Mukden, Manchuria forms and habit very like those of Montana crystals.

The crystallographic data of these papers is collected in the following table which shows the forms previously found on parisite. Discussion of the relation of synchisite to parisite will be found on a later page.

The parisite crystals found at Quincy are, on the whole, favorable to crystallographic study. They are mostly small; 1 to 3^{mm} in length, with a maximum of about 2^{cm} and for the most part very slender. Many hundreds of these tiny crystals and crystal fragments were found in the sand-like debris left after washing the large collection of specimens of pegmatite; many crystals are also visible, of course, still attached to the matrix. The crystals vary enormously in habit and quality

* Min. ii, 162, 1874. † Zs. Kr., xv, 210, 1888.
‡ This Journal, viii, 21, 1899. § Bull. Ac. Belg., 321, 1907.
‖ Vehr. Min. Ges. St. Petersb., xliv, 507–545, 1906, Abstract in N. Jahr. Min., 1909, ii.

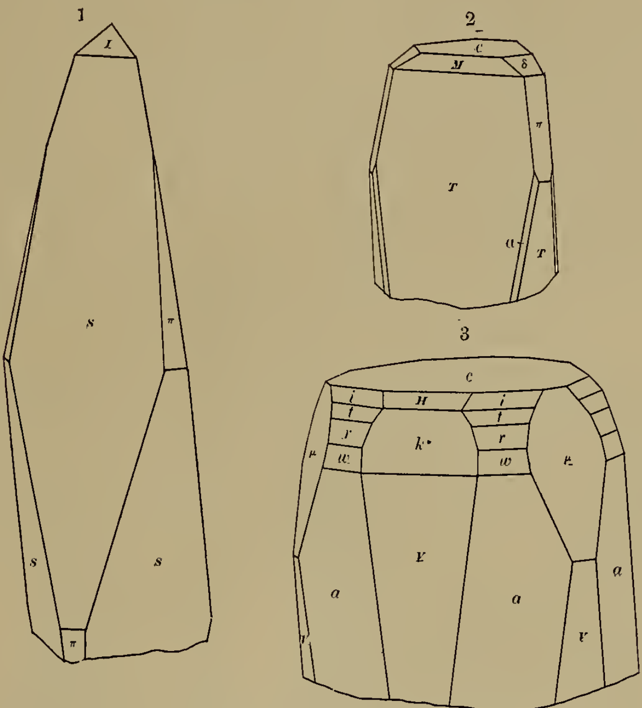
TABLE I.

Dana Letter / Symbol		Des Cloizeaux, Muso, 1874 $c = 3{\cdot}2891$	Vrba, Muso, 1888 $c = 3{\cdot}4050$	Penfield & Warren, 1899 Montana	Cesaro, Muso, 1907 $c = 3{\cdot}4050$	Cesaro, the same. Rhombohedral $c = 1{\cdot}4744$	Cesaro, the same. Rhombohedral $c = 1{\cdot}965$	Goldschmidt, G_2 $p = 1{\cdot}310$	Tschernik, Mukden, 1906
c	0001	*p*		*c*		0001	0001	0	*c*
m	$10\bar{1}0$	*m*		*m*		$11\bar{2}0$	$11\bar{2}0$	∞0	
a	$11\bar{2}0$			*a*		$10\bar{1}0$	$10\bar{1}0$	∞	
q	$10\bar{1}2$	b^2				$22\bar{4}3$	$11\bar{2}2$	3/2 0	
r	$20\bar{2}3$	$b^{\frac{3}{2}}$		*r*		$8.8.\bar{16}.9$	$22\bar{4}3$	20	*r*
	$50\bar{5}3$	$b^{\frac{3}{5}}$			$50\bar{5}3$	$10.10.\bar{20}.9$	$5.5.\bar{10}.6$	5/2 0	
p	$10\bar{1}1$	b^1				$44\bar{8}3$	$11\bar{2}1$	30	
	$50\bar{5}6$	$b^{\frac{6}{5}}$			$50\bar{5}6$	$20.20.\bar{40}.9$	$5.5.\bar{10}.3$	50	
o	$20\bar{2}1$	$b^{\frac{1}{2}}$	*o*	*o*	$20\bar{2}1$	$8.8.\bar{16}.3$	$22\bar{4}1$	60	*o*
d	$11\bar{2}8$	a^8			$10\bar{1}2$	$10\bar{1}2$	$30\bar{3}8$	3/8	
e	$11\bar{2}6$	a^6				$20\bar{2}3$	$10\bar{1}2$	1/2	
f	$11\bar{2}4$	a^4				$10\bar{1}1$	$30\bar{3}4$	3/4	
g	$11\bar{2}3$	a^3				$40\bar{4}3$	$10\bar{1}1$	1	
	$22\bar{4}5$	$a^{\frac{5}{2}}$			$22\bar{4}5$	$08\bar{8}5$	$06\bar{6}5$	−6/5	
h	$11\bar{2}2$	a^2			$11\bar{2}2$	$02\bar{2}1$	$03\bar{3}2$	−3/2	
k	$22\bar{4}3$	$a^{\frac{3}{2}}$				$80\bar{8}3$	$20\bar{2}1$	2	
s	$11\bar{2}1$	a^1	*s*	*s*	$11\bar{2}1$	$40\bar{4}1$	$30\bar{3}1$	3	*s*
x	$63\bar{9}5$	$b^{\frac{1}{3}}b^{\frac{1}{6}}h^{\frac{1}{5}}$				$16.4.\bar{20}.5$	$12.3.\bar{15}.5$	18/5 9/5	

of faces, so that of the hundred or more placed on the goniometer for trial, more than two-thirds had to be rejected. Some thirty crystals, however, proved to be measurable and the results of their study are here presented.

The basal plane is almost always present, generally relatively large and always very brilliant, so that it served admirably for the adjustment of the crystals on the two-circle goniometer. Although of prismatic habit, the prism planes are rarely more than rudimentary, the prismatic appearance being produced by oscillatory combination of steep rhombohedrons or pyramids, as in other occurrences of parisite.

Three types of combination may well be distinguished: (1) *rhombohedral*, a single rhombohedron of either position being dominant (figures 1, 2); (2) *pyramidal*, the dominant forms being rhombohedrons of both positive and negative positions, so balanced, that without measurement, the rhombohedral character is not apparent; (3) *pyramidal* (corundum habit), showing a series of second order pyramids and the prism, the pinacoid always broad; rhombohedral planes, when present, slightly modify the basal edges. (Figure 3.)



Figs. 1–3. Parisite.

In all types the rhombohedral character is clearly demonstrable in almost every crystal, sometimes by simple inspection, more often only after study of the distribution of the measured faces in vertical zones. In practically all cases it is safe to assume that the prism, rarely wholly absent, is of the second order, and this was made the basis of the general orientation of the crystals. The determination of the sign of the rhombohedrons is often difficult and sometimes impossible since many of them occur in both positions. The series chosen as positive is the more complex, not only as a whole, but on most crystals, and it was generally only by a study of the form series of the whole crystal that decision could be reached as to position of the rhombohedral series.

In the best crystals all the faces are brilliant and give sharp images of the goniometer signal when not too narrow; the steeper forms are often developed as mere lines and the signals are then apt to be dim. The frequent oscillatory striations, however, do not seem to produce false faces, the signals of a series of faces being generally quite distinct. All the crystals examined had been implanted by one end and were, therefore, but singly terminated, but occasionally faces of very steep forms belonging to the lower half of the crystal came within the range of measurement of the goniometer.

Twinning on the basal pinacoid was to be expected (see synchisite below), but could not be established; it would be more or less completely concealed by the striated character of the lateral surfaces of the crystal.

Table II shows the forms found on the Quincy parisite. These forms include practically all those previously discovered

Table II.—Forms found on Quincy Parisite.

Bravis-Miller.	Gold.	G_2	Positive Rhombohedrons		Negative Rhombohedrons	
c (0001)	0		A $(10\bar{1}4)$	1/4	β $(0.4.\bar{4}.15)$	−4/15
m $(10\bar{1}0)$	∞		B $(4.0.\bar{4}.15)$	4/15	γ $(02\bar{2}7)$	−2/7
a $(11\bar{2}0)$	∞	0	C $(3.0.\bar{3}.11)$	3/11	δ $(0.3.\bar{3}.10)$	−3/10
Pyramids			D $(3.0.\bar{3}.10)$	3/10	ϵ $(0.9.\bar{9}.25)$	−9/25
b $(4.4.\bar{8}.15)$	4/5	0	E $(5.0.\bar{5}.16)$	5/16	*d* $(03\bar{3}8)$	−3/8
i $(11\bar{2}3)$	1	0	F $(10\bar{1}3)$	1/3	ζ $(01\bar{1}2)$	−1/2
l $(11.11.\bar{22}.27)$	11/9	0	G $(5.0.\bar{5}.13)$	5/13	θ $(05\bar{5}8)$	−5/8
n $(5.5.\bar{10}.12)$	5/4	0	H $(20\bar{2}5)$	2/5	*f* $(03\bar{3}4)$	−3/4
t $(44\bar{8}9)$	4/3	0	*e* $(10\bar{1}2)$	1/2	η $(06\bar{6}5)$	−6/5
q $(11\bar{2}2)$	3/2	0	*i* $(8.0.\bar{8}.11)$	8/11	λ $(05\bar{5}4)$	−5/4
u $(5.5.\bar{10}.9)$	5/3	0	J $(70\bar{7}8)$	7/8	μ $(02\bar{2}1)$	−2
r $(22\bar{4}3)$	2	0	*g* $(10\bar{1}1)$	1	π $(05\bar{5}2)$	−5/2
v $(55\bar{6}6)$	5/2	0	L $(50\bar{5}4)$	5/4	σ $(03\bar{3}1)$	−3
p $(11\bar{2}1)$	3	0	M $(40\bar{4}3)$	4/3	ϕ $(07\bar{7}2)$	−7/2
w $(44\bar{8}3)$	4	0	*h* $(30\bar{3}2)$	3/2	ρ $(04\bar{4}1)$	−4
o $(22\bar{4}1)$	6	0	N $(11.0.\bar{11}.6)$	11/6	ψ $(05\bar{5}1)$	−5
Scalenohedron			*k* $(20\bar{2}1)$	2	ω $(06\bar{6}1)$	−7
y $(4.2.\bar{6}.11)$	8/11	2/11	P $(11.0.\bar{11}.4)$	11/4		
			S $(30\bar{3}1)$	3		
			Q $(10.0.\bar{10}.3)$	10/3		
			R $(40\bar{4}1)$	4		
			T $(50\bar{5}1)$	5		
			V $(60\bar{6}1)$	6		

elsewhere together with a much greater number of new ones. No explanation is attempted of the prevalence of complex symbols among these forms. The choice of unit is clearly justified by the constant recurrence upon the crystals of the forms having the simplest symbols in the pyramid series; the infrequent occurrence of correspondingly simple symbols among the rhombohedral forms is curious and appears to be characteristic for at least this occurrence of parisite. The last two columns of Table III, in which the number of faces of each form is given for all crystals, gives better than words the relative abundance of the forms. It may be well to state in explanation of that table that where faces of any form are less on a particular crystal than the full theoretical number, the lack may be from two causes: in case of the pyramid series and prism it is generally from the distortion of the crystal reducing the size of some faces so that they are not measurable; in case of rhombohedrons it is more often due to faces of two or more forms near each other in inclination occurring together as though they composed a single form.

Table III contains the data upon which the new forms are based, as well as that which served for the calculation of the axial ratio. For the latter there were used the readings from 254 faces of 27 forms on 32 crystals, the value of the element derived from each form being given a weight proportional to the frequency of the readings for that form in making up the final average. The value adopted in this table is stated for comparison with those of other authors, recalculated to this new position and unit as follows:

Palache	c=1·9368	p_0=1·2912
Des Cloizeaux	1·899	1·266
Vrba	1·9425	1·295
Cesàro	1·965	1·310

It will be noted that the new value is in very close agreement with that of Vrba.

Concerning the individual forms there is little to say in addition to the statistical information contained in the various tables. The single scalenohedron observed had two distinct but narrow faces in zone with the forms H and i so that its symbol is well established. The scalenohedron x of Des Cloizeaux was not observed and is probably to be regarded as a doubtful form.

Optical properties of Parisite.—As seen under the microscope, very small crystals or fragments are very pale yellow to almost colorless and show a barely perceptible dichroism. For crystals $\frac{1}{2}^{mm}$ thick the ω ray is bright yellow, often with a brownish tone; the ϵ ray is golden yellow. The absorption is

Table III.—Calculated and Observed Angles of Parisite, Quincy.

$a : c = 1 : 1{\cdot}9363 \qquad p_0 = 1{\cdot}2912$

	Calculated			Measured, mean		Limits	No. of faces	No. crystals
	G_2	ϕ	ρ	ϕ	ρ	ρ		
c	0		00° 00		00° 00		30	30
m	∞	30° 00	90 00	30° 00	90 00		4	4
a	∞ 0	00 00	90 00	00 00	90 00		111	26
b	4/5 0	"	45 56	"	45 47		1	
i	1 0	"	52 14	"	52 10	51° 45–52° 36	44	18
l	11/9 0	"	57 38	"	57 33	57 30–57 43	10	4
n	5/4 0	"	58 13	"	58 23	58 11–58 36	17	9
t	4/3 0	"	59 51	"	59 45	59 34–60 00	27	10
q	3/2 0	"	62 41	"	62 47		4	4
u	5/3 0	"	65 04	"	65 14	65 11–65 18	4	2
r	2 0	"	68 50	"	68 48	68 36–69 00	38	10
v	5/2 0	"	72 47	"	72 58	72 48–73 04	7	6
p	3 0	"	75 31	"	75 21	74 59–75 43	3	3
w	4 0	"	79 02	"	79 01	78 48–79 23	32	9
z	5 0	"	81 12	"				
o	6 0	"	82 39	"	82 30		2	2
A	1/4	30 00	29 13	30 00	29 09	28 57–29 35	4	4
B	4/15	"	30 49	"	30 34	30 24–30 49	17	11
C	3/11	"	31 23	"	31 41	31 30–31 50	18	9
D	3/10	"	33 51	"	33 36	33 20–33 51	7	4
E	5/16	"	34 57	"	34 57	34 20–35 20	12	10
F	1/3	"	36 42	"	36 54		3	3
G	5/13	"	40 46	"	40 48	40 40–40 56	9	6
H	2/5	"	41 49	"	41 40	41 25–41 58	13	8
e	1/2	"	48 12	"	48 04	47 54–48 14	5	5
I	8/11	"	58 25	"	58 21	58 18–58 24	5	5
J	7/8	"	62 56	"	62 54	62 43–62 58	5	3
g	1	"	65 54	"	65 53	65 48–65 57	4	3
L	5/4	"	70 19	"	70 22	69 56–70 40	10	5
M	4/3	"	71 28	"	71 23	71 10–71 35	3	2
h	3/2	"	73 24	"	73 35	73 27–73 45	12	6
N	11/6	"	76 16	"	76 18	76 13–76 28	6	6
k	2	"	77 24	"	77 27	77 14–77 35	16	10
P	11/4	"	80 46	"	80 52	80 50–80 54	4	4
S	3	"	81 31	"	81 40	81 32–81 51	8	4
Q	10/3	"	82 22	"	82 17	82 04–82 25	6	5
R	4	"	83 37	"	83 32	83 22–83 45	15	8
T	5	"	84 53	"	84 53	84 34–85 09	37	14
V	6	"	85 44	"	85 39	85 21–85 58	12	6
β	−4/15	−30 00	30 49	−30 00	30 44	30 28–30 56	12	8
γ	−2/7	"	32 35	"	32 29	32 20–32 41	13	8
δ	−3/10	"	33 51	"	33 45	33 22–34 34	27	19
ε	−9/25	"	38 50	"	38 47	38 25–39 02	32	23
d	−3/8	"	39 59	"	40 02	39 53–40 21	2	1
ζ	−1/2	"	48 12	"	47 54	47 47–48 00	5	5
θ	−5/8	"	54 25	"	54 35	54 13–54 52	5	4
f	−3/4	"	59 12	"	59 44		3	3
η	−6/5	"	69 34	"	69 47	69 42–69 52	2	1
λ	−5/4	"	70 19	"	70 39	70 26–70 53	3	1
μ	−2	"	77 24	"	77 23	77 00–78 00	20	10
π	−5/2	"	79 52	"	80 02	79 45–80 25	30	16
σ	−3	"	81 31	"	81 42	81 24–81 55	21	11
ϕ	−7/2	"	82 43	"	82 55	82 53–82 58	5	4
ρ	−4	"	83 37	"	83 32	83 23–83 48	5	4
ψ	−5	"	84 53	"	84 36	84 17–84 50	7	5
ω	−6	"	85 40	"	86 38	85 05–86 00	4	3
χ	−18/5 9/5	19 06	80 46					
y	−8/11 2/11	10 53	47 05	10 38	47 04			

$\omega > \epsilon$ slight. For crystals 1^{mm} thick the dichroism and absorption are but slightly greater. Upon alteration the crystals become filled with a dusty product, are less transparent and often exhibit a brownish or brownish red stain of varying intensity.

The indices of refraction were determined by the immersion method, using a barium-mercuric-iodide solution. The determinations were made on a number of perfectly clear, small crystals chosen on account of the uniform development of their prism zones; also upon one larger crystal ($1\frac{1}{2}^{mm}$ in diam.) terminated by a perfect basal plane which made it possible to orientate the crystal and cut a section parallel to the prismatic axis. An attempt was made to measure the indices directly upon this crystal by means of the Abbe refractometer, but without success, owing to the small size of the section and its low degree of transparency. The fine striations parallel to the edge between the base and the prism stand out very sharply under the microscope and make it possible to orientate the crystals with great accuracy on the microscope stage. The values obtained with sodium light are given below, also those heretofore given for parisite as determined by Senarmont and those for synchisite according to Flink.

	Parisite, Quincy Warren	Parisite, Muso Senarmont	Synchisite, Greenland Flink
$\epsilon =$	1·757	1·670	1·7701
$\omega =$	1·676($\pm$0·002)	1·569	1·6742
$\epsilon - \omega =$	0·081	0·103	0·0959

The Montana parisite, analyzed and described by Penfield and Warren (loc. cit.), also crystals from Muso valley taken from the mineral collection of Harvard University, were tested by the immersion method and their indices were found to correspond to the values given for the Quincy mineral. The older values given for the Muso mineral appear to be quite wrong. The ordinary rays for parisite and synchisite are almost identical. The extraordinary rays appear to differ by 0·0131. While the extraordinary ray for the Quincy mineral is probably not as accurately determined as the value for the ordinary, the error can hardly be as great as 0·0131 and the difference between the two minerals for this constant may perhaps be a real one.

Chemical composition of Parisite.—About a kilo of fine-grained material recovered from the fragile lining of the central pockets was carefully washed and fractioned by means of screens, an electro magnet, and heavy solutions until a fraction was obtained weighing about ten grams and consisting largely of parisite mixed with more or less aegirite, anatase, feldspar and quartz. From this about three grams of *clear yellow* or *amber*-colored crystals were separated by hand-picking under a powerful lens. Aside from a slight stain in a few crystals, the only impurities visible under the microscope were minute adhering grains of anatase and aegirite, hardly amounting to more than a trace.

A partial analysis was also made on a few carefully selected crystal fragments of parisite from Muso valley taken from the mineral collection of Harvard University, to serve as a check on the earlier analyses made by Warren on crystals of the Muso mineral from the Brush collection, in New Haven, Conn.

	1 Montana 1899	2 Muso 1899	3 Muso 1910	4 Quincy 1910	5 Muso Damour & Deville	6 Synchisite Fink	7 Synchisite* Mauzelius Greenland	8 Cordylite† Mauzelius
	Warren		analyst					
Spec. Gr.	4·128	4·302		4·320	4·358	3·902	3·900	4·358
CO_2	22·93	24·22	24·34	24·16	23·48	26·54	25·99	23·47
Fluor.	5·90	6·82		6·56	5·55	5·82	5·04	[4·87]
Ce_2O_3	26·14	30·67	29·92	30·94	44·21	28·14	21·98	23·72
$(LaDi)_2O_3$	28·46	29·74	28·75	27·31	18·00	22·88	28·67	25·67
Yt_2O_3	tr.	tr.		tr.		1·23	1·18	tr.
ThO_2							·30	
Fe_2O_3	·80	·25		·32				
FeO							·11	1·43
CaO	10·98	10·70	11·50	11·40	10·10	17·13	16·63	1·91
SrO				tr.				
BaO								17·30
Na_2O	·69	·20	·30	·30		·19		
K_2O	·19	·10	·22	·20		·12		
H_2O	·26	·10		tr.			2·10	·80
Gangue	6·13	(diff.)		1·02				2·58
	102·48	102·65		102·21	101·34	102·05	102·00	102·05
O = 2F.	2·48	2·87		2·76	2·34	2·45	2·12	2·05
Totals	100·00	99·78		99·35	99·00	99·60	99·88	100·00

* Material somewhat altered and impure. H_2O 2·10; 1·56 expelled at 100°.
† Material scanty, impure, and perhaps slightly altered.

The molecular ratios derived from the above analyses are as follows:

	CO_2	F.	R_2O_3	CaO or	CO_2	F.	R_2O_3	CaO	
1. Montana,	0·550 :	0·310 :	0·166 :	0·196	= 3 :	1·79 :	0·96 :	1·13	
2. Muso, '99,	·550 :	·359 :	·183 :	·191	= 3 :	1·96 :	1·01 :	1·04	
3. Muso, '10,	·553 :		·178 :	·203	= 3 :		0·97 :	1·10	
4. Quincy,	·549 :	·345 :	·178 :	·205	= 3 :	1·88 :	0·97 :	1·11	
5. Muso, (D. & D.)—	·553 :	·292 :	·187 :	·180	= 3 :	1·65 :	1·05 :	1·01	
6. Synchisite,	·603 :	·306 :	·160 :	·306	= 3 :	1·52 :	0·79 :	1·52	or
Flink :					= 4 :	2·02 :	1·06 :	2·02	
7. Synchisite,	·590 :	·265 :	·189 :	·298	= 3 :	1·34 :	0·96 :	1·56	or
Mauzelius :					= 4 :	1·78 :	1·22 :	1·00	
8. Cordylite,	·533 :	·256 :	·181 :	·148	= 3 :	1·44 :	1·01 :	1·00	

The analyses were made in duplicate and agreed closely. Regarding the method of analysis it may be stated that the earths were separated from lime by precipitation with ammonia after the complete removal of fluorine by evaporations and fuming with sulphuric acid in order to ensure that no fluorides were precipitated with the earth-hydroxides. The cerium was separated from the lanthanum and didymium by precipitation of the cerium with chlorine in a potassium-hydroxide solution, a departure from the method employed in the earlier analyses of the Muso and Montana minerals. Care was taken to examine all filtrates from oxalate precipitations of the earths to recover, if present, any unprecipitated earths, a necessary precaution, as has been pointed out by Hillebrand and others. The results of these analyses are given above and in parallel columns are given for comparison the older analyses of parisite; also the analyses of synchisite and cordylite.

For synchisite the ratios derived from Flink's analyses are sharply—$CO_2 : F : R_2O_3 : CaO = 4 : 2 : 1 : 2$. This leads to the formula given by Flink, $(RF)_2Ca_2(CO_3)_4$. The analysis of Mauzelius (7), though perhaps on less satisfactory material, leads to the same formula. From this it appears that the formula of synchisite, as determined by Flink, differs from that of parisite in containing exactly one more molecule of calcium carbonate. To make the chemical compositions of parisite and synchisite identical calls for a change of 2·3 per cent in the CO_2 and of 6·0 per cent in the CaO. These are very serious differences, for they involve unallowable errors in the determination of the two constituents whose determination can be made with great accuracy. Small differences in the proportions of the rare-earth oxides are to be expected in minerals from different localities, and, indeed, analytical errors in the determination of the earths, unless considerable, would not seriously affect the ratios on account of the large molecular weights of these oxides. The close agreement in the lime and carbon dioxide determinations of the Muso, Montana and Quincy parisites (in all ten determinations have been made) leads us to place great confidence in their correctness, as well as upon that of the formula derived for the mineral from these localities.

In discussing the analyses by Tschernik on the Manchurian parisite we are at a disadvantage, as the discussion appears in full only in Russian. The ratios derived from these analyses, however, do not correspond, so far as we can see, with the ratios given above for either parisite or synchisite, being far more complex. The presence of considerable amounts of water in all three analyses, as well as the variable and zonal character of the crystals analyzed by Tschernik, suggests strongly that the material had undergone considerable alteration with consequent changes in composition.

Relation of Synchisite to Parisite.—The synchisite of Flink differs in most respects but little from parisite, and was indeed, but on insufficient material, earlier described as such by Nordenskiöld. The present writers, in view of the results of this study of parisite, believe that no valid distinction exists between these substances, and that synchisite must stand as a synonym for parisite.

Synchisite is rhombohedral with forms which permitted of only approximate measurement, on the basis of which they were interpreted in terms of the parisite axes. Most of these rhombohedral forms have now been found on parisite, but the new position chosen for the latter requires a readjustment of the symbols as given by Flink. This is made in the following table, it being understood that the angle given for synchisite forms, in each case, is that of the nearest then known form of parisite to the measured angle, none of the latter being given :

Synchisite (Flink)			Parisite equivalent (Palache)			
c	(0001)		*c*	(0001)		
m	$(10\bar{1}0)$		*m*	$(10\bar{1}0)$		
n	$(11\bar{2}0)$		*a*	$(11\bar{2}0)$		
z	$(11\bar{2}1)$	81° 33′	*z*	$(5.5.\bar{10}.3)$	81° 12′	
t	$(20\bar{2}9)$	40 48	*d*	$(03\bar{3}8)$	39 59	
r	$(20\bar{2}3)$	68 53	*η*	$(06\bar{6}5)$	69 34	
v	$(30\bar{3}4)$	71 04	λ	$(05\bar{5}4)$	70 19	
p	$(10\bar{1}1)$	75 34		$(05\bar{5}3)$	74 59	not found
s	$(40\bar{4}3)$	79 05		$(07\bar{7}3)$	79 09	not found
a	$(30\bar{3}2)$	80 13	*π*	$(05\bar{5}2)$	79 52	
i	$(01\bar{1}5)$	37 51	F	$(10\bar{1}3)$	36 42	
u	$(02\bar{2}9)$	40 48	G	$(5.0.\bar{5}.13)$	40 46	
q	$(01\bar{1}2)$	62 46	J	$(70\bar{7}8)$	62 56	
y	$(03\bar{3}4)$	71 04	M	$(40\bar{4}3)$	71 28	
β	$(03\bar{3}2)$	80 13	P	$(11.0.\bar{11}.4)$	80 46	
γ	$(03\bar{3}1)$	85 06	T	$(50\bar{5}1)$	80 53	

It is evident that the form series of synchisite fits into that of parisite perfectly, and as both are rhombohedral no distinction of form can be made. The new determination of the optical constants of parisite has shown that the two substances have sensibly the same values. Parisite has been shown to have the same cleavage property which Flink showed to be characteristic of synchisite; the basal cleavage of both is visible only in altered specimens, the fresh minerals breaking with conchoidal fracture.

There remain but two sensible differences between the two substances; synchisite has a slightly lower specific gravity; and its chemical composition shows the presence of exactly one molecule of $CaCO_3$ more than is present in parisite. It is hardly possible that this large difference in composition can rest in analytical errors; on the other hand, it is quite impossible for the writers to believe that two substances with such a profound chemical difference as this could be so nearly identical in all their physical properties. The following consideration is offered as a possible interpretation of the matter.

In describing the crystals of synchisite Flink states that many of them show an enlarged central portion with forms and luster differing from the smaller crystals and with slightly altered optical character. This is a character common to the larger crystals. Now there is no statement in the paper of the quality of the analyzed crystals. Are we not justified in believing that the analysis material contained enough of this altered substance which might well be $CaCO_3$ to produce the differences found? The alteration would tend to lower the specific gravity, so that this difference too would be accounted for. A new analysis of perfectly fresh synchisite can alone settle the question.

Microcline.—Microcline in well-formed crystals of orthoclase habit makes up the greater part of the porous material near the great central pocket. The crystals range from a diameter of two and a half centimeters downwards to mere crystal specks; they are, however, very constant in habit, presenting a remarkably cuboid form due to the dominant development of the base, clinopinacoid and orthodome; prism and unit pyramid, the only other forms found, being very subordinate in size. The faces are smooth and give fairly good reflections of the goniometer signal. The albite twinning, shown by microscope study to be universally present, is not apparent on the exterior of the crystals; its presence makes the crystals sensibly monoclinic however, and the measurements obtained approximate to those of orthoclase. Well-formed Baveno twins are seen in a few specimens, but most of the crystals are in clusters without apparent definite relation of the constituent individuals. The color of the microcline is white to pale ivory-yellow. On faces of the prism there is often a secondary coating of colorless glassy feldspar in parallel position to the main crystal, which the microscope shows to be also microcline, although its appearance strongly suggested the growths of albite so common on orthoclase from numerous localities.

Orientated sections, cut from the freely developed crystals of the pocket lining and from some of the larger crystals without, show that the microcline is twinned after the albite law only and thus lacks the grating structure characteristic of microcline in general. In basal sections the twinning is seen to be very finely polysynthetic. The individual lamellæ appear as short strips slightly elongated parallel to 010. Their boundaries are as a rule not sharp. The two sets of lamellæ extinguished symmetrically on either side of the trace of the twinning plane at an angle of 16 degrees (average of 12 meas-

Fig. 4.

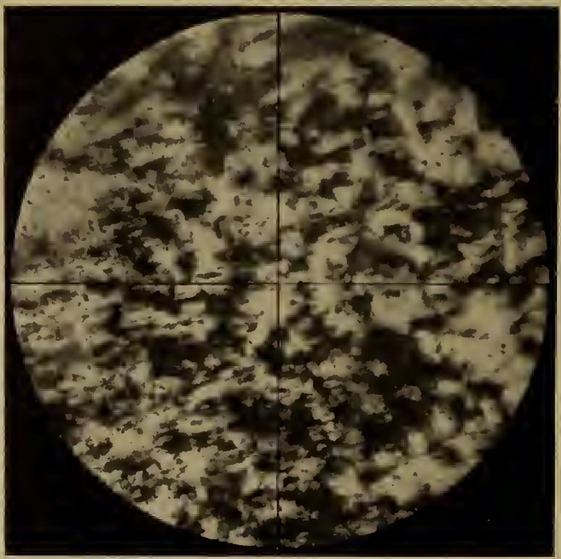


Fig. 4. Micro-photograph of a basal section of microcline cut from a freely developed crystal of the pocket lining, Fallon quarry pegmatite. Shows twinning after the albite law only. One set of twin lamellæ is extinguished at an angle of 16° with the trace of 010.

Crossed nicols. Magnification about 300 diameters.

urements). The clearer growths of later age are in parallel position to the older crystal and in them the twinning lamellæ are often longer and more sharply defined. In the small microclines throughout the finer-grained portions of the pipe the twinning is usually more sharply defined. The extinction of 010 sections was found from the average of ten measurements to be 5°. Figure 4 is a micro-photograph, using polarized light, of a basal section of a small microcline crystal.

Riebeckite.—The riebeckite occurs in the form of elongated prismatic individuals, possessing a black color and a lustrous cleavage, scattered through the coarser-grained main portion of the pegmatite pipes. The associated minerals are quartz, microcline-albite-microperthite and aegirite with accessory zir-

FIG. 5.

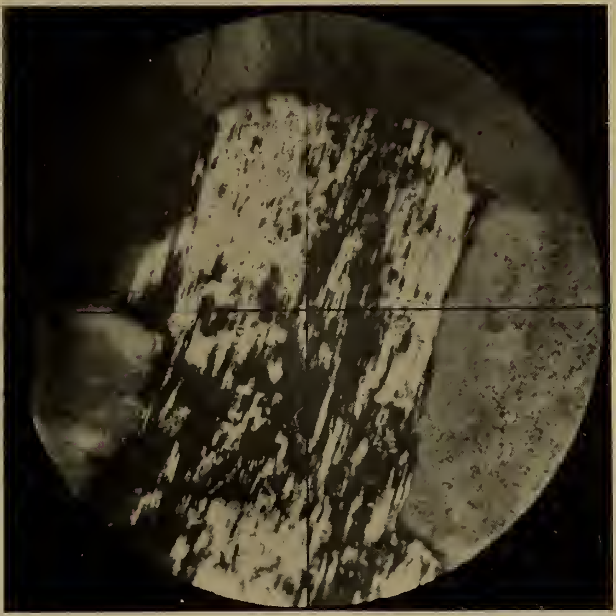


FIG. 5. Micro-photograph of a basal section of a small microcline crystal in the fine-grained portion of pegmatite in the Fallon quarry. Shows twinning after the albite law only. One set of lamellæ are extinguished at an angle of 16° with the trace of 010.
Crossed nicols. Magnification about 250 diameters.

con, fluorite and ilmenite. It varies in size from quite small individuals up to crystals one or two centimeters thick and ten or twelve long; individuals a centimeter thick and five or six long being quite common. The crystals show a tendency toward a crystal outline consisting of the unit prism occasionally truncated by the clinopinacoid. The immediate boundaries are, however, always more or less intergrown with the surrounding minerals. Terminal planes are not observed. Measurements of the prismatic cleavage made on two individuals yielded identical values of 55° 05′, an angle considerably larger than that of common hornblende, which is 55° 49′. The mineral is always to a greater or less extent intergrown with aegirite. While the latter is frequently included in the body of the former, its most common position is about the outside, particularly the ends of the crystal, and although the riebeckite contains unorientated grains of aegirite, the usual mode of intergrowth is with the prismatic axes of the two minerals parallel. As the sides and particularly the ends of the crystals are approached, narrow strips of aegirite are interlaminated with the riebeckite, the amount usually increasing until the latter is entirely replaced. The riebeckite usually contains considerable amounts of black dust, often arranged in wavy lines, as well as larger grains of black oxides, mostly ilmenite. Occasional grains of feldspar, fluorite and zircon are also included, sometimes singly and again forming patches of varying size.

Optical.—The deep color and strong absorption of the mineral makes the determination of its optical properties, with any precision, very difficult. This difficulty is increased by the fact that it has been found impossible after many trials to obtain altogether satisfactory sections of the mineral across the cleavage owing to its extreme brittleness. By the study of finely crushed material and thin sections the following characters have been made out:–

Ray near $c = \mathfrak{a}$. For sections 0·03mm or under, deep blue to bluish, smoky green. For over 0·03mm nearly or quite black.	Ray $\parallel$ to $b = \mathfrak{c}$. For 0·03mm thickness, very dark smoky green to almost black.	Ray near $a = \mathfrak{b}$. For thickness under 0·03mm yellow. For 0·03 and over brownish yellow with a greenish shade.

Absorption $\mathfrak{a} < \mathfrak{c}$ much greater than $\mathfrak{b}$. For many sections intermediate in position between the front and side pinacoids, a peculiar dull, grayish blue (some might call this a drab or even a violet tone of color) is seen. This is particularly true of thin cleavage fragments. In many sections parallel to the clinopinacoid it has been observed that the distribution of color is not uniform, the blue being seen in streaks parallel to the cleavage, or lying along lines crossing the cleavage, suggesting in appearance minute cracks along which there has been some slight chemical change. In such cases the remainder of the section has a dull bluish green color. In the riebeckite, from the pegmatites at least, such variation in color does not appear to be connected with any significant change in the chemical composition. Tests with the sensitive tint on very thin cleavage fragments show always a negative elongation. The extinction in 010 sections does not exceed four or five degrees, measured on the prismatic cleavage. Its accurate determination is rendered difficult by the strong natural color and strong dispersion of the mineral. A single section perpendicular to the prismatic axis which was sufficiently thin to yield, in convergent light, using a powerful illumination, a faint biaxial interference figure, was cut by the firm of Voigt and Hochgesang. The hyperbolæ move well out of the field on rotation of the preparation, indicating a large axial angle. The axial plane bisects the *acute* angle of the cleavages. This is substantiated by the interference figure obtained from the 010 section, which is clearly that of an obtuse bisectrix with the axial-plane lying parallel to the cleavage direction. The hyperbolæ in figures from this section are faintly colored red and blue; also interference brushes obtained from random sections are strongly colored red or blue, indicating a strong dispersion, the exact character of which has not been made out. From the above it appears that the axial-plane in this riebeckite lies *perpendicular to b 010, an unusual relation for a hornblende*, while the acute bisectrix lies inclined by not over four or five degrees to c', and is negative. A determination of the index of refraction for the yellowish ray, by the immersion method, gave a value of 1·695 (sodium).

Chemical composition.—Material for a chemical analysis was obtained from a single large crystal which appeared exceptionally free from impurities. This was broken up and most carefully picked over by hand under a powerful glass. When examined under the microscope it appeared agreeably free from alteration and included grains, except some inevitable black dust and a few black oxide particles as well as traces of aegirite and microcline. The average of closely agreeing duplicates is as follows:—

	Per cent.	Molec. ratios.
SiO_2	51·79	0·833
TiO_2	1·28	0·015
Al_2O_3	·68	·097 (Al₂O₃, Fe₂O₃)
Fe_2O_3	14·51	
FeO	21·43	·337 (FeO, MnO, CaO, MgO)
MnO	1·15	
CaO	1·28	
MgO	·10	
Na_2O	6·16	·111 (Na₂O, K₂O)
K_2O	1·10	
F	·20	·082 (F, H₂O −115, H₂O +115)
H_2O −115	·10	
H_2O +115	1·30	
Total	101·08	
Less O=2F	·09	
	101·17	
Spec. gr.	3·391	

The total of the analysis is a little high, a fault that is almost or quite unavoidable in a long silicate analysis made in a laboratory located in an excessively dusty part of a large city, particularly in the summer when the windows have to be open. If the TiO_2 is deducted with a proportionate amount of FeO to form ilmenite, the ratios derived from the analysis are: $SiO_2 : R_2O_3 : (RO + R_2O + H_2O) = 8 : 0{\cdot}90 : 4{\cdot}76$. These may be apportioned between appropriate molecules as follows : $Na_2Fe_2Si_4O_{12} = 0{\cdot}582 : R_4Si_4O_{12} = 0{\cdot}834 : SiO_2$ left $= 0{\cdot}058$. The excess of silica is considerable. The cause of this is not entirely clear. A little feldspar was present in the material analyzed, perhaps also unnoticed bits of quartz, and if the alumina in the analysis be taken out and combined with a proportionate amount of potash and silica to form microcline, the excess of silica is considerably reduced and the metasilicate ratios become more satisfactory. The potash seems rather high and may be in error.

A comparison of the Quincy riebeckite with other varieties of the mineral has been made elsewhere* and need not be repeated here further than to call attention to the fact that, owing to its relatively low ferric and high ferrous oxide, it contains only 42% of the $Na_2Fe_2Si_4O_{12}$ molecule, showing in this respect a rather close agreement with the riebeckite from Colorado, described by Koenig,† that from Red Hill, New Hampshire, described by Pirsson and Washington,‡ which contains 43 and 44 per cent respectively, but departs widely from the riebeckite from Socatra, analyzed by Sauer,§ which contains from 68 to 69 per cent of this molecule. The Quincy mineral also corresponds quite closely in the same way to several crocidolites whose analyses are quoted by Dana.‖ This last resemblance is especially interesting in the present connection because, in the central pocket of one of the pegmatites in which the riebeckite is found, there occurs an abundant crystallization of a black needle-like amphibole and crocidolite which seem to be, if not identical with the riebeckite in composition, at least very nearly so.

Aegirite.—The aegirite of the central pocket is also prismatic in development, sometimes, and especially in the smaller crystals, showing distinct and measurable terminations. There is, however, even in the best crystals much facetting and curvature of part of the terminal planes, especially in those highly inclined to the vertical axis. The faces of the prism zone are

* The Pegmatites of the Quincy Granite, etc., Warren and Palache. Proc. Amer. Acad. Arts and Sciences, 1911.

† Zs. Kr., i, 430, 1877.

‡ This Journal, xxxiii, 439, 1907.

§ Zs. D. Geol. Ges., xl, 138, 1888. See also Dana's System of Mineralogy, p. 400.

‖ Dana's System of Mineralogy, p. 400.

generally plane and measurements of sufficient accuracy were obtained to make it clear that these crystals may be referred satisfactorily to the axial elements of aegirite as described by Brögger. As a rule the smaller the crystal the better the quality of its faces; the best ones were minute needles of clear green color. Larger crystals are dark green to blackish green in color and often occur in subparallel groups, sheaf or rosette forms; many show fractures more or less healed or extreme bending.

Twinning on the orthopinacoid is common in larger crystals but is invariably associated with rounding and irregularity of the terminal planes to a degree that entirely precludes measure-

Fig. 6.

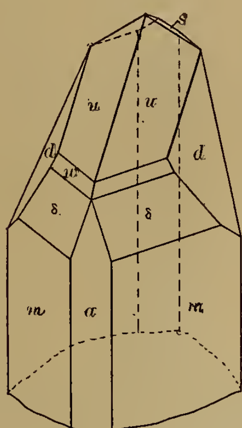
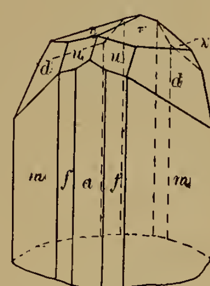


Fig. 7.



Figs. 6, 7. Aegirite.

ments. The basal plane was not observed. The form series as a whole is much more like that of augite than like that described as typical for either aegirite or acmite. None of the forms supposed by Brögger to be peculiar to those species were discovered. On this account and because several of the forms determined have not been recorded for aegirite; since moreover, this aegirite is shown by the analysis to be nearer to the theoretical aegirite molecule $Na_2Fe_2Si_4O_{12}$ than any previously described, it was deemed advisable to calculate the angles of the forms found on the basis of the axial ratio derived from these measurements, and they are accordingly presented in the following table together with the observed angles:

The axial ratio calculated from fifty faces of six forms on eight crystals gives the values of the first line below, with which may be compared the ratios of aegirite and acmite as determined by Brögger.

	a		*b*		*c*	*β*
Aegirite, Quincy	1·1044	:	1	:	·6043	73°27′
Aegirite, Norway, Brögger	1·0975	:	1	:	·6009	73 09
Acmite, " "	1·0996	:	1	:	·6012	73 11

Table of angles of Aegirite, Quincy.

$p_0 = 54·72$ $q_0 = ·5762$ $e = ·3015$ $\mu = 72°27'$

	Calculated		Measured		Limits	No. of Faces	Quality
	ϕ	ρ	ϕ	ρ			
a 100	90°00′	90°00′	89°57′	90°00′	89°37′-90°04′	5	poor
b 010	00 00	90 00	00 37	90 00		1	poor
m 110	43 35	90 00	43 33	90 00	43 00-43 55	27	good
f 310	70 42	90 00	70 26	90 00	69 56-70 56	5	poor
u 111	55 50	47 06	55 54	47 08	55 17-56 16		
					46 54-47 31	11	good
s $\bar{1}11$	-23 15	33 20	-23 40	33 24		1	fair
w 331	48 21	69 52	48 29	69 50	47 45-49 13		
					69 36-70 00	4	poor
λ $\bar{3}31$	-37 47	66 27	-37 46	66 42		1	poor
δ 551	46 31	77 10	44 46	77 57	44 02-45 31		
					77 30-78 25	2	v. poor
τ $\bar{1}12$	-5 32	16 53	-5 51	16 50	5 16-6 19		
					16 40-16 57	5	good
Δ $\bar{3}11$	-66 44	56 50	-66 40	56 45	66 37-66 44	2	v. poor
d 131	26 09	63 39	26 40	63 48	26 19-26 52		
					63 34-64 03	3	good

The forms *w* (331), (551), ($\bar{1}12$), and *d* (131) are new to aegirite although all are known on augite. The habit of the Quincy aegirite crystals is shown by figures 6 and 7.

Optical.—Small crystals or crystal fragments show under the microscope the following pleochrism:

𝔞 = pale to deep green, sometimes with a slight bluish tone. The color naturally varies with the thickness, but also varies quite widely in the same crystal. In fact portions of a crystal may be a very pale green to almost colorless, and the other portions medium to dark green, without there being, however, any other optical variation so far as can be told.

𝔟 = pale yellowish green to almost colorless.

𝔠 = pale yellow to yellowish green; almost colorless.

In many crystals the whole or a part may show a brownish-yellow or even reddish-yellow color. This is often most pronounced about black oxide (ilmenite) grains and is believed to be a pigment stain of ferruginous character. There appears, at least, to be no regularity in the distribution of the brownish or reddish colorations. The extinction, 𝔞 ∧ *c*′, is 6 degrees. Other optical characters appear to be as usual for aegirite.

Chemical composition.—The almost universal contamination of the aegirite with other minerals made the obtaining of suitable material for chemical analysis very difficult. By means of magnetic and heavy solution separations combined with handpicking under the microscope, about three grams of material were finally obtained which showed as impurities only a little ilmenite and traces of octahedrite and quartz.

The analysis made in duplicate averaged as follows: Aegirite, Fallon Quarry, North Common Hill, Quincy, Mass., U. S. A. (analyst, Warren).

	Per cent.	Molec. ratios.	
SiO_2	51·73	0·862	0·862
TiO_2	·64	·008	0·008
Al_2O_3	1·91	·018	0·217
Fe_2O_3	31·86	·199	
FeO	·87	·012	0·226
MnO	·60	·008	
CaO	·87	·015	
MgO	·14	·003	
Na_2O	11·43	·184	
K_2O	·40	·004	
H_2O	·20		
F	none		
Total	=100·65		
Spec. grav. at 25° C.			=3·499

Although a portion of the TiO_2 was probably present as TiO_2 (octahedrite), most of it is combined with RO as ilmenite, and after deducting the TiO_2 and the proportionate amount of RO as ilmenite, the combined ratios are: $SiO_2=0·838$, $R_2O_3=0·217$, $RO+R_2O=0·218$; or very nearly $SiO_2:R_2O_3:RO+R_2O=4:1:1$, leading to the formula $(R''_2R)\ Fe_2Si_4O_{12}$. So far as known to the writers, the ferrous iron is lower in this aegirite than in any other hitherto analyzed, and the composition approaches very closely to the theoretical composition of the compound, $Na_2Fe_2Si_4O_{12}$, which is SiO_2, 52 per cent; Fe_2O_3, 34·6 per cent; Na_2O, 13·4 per cent.

Fig. 8.

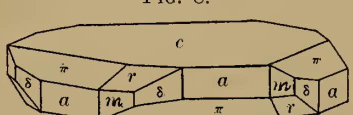
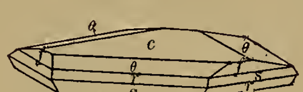


Fig. 9.



Figs. 8, 9. Ilmenite.

Ilmenite.— Ilmenite occurs in moderate abundance in both the Ballou and Fallon pegmatites. It appears to have been of rather late formation and is particnlarly associated with aegirite: as embedded xenomorphic plates, and groups of tiny crystals implanted on crevices of fractured aegirite crystals (Ballou quarry); and as clusters of larger crystals upon the walls of cavities left by the destruction of such crystals by magmatic resorption (Fallon quarry). The crystals are small, not exceeding a diameter of 2^{mm}, and are always very thin tabular in habit. A dull-black coating of manganese oxide commonly gives them a lusterless appearance, but in two specimens brilliant crystals were obtained which, despite minute size, gave good measurements on the goniometer. Octahedrite is almost always sparingly present with ilmenite.

The forms observed are as follows: $c(0001)$, $m(10\bar{1}0)$, $a(11\bar{2}0)$, $(21\bar{3}0)$* $\delta(10\bar{1}9)$, $u(10\bar{1}4)$, $\zeta(20\bar{2}5)$, $r(10\bar{1}1)$, $f(0.7.\bar{7}.20)$, $e(01\bar{1}2)$, $\Lambda(04\bar{4}5)$*, $s(02\bar{2}1)$, $\lambda(05\bar{5}2)$*, $g(0.3.\bar{3}.11)$*, $k(0.3.\bar{3}.10)$*, $\pi(11\bar{2}3)$, $n(22\bar{4}3)$.

The crystals from Ballou quarry showed the forms *c*, *m*, *a*, *δ*, *r*, and π_1, the prism zone being well developed and the base large and very brilliant. The prism is new to ilmenite.

Crystals from Fallon quarry are dominantly rhombohedral, prism faces being reduced to mere lines. The crystals measured showed the following combinations:

1. , , *r*, *f*, *e*, *s*, *n*.
2. *c*, , , *r*, *k*.
3. *c*, *m*, *r*, *u*, *e*, *k*, *n*.
4. *c*, *m*, *r*, *n*.
5. , *r*, *e*, *g*, *n*.
6. *c*, *m*, *r*, *e*, *n*.
7. *c*, *u*, *r*.

As shown in the figures (figs. 8 and 9), flat positive rhombohedrons are largely developed on these crystals, recalling the description of one (the common) phase of "Crichtonite" from Oisans by Des Cloizeaux.† That author considered the rhombohedrons which he measured $(10\bar{1}5)$, and $(10\bar{1}9)$, and $(1.0.\bar{1}.11)$ as negative, but left the determination of sign doubtful. The second of these forms is common to all the crystals from Fallon quarry and is certainly positive, so both the others should be likewise so considered. Several negative rhombohedrons new to ilmenite were observed and are based on the following data:

Form		Calculated ϕ	Calculated ρ	Measured ϕ	Measured ρ	No.	Limits of ρ.
g	$(0.3.\bar{3}.11)$	30°00′	23°34′	30°00′	23°46′	3	23°28′ to 24°05′
k	$(0.3.\bar{3}.10)$	"	25 27	"	25 34	1	
Λ	$(04\bar{4}5)$	"	51 59	"	51 57	2	51 53 to 52 00
λ	$(05\bar{5}2)$	"	75 57	"	76 06	1	
δ	$(21\bar{3}0)$	10 53	90 00	10 30	90 00	4	10 36 to 11 34

* New forms.

† Mineralogie, ii, 222, 1893.

The presence on one crystal of the form *f*, observed before only by Solly on a Binnenthal crystal, confirms this form. All the forms present gave angles agreeing very closely with the values calculated from the axial ratio of Koksharow as used by Dana.

Chemical tests on the ilmenite from both quarries revealed strong qualitative reactions for manganese; an analysis would be interesting, but it was not possible to separate enough of the fresh mineral for this purpose.

Octahedrite.—Octahedrite is found chiefly in the large central pocket of the Fallon pegmatite, generally in close associ-

FIG. 10.

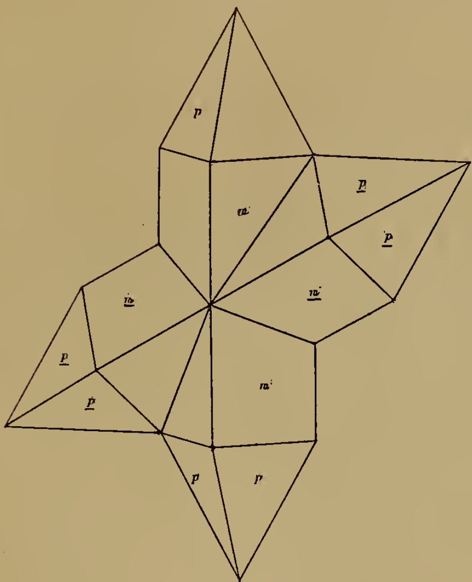
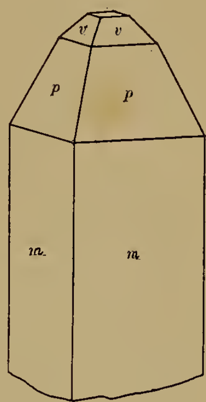


FIG. 11.



ation with aegirite and often formed posterior to the alteration of that mineral, since it is not infrequently seen on the walls of hollow casts of aegirite crystals associated with fluorite and ilmenite. Isolated crystals were also found implanted on feldspar crystals. The crystals of octahedrite are small, of a deep black color, and of very brilliant luster. They show only the forms *c* (001), *m* (110), *p* (111), *k* (112). and *z* (113), the two last the least common. These crystals are marked by two peculiarities; they are in large part of prismatic habit with the first order prism dominant, a habit not before described for this mineral, and causing the crystals to be at first mistaken for zircon; and they occur in cruciform twin groups with the form (101) as twin plane. The twins are sometimes complete interpenetrations of two equal crystals as shown in the figure; sometimes but one end of each is developed; again a larger crystal has a much smaller one in twin relation to it. The groups are exquisitely sharp and leave no doubt as to the definiteness of the twinning since the two upper faces of the unit pyramid of each crystal and the two lower, parallel and opposite faces to these, reflect the signal simultaneously in pairs; thus the faces of (101) which are in zone with these unit pyramid faces must be parallel to the twin plane.

This twin law has been observed but once before on this mineral, on crystals from the titaniferous calcite-quartz veins of Somerville, Mass.* There twins were extremely rare, while here they are sufficiently numerous to be considered as characteristic for the locality. Combinations of prism and unit pyramid are far the most common among these crystals. A few, however, show the base as a tiny facet, and in a few the flatter pyramids *k* or *z* replace the acute summit of the common form. Figs. 10 and 11 illustrate the habit of the octahedrite crystals.

Fluorite.—Fluorite is distributed throughout all parts of the pegmatite masses. It is generally in small grains, but near the central pocket, especially in that part where crocidolite was abundant, the fluorite individuals were larger, one mass showing cleavage faces nine inches across having been found. Where wholly embedded in crocidolite the fluorite crystals are idiomorphic, octahedrons up to one inch in diameter thus occurring; they are dull and somewhat rounded, the color a deep purple like all the fluorite of this locality, but occasionally there is a surface layer of bluish green color due to included fibers of the blue crocidolite. The hollow castes left by the solution of such crystals have already been described.

In one or two cavities in the Fallon pegmatite there were seen tiny cubes of fluorite implanted on quartz, and in another such pocket, peculiar in containing also crystals of calcite, the cube was modified by two hexoctahedrons which appear to be new to fluorite. The measurements and derived symbols of these forms follow:

	Calculated.		Measured		Limits		No. of read'gs
	ϕ	ρ	ϕ	ρ	ϕ	ρ	
⎧ 3.10.16	16°42′	33°07′	15°45′	33°20′			
⎨ 3.16.10	10 38	58 26	10 36	58 33	10°30′— 10°42′	58°30′ —58°36′	2
⎩ 10.16.3	32 00	80 58	32 04	81 05	31 52 — 32 16	80 50 —81 20	4
⎧ 259	21 48	30 54	21 01	31 15	20 45 — 21 18	31 11 —31 19	2
⎨ 295	12 32	61 32	12 32	61 25	12 27 — 12 37	61 23 —61 26	2
⎩ 592	29 03	79 00					

* On Octahedrite, Brookite, and Titanite from Somerville, Mass. C. Palache. Rosenbusch Festschrift, 1906, 311.

Wulfenite.—Thin coatings of light yellow color as well as tiny crystals of wulfenite were found on smoky quartz in the crocidolite pocket. The crystals are in part model-perfect combinations of first-order pyramid with third-order prism *n* (111), and *f* (320), (see fig. 6, p. 990, Dana, System), in part cube-like combinations of a prism and the base. The amount of wulfenite is very small, and its presence is easily accounted for by the association, in the same region of the pegmatite, of molybdenite and galena.

Boston and Cambridge, Mass.,
February, 1911.

Art. XLVI.—*Notes on the Absence of a Soil Bed at the Base of the Pennsylvanian of Southern Ohio*;* by Jesse E. Hyde.

Bailey Willis has recently urged, as one of the fundamental principles of paleogeography, the theorem that the failure of representation of many horizons and formations in an area where sedimentation has otherwise apparently been continuous, is to be explained by submarine erosion or failure of deposition due to current action, and that it is unnecessary to assume subaërial erosion in order to explain such a break in sequence.† E. O. Ulrich has since seriously questioned the validity of the grounds for Willis' stand, and his discussion with Willis' reply are briefly abstracted in the minutes of two recent sessions of the Geological Society of Washington.‡ Although these remarks are not a formal presentation of either side, it is felt that they open up to discussion one of the most important points in paleogeography and one about which it is apparent much remains to be learned. John M. Clarke's eloquent appeal for more facts to support scientific theory, appearing in the same number of Science with these abstracts, is as timely to the present instance as to any of the unproved propositions.

One of the principal arguments cited by Willis to support this theorem is the absence of anything resembling a soil bed or in any way suggesting weathering due to exposure to the atmosphere at the plane which marks such an omission from the column. It is maintained that if the bed whose absence it is desired to explain had been eroded while the whole stood

* By permission of the State Geologist of Ohio.
† Science, N. S., vol. xxxi, pp. 241–260, 1910.
‡ Science, N. S., vol. xxxiii, pp. 312–316, 1911.

above sea-level, some trace of the subaërial exposure would be visible at the contact.

The following facts concerning one erosion surface are presented solely as evidence against Willis' interpretation of the significance of the absence of soil beds or other evidence of exposure. The point which it is desired to make is that there may be no evidence of such a period of exposure at a contact which undoubtedly stands for several hundred feet of erosion, apparently under conditions highly favorable for soil formation. The explanation of the absence in this case cannot possibly be the one given by Willis, but no reason is, as yet, to be assigned.

The base of the Pennsylvanian series, or Coal-measures, along the outcrop belt in central and southern Ohio usually rests directly on the Logan formations whose general age is early Mississippian. The latter were subjected to erosion which removed an unknown thickness and a relief of 200 to 300 feet was established before the Coal-measures were accumulated. At several points the Maxville limestone, late Mississippian in age, is found between the two, but it occurs only in patches. There was some erosion of the Waverly prior to the formation of this limestone, but it is very probable from the general field relations that by far the most of the erosion was in post-Maxville time. The irregularity in the distribution of this formation is to be explained, in large part at least, by the attitude of the post-Maxville erosion surface.

This plane of disconformity extends entirely across Ohio. It has recently been followed in some detail from the center of the state to the Ohio river. In places, it cuts very abruptly into the fine-grained yellow sandstones of the Logan formations, sometimes removing them entirely, and letting in coarse, massive Coal-measure sandstones, but usually the irregularities are gentle and observations of the contact may be necessary over a mile or more, in order to detect any considerable variation. Differences in elevation of 100 feet are not uncommon, although most of them are less. Finally, it is the rule to find it standing uniformly high over considerable areas—several townships—and tending to be lower in adjacent townships. For example, in eastern Fairfield and southern Licking counties it stands very high, about 300 feet of Logan being present at one point. To the northeastward and southwestward it sinks gradually until the Logan averages 60 or 80 feet and to the southwestward may be wanting entirely. At several points where the coarse Coal-measures sandstones are let into the Logan to a depth of 100 or even 200 feet, they take the form of a long, narrow mass which can be traced sometimes three or four miles, and clearly indicate the presence of a valley on the old Waverly surface.

The Pennsylvanian rocks consist usually of coarse sandstone, frequently feldspathic and sometimes pebbly. One or two coal horizons are present near the base, but the coal is usually thin. Shale beds are not infrequent, but they are usually found higher up in the series, those beds near the contact being commonly sandstones, the so-called "Sharon conglomerate." Usually the poor outcrops and the short time at hand have prevented the determination of the effect of the Logan hills on the strata of the basal Coal-measures, but at one point in Vinton county and again in Perry county it can be shown that the hills were gradually covered by the Coal-measures and that the first coal swamps were broken by "islands" of Logan, which were later wholly covered by the coarse accumulations. Apparently none or, at most, very little of the material was obtained by the erosion of the Logan; it is much coarser and has come from some other source.

There is no evidence of marine influence in these basal beds. It was not until later, until the Logan eminences had apparently been entirely covered, that the first marine beds, of which there are several, were formed.

With the exception of the occasional marine beds which are intercalated, the Pennsylvanian formations of the Appalachian province, including eastern Ohio, are now quite generally held to be the result of some phase of continental deposition. Following the post-Maxville period of erosion, which developed the sub-Pennsylvanian topography, the simplest interpretation is to suppose slight subsidence sufficient to cause the cessation of erosion and the initiation of deposition, or a climatic change leading to the same result. The area which had been land in post-Maxville time would so continue, except that the topography would gradually be buried beneath the plain of accumuating material, over which coal swamps were spread, even while the tops of some of these hills were yet visible.

In connection with the discussion mentioned earlier, it is to be noted that there are few erosion contacts where one would look for an old soil bed with better reason than at this one. The old land surface, gradually buried under supposedly continental deposits in a climate of at least moderate humidity, it would seem, ought to carry some trace of surface weathering if not a well-developed soil bed. The actual contact is seldom seen because of poor outcrops. However, it has been seen at several points and there is no suggestion of pre-Pennsylvanian weathering in the rocks below the erosion plane. In three places the Coal-measures sandstones and conglomerates are fused on to the Logan. The writer has in his possession one small hand specimen, one side of which is Logan and the other side the coarse Pennsylvanian sandstone with the impression of a calamite stem. In this case, there was no tendency to break at the contact. At those localities where carbonaceous shales or coals with their accompanying white clays rest on the Logan, the basal beds are clearly of the Coal-measures series and not a soil bed antedating the Pennsylvanian.

It is not the purpose to here explain why there is no soil bed present. That seems to involve to a high degree the manner in which the basal Pennsylvanian beds were formed, that is, whether they were truly continental or whether there was subsidence below a body of water and removal of the soil from the Logan hills by wave action. In support of the latter is the occasional occurrence in the basal beds of the Pennsylvanian sandstones of considerable numbers of fossiliferous limestone or chert pebbles which appear to have been derived from the breaking up of some part of the Maxville limestone, which is otherwise unrepresented in the immediate vicinity. However, the presenee of the limestone pebbles and the absence of the soil beds are the only features whieh suggest that the basal Coal-measnres are not truly continental or that the interval marked by the crosion plane has been one of greater complexity than simple subaërial erosion.

Whatever may have been the intermediate stages, the occurrenee is believed to show that a soil bed or evidenee of weathering at an erosional contact is not essential to its interpretation as a plane of subaërial erosion, even when the next succeeding beds appear to be of eontinental origin, and that the absence of such a bed at sueh a contact may demand a much more eomplicated explanation than that of simple submarine or subaërial erosion.

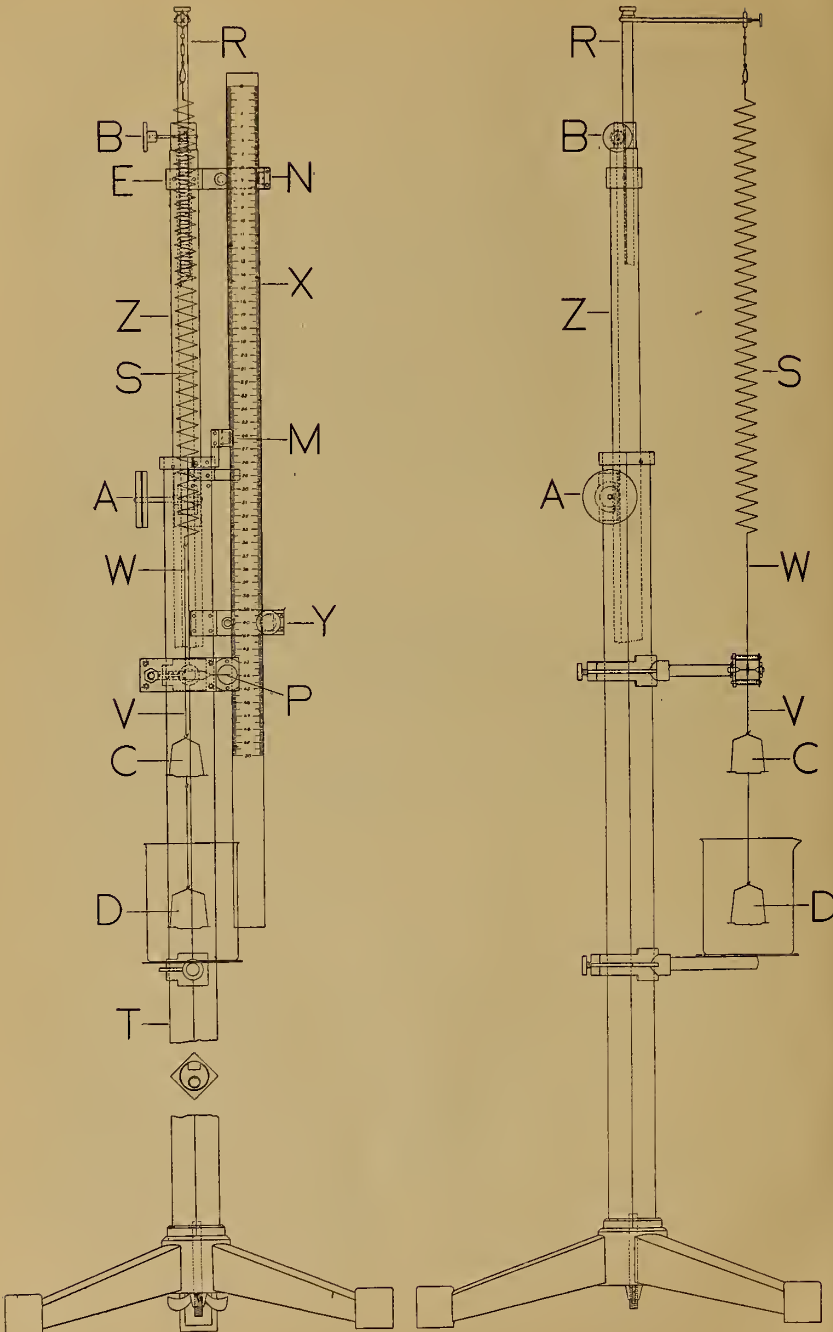
Art. XLVII.—*A New Jolly Balance;* by Edward H. Kraus.

The first important modification of the spiral spring balance, devised by Jolly, was introduced by Linebarger* in 1900, whose improved balance has since been used rather extensively. The balance to be described has several new features, of which the recording of the elongations of the spiral spring and the reducing of the number of readings necessary to determine the specific gravity are the most important.

The balance consists of the square upright tube T to which the fixed vernier M and the movable graduated scale X are attached, as shown in the accompanying figure. A second tube Z is movable within T by means of the milled-head A. The movable vernier N is attached to Z by the arm E. The screw B controls the rod R, movable within the tube Z. From R the spiral spring S and scale pans C and D are suspended, the thin wire rods W and V connecting the spring and scale pans with the pointer P, which swings freely in front of a small circular mirror.

In using the balance for the determination of the specific gravity of a solid, for example a mineral, it is necessary that the graduated scale X, the verniers M and N, and the pointer P all be at zero, the lower scale pan being immersed in water. Since the vernier M is fixed, the zero positions of N and X will be opposite M. The pointer P is brought to zero by being made to coincide with the index on the small circular mirror, the adjustment being accomplished by the screw B. A fragment is now placed on the upper pan C and the elongation of the spring determined by again bringing the pointer P to the zero position. This is now done by turning the mill-head A, which moves the tube Z, the graduated scale X and the vernier N, upward. After the zero position of the pointer is obtained, the scale X is clamped by the screw Y. It is obvious that the reading at M will give directly the elongation of the spring due to the weight of the specimen in air. The fragment is now transferred to the pan D under water. The pointer P is again, for the third time, brought to zero; this time by moving the tube Z and the vernier N downward by means of A, the scale X remaining fixed, having been clamped by the screw Y. The reading at N gives at once the loss in the elongation due to the immersion of the fragment in water. Hence, if the weight in air be represented by W, the reading at M, and the loss of weight when immersed in water by

* Physical Review, xi, 110–111, 1900.


R
B
E
N
X
Z
S
M
A
W
Y
P
V
C
D
T
R
B
Z
S
A
W
V
C
D

L, the reading at N, we have the simplified formula: Specific gravity $= \frac{W}{L}$.

The figure shows the balance* with the specimen immersed in water and indicates clearly that the chief advantages of this new form, over other balances in common use, are to be found in the recording of the elongations so that they may be verified if necessary at the end of the operations, and further but two readings and a simple division are sufficient to determine the specific gravity.

I am under especial obligations to Mr. Ralph Miller, whose skill and experience as an instrument-maker were largely drawn upon in perfecting the balance.

Mineralogical Laboratory, University of Michigan,
February 15, 1911.

* Made by Eberbach & Son Company, manufacturers and importers of scientific apparatus, Ann Arbor, Michigan.

Art. XLVIII.—*The Independence of the Coronas of the Thickness of the Fog Layer*; by C. Barus.

1. *Introductory.*—As an adequate theory of coronas is yet to be given, experiments with a definite bearing on the various features of the phenomenon are desirable. In my earlier work* I endeavored to elucidate the character of the interference phenomenon superimposed on the diffraction phenomenon, whereby the discs of coronas with white light eventually show a rhythmic succession of colors. A theory was suggested corresponding to that given by Verdet for the lamellar grating. Inferences so deduced were quantitatively in accord with facts. I showed that the reappearance of the same type of corona corresponds to a succession of diameters of fog particles in the order of the natural numbers $n = 1, 2, 3, 4$, etc. Finally, in a survey of coronas obtained with monochromatic light (mercury), it appeared that the disc and the first ring are alternately luminous in a way corresponding to the interference phenomenon in question. Finally, that in case of even the largest true coronas fog particles of an order of size greater than $10^{-4\,cm}$ were in question, beyond which the corona degenerates into a mere fog.

In another paper† I touched upon the question of the interference with each other of coronas due separately to two successive layers of fog particles normal to the line of sight, but the quantitative relations did not seem to be as promising as interferences inferred from the mere thickness of fog particles, already alluded to in comparison with the lamellar grating.

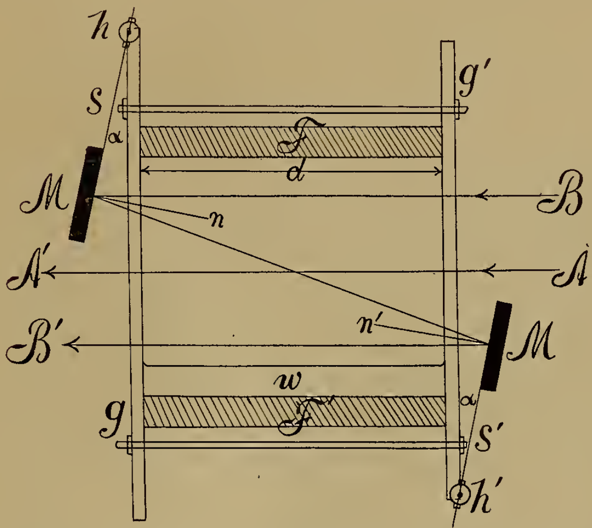
2. *Effect of Thickness: Apparatus.*—From the point of view of the elementary theory the effect of the thickness of the fog layer should be negligible; but it does not by any means follow that this is actually the case. In very many experiments with coronas, the thickness of the fog layer is not at the observer's disposal; or cases of different thicknesses have to be compared. Hence the following experiment was devised, with the object of definitely testing the question.

In the figure, FF' is a cross section of the fog chamber, a long rectangular trough of wood, cloth-lined and provided with two glass plates, g and g', on the broad sides of the trough. The pool of water is seen at w. Two mirrors, M and M', of plate glass (their normals at n, n'), horizontally hinged at h and h' and capable of being displaced parallel to their own plane by

*See Carnegie Publications, No. 96, Part I, 1908; ibid., Part II, 1910. This Journal, xxv, p. 224, 1908 (axial colors): ibid., xxiv, pp. 309–12, 1907 (cycles of coronas); ibid., xxvii, pp. 73–81, 1909 (mercury light).

† Proc. Am. Philos. Soc., April, 1911.

virtue of the screw extension adjustment s and s', are attached parallel to each other. The lower margin of M is somewhat above the upper margin of M'. Hence the observer on the left of the apparatus (in front) sees the direct rays AA' from the source as well of the reflected rays $B\ M\ M'B'$. By properly adjusting the angle a, the small round distant source of white light and its image in the mirrors (A' and B' respectively) may be made to coincide at the upper edge of M'. In such a case the corona due to the direct rays produced by a single thickness, $d=15{\cdot}5^{cm}$ of fog layer, should exactly coincide with, i. e. be the complement of, the coronas due to the reflected rays and produced by a triple thickness $d'=46{\cdot}5^{cm}$ of fog layer, if the variation of thickness in question is without effect. Otherwise the coronas should be dislocated at the margin of the mirrors.



3. *Results and Summary.*—These experiments were carried through in regular series, both for the dust nuclei of ordinary air as well as for an artificial nucleation due to phosphorus. The exhaustions were made systematically, every two minutes. The coronas due both to the A rays (direct) and the B rays (reflected) were read off as quickly as possible, after which filtered air was introduced to dispel the coronas by evaporating the fog particles. In this way about twenty coronas were successively compared, from the largest easily observable having an aperture of about 34°, to the small ones of vanishing size, the nucleation ranging from about 10^6 to zero (particles per

cubic centimeter), and the fog particles from a diameter of about $2\times10^{-4\,cm}$ to $10^{-3\,cm}$.

In no case was there any dislocation of coronas, or of color, detected, though naturally the coronas in case of reflection from the mirrors were somewhat more yellowish in color (due to the reflecting surfaces) and less vivid (due to the reflections and greater thickness of fog layer); for it is hardly probable that the fog particles are quite of a size. The continuity of corresponding colored rings, however, was exact within the limits of observation. Hence thicknesses of 15^{cm} and over 45^{cm} produce identical coronas identical in aperture; or the thickness of the cloud layer is without influence on the coronas.

Brown University, Providence, R. I.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The Radium Contents of some Uranium Minerals.*—It has been shown by Boltwood and also by Strutt that in many minerals a constant relation exists between the amounts of uranium and radium present, as would be expected from the theory of the formation of radium through the intermediate uranium-X and ionium. Recently Mlle. Gleditsch has found these relations to vary considerably (in the ratio 100 : 86 : 68) in thorianite, Joachimsthal pitchblende, and autunite. Soddy and Pirret, while finding a constant ratio in thorianite and the pitchblende, have also found a deficiency of radium in autunite. Marckwald and Russell have now confirmed the last mentioned result, and have made a further study of the autunite, which is a calcium-uranium phosphate with the formula $Ca(UO_2)_2(PO_4)_2.8H_2O$. This mineral, besides containing less than the expected amount of radium, is remarkable in containing no appreciable amount of lead as well as less helium than the required amount. From the amount of helium present, Soddy has calculated that the age of the mineral would be only about 30 years if none of this gas had been lost, whereas the radium corresponded to an age of many thousand years, so that he assumed that the radium in the mineral came from without and crystallized as an isomorphous replacement of calcium, instead of being a product of the uranium. This view of Soddy's appeared improbable to Marckwald and Russell, so that they investigated the ionium contents of the mineral and found its amount to be only slightly less than normal in proportion to the uranium. Since ionium has an average life of not less than 30,000 years, it follows that the age of the autunite must be

at least hundreds of thousands of years. The facts thus found lead to the view that the porous structure of the autunite, in comparison with the dense oxides, has allowed the escape of helium, and also the leaching out of the lead and a part of the radium. From a consideration of this and other minerals it appears that lead is more easily removed than is radium.—*Berichte*, xliv, 771.

H. L. W.

2. *The Determination of Cane Sugar in the Presence of other Sugars.*—Adolf Jolles has devised a new and very simple method for the determination of saccharose when other sugars are present. He finds that the other sugars, such as dextrose, levulose, maltose, mannose, galactose, arabinose, lactose, and rhamnose are readily decomposed by the action of dilute sodium hydroxide solution, while the saccharose may be left undecomposed and may then be determined by the polariscope. A one-tenth normal solution of sodium hydroxide is recommended, in which the cane sugar may be present in any convenient amount, but the contents of dextrose, levulose, invert-sugar, etc., should not exceed 2 per cent. The treatment may consist in boiling the liquid for three quarters of an hour in connection with an inverted condenser, or the liquid may be placed in a pressure-flask or sealed tube and heated in boiling water for the same length of time, or finally the solution may be allowed to stand in a closed flask at 37° C. for 24 hours. The last treatment is preferred for exact work because it gives a minimal amount of discolorization, but the other methods give reliable results, and colored liquids may be treated with basic lead acetate. It seems probable that the method will be very useful in connection with food-analysis, etc.—*Monatshefte*, xxxii, 1. H. L. W.

3. *The Action of Sulphur Dioxide upon Ammonia.*—The products of the reaction of these common gases have been frequently studied, and it seems remarkable that they have not been fully explained, but it appears from the recent work of Ephraim and Piotrowski that such is not the case. These investigators have found that there are three different compounds formed instead of two as has previously been supposed. With an excess of sulphur dioxide, amido-sulphinic acid, $NH_2.SO_2.H$ is produced, while with an excess of ammonia, according to the temperature, there may be formed either the ammonium salt of the above acid, ammonium amido-sulphite, $NH_2.SO_2.NH_4$, which is white, or a red compound having the same empirical formula as the last, but with double its molecular weight. This has been found to be the tri-ammonium salt of imido-sulphuric acid, having the formula $(NH\ )N<\begin{matrix}SO_2(NH_4)\\SO_2(NH_4)\end{matrix}$. This constitution was established by finding that one-quarter of the nitrogen was differently combined from the other three-fourths, so that at least four nitrogens must be present in it. By proper treatment it gives a silver salt, $AgN<\begin{matrix}SO_2Ag\\SO_2Ag\end{matrix}$, which is rather unstable.—*Berichte*, xliv, 379.

H. L. W.

4. *The Quantitative Chemical Analysis of Mixtures by Use of Differences in Specific Gravity.*—HANS FRIEDENTHAL has applied a method which, in a modified form, is well known to mineralogists to the analysis of complicated mixtures of organic and other substances. He states that in many cases the investigation of blood, milk, urine, gall, and other complex mixtures may be facilitated by removing the water, grinding the residue very fine with a mechanical agate mortar, and then separating the ingredients by specific gravity. As a liquid he uses bromoform diluted with toluol or xylol, whereby a range of specific gravities from 2·90 to 0·70 may be covered. A separatory funnel may be employed, or in certain cases a centrifugal machine. The statement is made that a solution of a mixture of sodium chloride and potassium chloride may be evaporated to dryness, and the two salts separated quantitatively by the use of a liquid of 2·04 specific gravity. No data are given in regard to the accuracy of any of the separations, so that an opinion cannot be advanced as to the value of the method.—*Berichte*, xliv, 904. H. L. W.

5. *On Metallic Colouring in Birds and Insects.*—It has been thoroughly proved that the usual "flat," "dead," uniform coloring, brilliant as this sometimes can be, *e. g.*, in birds, butterflies, and flowers, finds its simple explanation in the existence of pigment cells. On the other hand, the lively, variable "metallic" glitter of burnished copper or gold ; the reflection from certain aniline dyes ; the colors of certain pigeons, peacocks, humming-birds, as well as a number of butterflies, beetles, and other insects, require another explanation.

After calling attention to the preceding facts, A. A. MICHELSON summarizes the distinguishing characteristics of "metallic" reflection in the following sentences :—

"1. The brightness of the reflected light is always a large fraction of the incident light, varying from 50 per cent to nearly 100 per cent."

"2. The absorption is so intense that metal films are quite opaque even when their thickness is less than a thousandth of a millimeter."

"3. If the absorption varies with color, that color which is most copiously transmitted will be the part of the incident white light which is least reflected—so that the transmitted light is complementary to the reflected."

"4. The change of color of the reflected light with changing incidence follows the invariable rule that the color always approaches the violet end of the spectrum as the incidence increases." "If the color of the normal reflexion is violet the light vanishes (changing to ultra-violet), and if the normal radiation be infra-red it passes through red, orange, and yellow as the incidence increases."

Since these four criteria are qualitative and necessary but not always sufficient, the author also makes use of the more refined quantitative optical tests which relate to the effects of reflection upon polarized light. In brief, he determines experimentally, for various angles of incidence, the ratio of the amplitudes and the difference in phase of the components of the elliptic vibrations resulting from reflection. The numerical data are plotted as "amplitude" curves and "phase" curves.

For sake of general orientation, the first figure contrasts the curves for silver, steel, graphite, selenium, flint glass, crown glass and quartz. Figure 2 relates to two typical aniline dyes, viz., fuchsine and diamond green. The third figure shows the modifications in the curves produced by changing from a thick film to a very thin film of magenta. The fourth and fifth figures present, side by side, the curves for two specimens of "copper beetle" and thin films of magenta. The correspondence between the two sets of curves is so remarkable that it leaves no room to doubt that in this case the metallic coppery color of the elytra is due to an extremely thin film of some substance closely analogous in its optical qualities to the associated aniline dye. For the first beetle and dye-film the thicknesses of the active layers were of the order of $0·00025^{mm}$, and for the second specimen and magenta film, about $0·00005^{mm}$. Figure 6 comprises the curves for a "green beetle" and for diamond green. These curves do not agree very well and, in fact, no aniline dye could be found to match this beetle. Nevertheless, the curves for the insect have all the characteristics pertaining to "metallic" reflection.

The beetle wing-cases furnish in many instances a fairly smooth surface, and the difficulties attendant upon obtaining the necessary data are far less than when working with feathers of birds or with butterfly scales. The simple device of replacing the objective of the collimator and of the observing telescope by low-power microscope objectives of small apertures removed these difficulties so far as to make it possible to obtain results which compare favorably with those found for the aniline films. "In some of the measurements it has been found possible to deal with a single butterfly scale; and in these the irregularities of the surface were often insignificant, or of such a nature that they could be taken into account."

Figure 7 gives the curves for the green of a peacock feather, for a green humming-bird, for a red humming-bird, for a blue humming-bird, and for the blue-winged butterfly *Morpho alga.* For all the feathers, except those belonging to the red humming-bird, the optical data were of such a nature as to lead to the conclusion that the film which gives rise to the surface color is extremely thin.

Michelson remarks: "The total number of specimens which have been examined is perhaps not so large as it should be to draw general conclusions, and it is clearly desirable that it be extended; but so far the evidence for *surface* film, as the effective source of the metallic colors in birds and insects, is entirely conclusive." In this connection, reference should also be made to the essay of Dr. B. Walter entitled "Die Oberflächen- oder Schiller-Farben."

The paper under review concludes with details of the optical peculiarities of some highly interesting *exceptional* cases. Suffice it to say that these exceptions are afforded by the blue-winged butterfly, *Morpho alga*, by the "Diamond Beetle," and by the coleopter *Plusiotis resplendens.—Phil. Mag.* (6), xxi, 554.

H. S. U.

6. *The Isolation of an Ion, a Precision Measurement of its Charge, and the Correction of Stokes's Law.*—In the earlier work of R. A. Millikan the following sources of error introduced some uncertainty in the final results. (1) Lack of complete stagnancy in the air through which the drop moved ; (2) lack of perfect uniformity in the electrical field used; (3) the gradual evaporation of the drops, rendering it impossible to hold a given drop under observation for more than a minute, or to time the drop as it fell under gravity alone through a period of more than five or six seconds ; (4) the assumption of the exact validity of Stokes's law for the drops, studied. The author says: "The present modification of the method is not only entirely free from all of these limitations, but it constitutes an entirely new way of studying ionization and one which seems to be capable of yielding important results in a considerable number of directions."

The essential modification of the method consists in replacing the droplet of water or alcohol by one of oil, mercury, or some other non-volatile substance, and in introducing it into the ionization chamber in a new way. By means of a commercial "atomizer" a cloud of fine droplets of oil is blown with the aid of dust-free air into a vertical, dust-free cylinder. The base of this chamber is made of a heavy, circular disc of brass which constitutes the upper plate of the electrical condenser and which is perforated through its center by a vertical hole having about the same diameter as an ordinary pin. This hole is provided with a trap-door or cover which is actuated electro-magnetically. This trap is kept open long enough to allow a few drops to fall through it into the condenser below and then the cover is closed. In this way it is possible to imprison droplets in a condenser containing dust-free air which is absolutely free from currents. The condenser plates were exactly 16^{mm} apart. A narrow, horizontal, parallel beam of light from an arc lamp entered the condenser through one window, illuminated the droplets in its path, and then passed out through a diametrically opposite window. The illuminated drops were observed through a third window by means of a suitable telescope of short focus. The appearance of a drop is that of a brilliant star on a black background. The drop falls, of course, under the action of gravity, toward the lower condenser plate ; but before it reaches the latter an electrical field of strength between 3,000 and 8,000 volts per centimeter is established between the plates by means of a battery. Hence, if the droplet had received a frictional charge of the proper sign and strength as it was blown out through the atomizer, it will be pulled up against gravity by this field, toward the upper condenser plate. The electric field is taken off before the droplet reaches the upper plate and then the droplet falls again. In this manner it is possible to keep the same droplet moving up and down in the field of view of the telescope for many consecutive hours. By observing the times taken by the same droplet to fall, and to rise respectively, through the distance corresponding to the distance between the horizontal cross-hairs in the telescope, it is easy to deduce the speeds attained under the action of gravity alone, and under the excess of the electric over the gravitational fields. This operation is repeated and the speeds checked an indefinite number of times, or until the droplet catches an ion either from among those which exist normally in air, or which have been produced in the space between the plates by any of the usual ionizing agents like radium or X-rays. The fact that an ion has been caught, and the exact instant at which the event happened, is signalled to the observer by the change in the speed of the droplet under the influence of the field. From the sign and magnitude of this change in speed, taken in connection with the constant speed under gravity, the sign and the value of the charge carried by the captured ion are determined.

"The experiment is particularly striking when, as often happens, the droplet carries but one elementary charge and then by the capture of an ion of opposite sign is completely neutralized so that its speed is altogether unaffected by the field." "In this case the computed charge is itself the charge on the captured ion."

The final value for the fundamental ionic charge is given as $e = 4{\cdot}891 \times 10^{-10}$ electrostatic units.

The paper contains many other facts which, for lack of space, must be omitted.

The article closes with a complete list of the most important of the molecular magnitudes as recalculated from $e = 4{\cdot}891 \times 10^{-10}$ E. S. U., and with a table of "weights and diameters of molecules" for 14 gases and vapors.—*Phys. Rev.*, xxxii, 349. H. S. U.

7. *Homogeneous Röntgen Radiation from Vapors.*—When elements having atomic weights equal to, or greater than, that of chromium are exposed to Röntgen radiation, they emit chiefly homogeneous, secondary X-rays which are characteristic of the element used as radiator, and which are independent of the penetrating power of the exciting primary beam. The homogeneity of this characteristic radiation causes it to suffer equal percentage absorptions when transmitted through equal thicknesses of aluminium. By determining these percentage absorptions the values of $\frac{\lambda}{\rho}$, (where $I = I_0 e^{-\lambda x}$ and $\rho =$ density of aluminium), have been calculated for the elements of the group defined above.

Since these elements had only been studied in the solid state, either pure or in the form of compounds, J. C. Chapman has extended the investigation to the cases of the elements—small in number—which could also be experimented upon in the vapor state.

For the vapor of ethyl bromide $\frac{\lambda}{\rho}$ came out equal to 16·4. The values of this ratio for solid bromine, in the compounds sodium bromide and bromyl hydrate, were respectively 16·2 and 16·3. The agreement between the value of $\frac{\lambda}{\rho}$ for the vapor and for the solid is about as good as could be expected from the nature of the experimental method. In the case of iodine in the solid condition and as present in the molecules of the vapor of methyl iodide, the ratio $\frac{\lambda}{\rho}$ was found to have the same value, viz., 2·3.

"Although it has only been proved in these two cases that elements in the solid and vapor state emit the same type of radiation, yet it is safe to conclude that what applies here holds generally; especially considering that the atomic weights of bromine and iodine are well separated." "It is evident that this similarity of character in the radiations is what would follow from the fact that the phenomena of secondary X-rays are atomic in their nature."

Some other experiments are described in the paper, which are interpreted as showing that the hypothesis which regards the characteristic secondary radiation as resulting from the subsequent bombardment of atoms by ejected corpuscles is quite untenable. However, for further details in this connection reference must be made to the original article.—*Phil. Mag.* (6), xxi, 446. H. S. U.

8. *Lehrbuch der Kristallphysik;* von Dr. Woldemar Voigt. Pp. xxiv, 964; 213 text-figures, 1 plate. Leipzig and Berlin (B. G. Teubner, Sammlung von Lehrbüchern, Band xxxiv).—This is an encyclopædic work upon the physical properties of crystals, omitting, however, their optical properties. The first chapter deals with the geometrical properties of crystals and the application of the principles of symmetry; the second and third chapters give an account of the vectorial analysis which is used by the author and of the mechanical and physical principles which find application later. The remaining five chapters deal with physical properties, such as pyro-electricity and pyro-magnetism, thermal expansion, conductivity for heat and electricity, thermo-electric and thermo-magnetic effects, elasticity and viscosity, piezo-electricity and piezo-magnetism. The classification of these effects is based upon their mathematical analogies—as to whether they involve a scalar and a vector, two vectors, etc.

It would be difficult for any one who has not paid especial attention to this intricate and rather recondite branch of physics to give an intelligent opinion upon a work like the present, which is very voluminous and abounds in details. It is quite certain that there is no one better qualified than Prof. Voigt to write a treatise upon this subject, which he has long made his own; and it is probable that this book will long remain the standard in its field. H. A. B.

9. *The Electrical Nature of Matter and Radioactivity;* by HARRY C. JONES. Second edition. 8vo, pp. 210. New York, 1910 (D. Van Nostrand Co.).—The first edition of this work appeared five years ago (see vol. xxi, p. 465), and many advances have been made in our knowledge of the subject during the intervening period. It is, therefore, difficult to conceal the disappointment one feels on finding much of the older and now superseded data of the earlier edition still in evidence, and especially so as one is led to believe from the title page and preface that a general revision of the subject matter has been carried out in the preparation of the present edition. The style of the writer is lucid, and his talent for the exposition of simple facts is particularly noticeable in many instances. It is unfortunate, therefore, that the value of the book as an elementary treatise should be somewhat impaired through what appears to be a certain lack of familiarity with the subject on the part of the author. B. B. B.

II. GEOLOGY AND MINERALOGY.

1. *Illinois State Geological Survey, Bulletin No. 16, Yearbook for 1909.* FRANK W. DEWOLF, Acting Director. Pp. 402; 37 plates, 9 figures, map in pocket. Urbana, 1910.—The reports of the Illinois Survey contain year by year the record of an unusual amount of work of a varied character, and indicate the advantages to be gained by coöperation between the Federal and State organizations engaged in mapping, geologic work, reclamation surveys, and investigations of soil and water supply. The Survey has a generous appropriation, and the published results amply justify the expense. The Year-book for 1909 contains the following chapters, some of which have been separately published: Administrative Report; Elizabeth sheet of the lead and zinc district, by G. H. Cox; Oil Resources of Illinois, by R. S. Blatchley; Studies of Illinois Coal, by F. W. DeWolf, A. Bement, S. W. Parr, G. H. Cady, T. E. Savage, E. W. Shaw, R. G. Williams, Jon Udden; Faunal Succession and Correlation of the Pre-Devonian formations of Southern Illinois, by T. E. Savage; The Occurrence of Structural Materials in Illinois, by Jon Udden and J. E. Todd. H. E. G.

2. *New Zealand Geological Survey. A Geographical Report on the Franz Josef Glacier;* by J. M. BELL. With Topographical Maps and Data by R. O. GREVILLE, and Botanical Notes by LEONARD COCKAYNE. Pp. 14; 3 maps, 6 photographs. Wellington, 1910 (John Mackay).—Geographers are indebted to Dr. Bell for the first detailed report on one member of the interesting group of glaciers which occupy valleys in the Southern Alps of New Zealand,—a series of glaciers unusually large in proportion to the height of the range and to latitude. The Franz Josef glacier is 7½ miles long, has a width at its terminus of 41 chains, while the snowfield at its head covers 4,758 acres. Owing to factors which

control rainfall, the glacier descends to a point only 692 feet above sea level. Fluctuations in volume of ice are plainly indicated, and show that during Pleistocene time the glacier deployed on the Westland coastal plain as an extensive piedmont glacier. About 150 years ago the ice in the valley stood 250 feet above its present level; then followed a period of retreat, succeeded by a second advance; the amount of elongation from March, 1908, to April, 1909, being 132 to 162 feet. As an aid in determining future movements of the ice, observation stations have been established by the Survey. In addition to a discussion of glaciation, the report contains a brief account of the geology of the region and also a list of plants. H. E. G.

3. *Geological Survey of Western Australia, Bulletin No. 39. Geological Observations in the country between Wiluna, Hall's Creek and Tanami;* by H. W. B. TALBOT. Pp. 88; 3 maps, 44 figures. Perth, 1910 (Fred. W. Simpson).—New and interesting information regarding the geology and geography of the great central Australian desert is being furnished as a result of the examination of coal, water, and mineral resources of West Australia. The present bulletin gives the results of a reconnaissance of a strip 150 miles in width, extending from Wiluna northeast to Hall's Creek, covering a region in which no geological work has previously been done. Perhaps the most important discovery is the fact that sedimentary rocks extend through 7° of latitude and occupy an area previously assumed to be part of an Archean mass which had never been submerged. Metamorphosed sedimentaries are overlain by Devonian sandstones, grits, and conglomerates, followed by Carboniferous quartzites, sandstones, and shales. No fossils were found, the age being determined by lithologic similarity and stratigraphic position. The surface cover includes alluvium from living and extinct streams, sand dunes, and extensive deposits of travertine. As a geographic report the bulletin is valuable for its descriptions of desert scenery, wind erosion, conditions of life, and character of vegetation. Extinct lakes, abandoned channels, and other topographic features, indicate that this region furnishes an unusual opportunity for the study of climatic changes in recent geologic time. H. E. G.

4. *Geological Survey of Canada;* Among the numerous publications of the GEOLOGICAL SURVEY BRANCH of the Canada Department of Mines, which have recently been issued (see vol. xxx, p. 357), are the following memoirs:

No. 6. (1081.) Geology of the Haliburton and Bancroft Areas, Ontario; by FRANK S. ADAMS and ALFRED E. BARLOW. Pp. viii, 419; 70 plates, 7 figures, 2 maps.

No. 1. (1091.) Geology of the Nipigon Basin, Ontario; by A. W. G. WILSON. Pp. 152; 16 plates, 4 figures, 1 map.

No. 2. (1093.) The Geology and Ore Deposits of Hedley Mining District, British Columbia, by CHARLES CAMSELL. Pp. 218; 20 plates, 8 figures, 4 maps.

No. 5. (110.) Preliminary Memoir on the Lewes and Nordenskiöld Rivers Coal District, Yukon Territory; by D. D. Cairnes. Pp. 70; 8 plates, 2 maps.

No. 8—E. (1115.) The Edmonton Coal Field, Alberta; by D. B. Dowling. Pp. 59; 5 plates, 2 figures, 2 maps.

No. 12—P (1141). Canadian Palæontology. Part III, Vol. II; Fossil Insects; by Anton Handlirsch. Pp. viii, 93–129; 36 figures.

No. 14—N. (No. 1143.) New Species of Shells Collected by John Macoun at Barkley Sound, Vancouver: described by William H. Dall and Paul Bartsch. Pp. 22; 2 plates.

Report on a Part of the North West Territories drained by the Winisk and Attawapiskat Rivers; by William McInnes. Pp. 58; 5 plates, one map. Report on a Traverse from Lac Seul to Cat Lake in 1902; by A. W. G. Wilson. Pp. 25.

In the Mines Branch, special papers have been published on the production of coal, iron, cement, and other products, for 1909; another on peat bogs and the peat industry, etc. A preliminary report by John McLeish (pp. 21) has also been issued giving a summary of production for 1910. The total value of all products amounts to 105 million dollars contrasted with 92 millions for 1904, an increase of over 14 per cent, which gain is distributed throughout the whole list. The value of the gold produced was upwards of 10 millions, of silver 13 millions, of nickel and pig iron each 11 millions, and copper 7 millions. Among the non-metallic minerals, it may be noticed that the production of coal was nearly 30 millions and of asbestos 2½ millions. The last subject is treated at length in a special volume by Fritz Cirkel entitled:

Chrysotile—Asbestos: its occurrence, exploitation, milling, and uses; pp. 316, 66 plates, 88 figures. This is the second edition of a work first issued in 1895 (see vol. xxi, p. 255). The importance of the subject can be appreciated from the fact that 82 per cent of the world's supply of asbestos is now produced by Canada, while the value of the product has increased from $24,700, in 1880, to the total already noted above. The author notes further that at the Black Lake quarries, Quebec, there are some 45 million tons of asbestos rock now in sight. The subject is treated in its various aspects with admirable fullness, and is illustrated by a large number of excellent plates.

5. *Mineral Production in the United States in 1909.*—The division of Mineral Resources, United States Geological Survey, in charge of E. W. Parker, has issued in rapid succession the individual chapters which will presently appear in the complete volume Mineral Resources for 1909. A comprehensive sheet has also been distributed, giving the quantity and value of each of the mineral products for the calendar years 1900–1909. The grand total valuation amounts to nearly 1900 million dollars, which has been exceeded only in the years 1906 and 1907. In 1900 the total value was only a little in excess of 1100 millions, while in

1890 it was 606 millions, and in 1880, 365 millions. The production of gold in 1909 reached a higher figure than ever before, very close to 100 million dollars. There was also a decided increase in the production of aluminum, but a falling off in the other metals as compared with 1906–7. In most of the other products, also, the total value for 1909 falls somewhat below the maximum already attained. A prominent exception is that of the clay products, the total value of which was 160 millions. Corresponding with the increase in aluminum there has also been an increase in the amount of bauxite, as noted below.

6. *The Production of Gems and Precious Stones in the United States in 1899.*—A summary of the precious stones industry in 1909 has recently been given by DOUGLAS B. STERRETT, as an advance chapter of the "Mineral Resources of the United States." The total valuation of the different kinds of precious stones amounts to about $534,000, which is an increase of 25 per cent over the preceding year. This increase is most conspicuous in the turquoise and turquoise matrix from Nevada, New Mexico, Arizona, and Colorado, especially in the first-named state. Variscite has also been produced in considerable amounts, particularly in Nevada, taking the place of the lower grades of the turquoise matrix. Other new points brought out are the occurrence of delicately-colored rhodonite in Siskiyou Co., California; a promising emerald locality in Cleveland Co., North Carolina; fine chrysoprase from Tulare Co., Cal. Serpentine, pseudomorphous after amphibole and somewhat resembling cat's-eye, has been placed on the market under the name *satelite.* Some other similar names, having, however, no special claim to scientific recognition, are noted. The report contains many other facts of mineralogical interest.

7. *Production of Bauxite in 1909.*—In an advance chapter by W. C. PHALEN, from the Mineral Resources of the United States, it is stated that the production of bauxite in 1909 amounted to 129,101 long tons, valued at $679,447; this is an increase of 23 p. c. in quantity as compared with 1907. The states from which the bauxite is obtained are Arkansas, Georgia, Tennessee, and Alabama; of these the first named shows an increase of 200 p. c. as compared with 1908 and over 70 p. c. compared with 1907.

8. *Origin of the Thermal Waters in the Yellowstone National Park.*—An interesting discussion on the hot springs of the Yellowstone Park was given before the Geological Society of America at the annual meeting of December 27, 1910, by the President, ARNOLD HAGUE. It closes with the following clear and concise summary: "In conclusion I may state that I have attempted to show: (1) that igneous activity was continued throughout Tertiary time; (2) that this activity came to an end with the close of Pliocene time; (3) that during the Eocene and Miocene deep-seated waters were active geological agents, and that these waters were essentially primitive in their origin; (4) that in strong contrast to the explosive, volcanic conditions of the Miocene, the

Pliocene lavas were emitted under far quieter conditions and built up the successive flows that formed the rhyolite plateau; (5) that during the many thousand years since the withdrawal of glacial ice the Pliocene rhyolites have, since the beginning of Pleistocene time, been steadily undergoing progressive changes, brought about by the action of enormous volumes of superheated vadose waters; (6) that the gases contained in the thermal waters were in great measure derived from vadose sources; (7) that the eruptions and periodicity of geysers are phenomena due essentially to varying conditions of reservoirs and channels of superheated waters situated only short distances below the surface; (8) that the phenomena as seen to-day represent a phase in the evolution of thermal springs.

9. *Tables for the Determination of Minerals by means of their Physical Properties, Occurrences, and Associates;* by EDWARD H. KRAUS and WALTER F. HUNT. Pp. 254, New York, 1911 (McGraw-Hill Book Company).—The determination of mineral species by means of their physical properties is particularly useful in the instruction of the science, since it calls the attention of the student to the characters with which it is most important that he should become thoroughly familiar. The tables of Weisbach, as translated into English by Frazer, have been before the public for many years, serving a useful purpose in many laboratories. We have now a new system of tables prepared with much completeness and based primarily upon the characters which appeal to the senses most directly: that is, (1) luster, (2) color, then streak, hardness, cleavage, and specific gravity. The fact that many minerals vary widely in color and sometimes also in luster leads to their being introduced in a variety of places in the successive tables; this enlarges the work considerably, but does not necessarily make the task of the student more difficult. A useful feature of the work is the statement of special characteristics and of associated species, which is often important in the matter of identification. The work opens with a concise explanation of physical properties and a glossary of mineral terms.

10. *Composition of Strüverite;* by R. C. WELLS (communicated).—In the paper upon strüverite in the May number of this Journal, pages 441 and 442, the formula $Fe(Ta,Cb)_2O_5.6TiO_2$ should read $FeO.(Ta,Cb)_2O_5.6TiO_2$ or expressed more simply $Fe(Ta,Cb)_2(TiO_3)_6$.

Although it is stated on page 441 that "the analysis yields no simple formula" a better statement would be that too much significance should not be attached to the simple formula deduced from the analysis, in view of the uncertainties of the analytical methods.

III. Miscellaneous Scientific Intelligence.

1. *Bulletin of the Bureau of Standards, S. W. Stratton, Director.*—The results of the accurate work in many lines of the Bureau of Standards is presented from time to time in their Bulletin, of which No. 1 of Volume VII has recently appeared. Among the papers here included are two by C. W. Waidner and G. K. Burgess on the temperature scale between 100° and 500°, and on the constancy of the sulphur boiling point. J. H. Dellinger discusses at length the temperature coefficient of resistance of copper, and with F. A. Wolff the electrical conductivity of commercial copper. A new form of candle-power scale and recording device for precision photometers is described by G. W. Middlekauff. This has been in frequent use during the past year and has given excellent results, both as regards accuracy and economy of labor. P. G. Nutting and Orin Tugman discuss the intensities of some hydrogen, argon and helium lines in relation to current and pressure.

2. *The Prehistoric Period in South Africa;* by J. P. Johnson. Pp. 89, 6 pls., 47 figs. London, 1910 (Longmans, Green and Co.).—Believing that geological and archeological research has established a definite sequence in the primitive cultures of the Old World, the author has used the one generally accepted for Europe as a basis for his classification of South African antiquities. In the introduction he emphasizes the importance of the data afforded by river terraces, citing as an example southern England, where a single section reveals the stratigraphic relationship of the main divisions of the entire stone age—eolithic, paleolithic, and neolithic.

A chapter is devoted to eoliths from the Leijfontein farm, below Campbell Rand, near Cambell village, where patches of very old gravel, having no connection with any existing river, occur at the foot of the escarpment. Mixed with the gravel are much worn and highly glazed eoliths, a few of which are shaped from artificially produced splinters or flakes. As to paleoliths, the author is of the opinion that those of the Acheulian type are distributed throughout the whole of South Africa, he himself having found them in the valleys of the Zambesi, the Elands-Rustenberg, the Magalakwin, the Selati, the Olifants, the Komati, the Vaal, the Caledon, the Orange, and the Zwartkops, at Algoa Bay. Solutrean (paleolithic) sites are also widely distributed over South Africa, the Solutrean industry being distinctly more recent than the Acheulian; and as is also the case in Europe, characterized by a pronounced development of the artistic faculty. South African petroglyphs and rock-paintings of Solutrean age are distributed over the whole area in question. The pecked or incised figures are mostly found on bowlder-like outcrops of rock, either among kopjes or in the open veld, while the frescoes are chiefly met with at the back of rock-shelters. Some of these bear a remarkable resemblance to paleolithic frescoes recently found by Breuil near Cogul (Catalonia), Spain. The objects represented are for the most part animals and men, generally in silhouette only. Geometric figures are abundant. The petroglyphs are disconnected units only, and usually larger than the paintings ; the latter frequently depict a scene, as, for example, a hunt or a fight.

The petroglyphs are mostly peckings ranging from crude outlines to veritable bas-reliefs. The most primitive series of petroglyphs are those discovered by Leslie in the neighborhood of Vereeniging. The principal animals illustrated are the eland, giraffe, rhinoceros, and elephant. Although the pecking is very irregular, the general effect produced is good. All the groups appear to be of the same age and are weathered to the same color as the rest of the rock surface. At Biesjesfontein, some thirty kilometers southwest of the village of Koffyfontein, some of the figures are scraped instead of pecked on the rock. Here also are found two engravings ; one of a hippotragus, the other of a quagga. In a vast majority of rock paintings the outline is filled in with a uniform tint, either red or black, red predominating. In eastern Orangia and in the region south of the Orange river, polychrome paintings occur. The eland, a great favorite with the Solutreans, is depicted in two or more colors, white ventrally and golden yellow, red, or dark brown dorsally. Some of the better polychrome examples "show distinct, though incipient, shading." The figures of animals often show real merit ; those of men are always grotesque.

The final chapter deals with the prehistoric Bantu, abundant proofs of whose activities are to be found throughout the now sparsely inhabited bush country of northeastern South Africa. The Steynsdorp valley, for instance, is everywhere dotted "with remains of old kraals," in and about which are mortars, pestles, rubbing stones, and other artifacts. Evidences of soil tilling are many ; also of mining and smelting operations in iron, copper, tin, and gold. The finest ruins occur between the Limpopo and the Zambesi. Of the smaller, more primitive ruins, the Inyanga fort is a good example. It is the prototype of the more imposing Zimbabwe type. The ruins are on commanding sites, taking their shape from the summit contours ; the walls were built of roughly rectangular blocks of granite laid in even courses. The best walls are solid throughout; many are merely faced with stone, the space between the faces being filled with rubble. No cement was placed between the blocks. The builders knew how to produce chessboard, cord, herring-bone, and chevron patterns. Courses of rock of a different color were also frequently inserted. Monoliths were placed upright on the walls of some of the buildings. At Zimbabwe, which was the "fortified kraal of the head chief," additional pillars of soapstone occur, "carved at the top to represent perched birds of prey." All these ruins are the work of a Bantu race that reached a more advanced culture stage than their descendants. The objects found in the ruins are characteristically Bantu.

The present work is the fourth on South Africa by the same author, three of which are archeological. His right, therefore, to be classed as an authority in this field can hardly be questioned.

G. G. MACCURDY.

3. *Field Museum of Natural History. Annual Report of the Director* for the year 1910. Pp. 100, with 15 plates. Chicago, 1911.—The Annual Report of Dr. F. J. V. SKIFF shows the progress made by the Field Columbian Museum during the past year. This was particularly marked in anthropology through the collections made by Dr. Laufer in China and Tibet. Several important expeditions in the same line are now in the field in New Guinea, Borneo, the Philippines, Venezuela, and elsewhere. The total amount expended in 1910 from Museum funds was about $200,000, and nearly $21,000 in addition were subscribed by friends of the Museum for special purposes. The excellent plates show a number of interesting natural history groups recently installed.

The Field Museum has also issued the following: *Meteorite Studies III;* by OLIVER CUMMINGS FARRINGTON. Pp. 165–193, plates LV–LIX. Dr. Farrington gives here an account of the meteoric stone which fell at Leighton, Alabama, on January 12th, 1907, weighing 850 grams; also of the remarkable Quinn Cañon iron, weighing 3,275 lbs., acquired by the Museum in April, 1909. A description of this iron was given by W. P. Jenney in this Journal (vol. xxviii, p. 431). Dr. Farrington also discusses further the subject of the times of fall of meteorites, earlier taken up by him in this Journal (vol. xxix, p. 211). A complete list of the meteorites of the United States, geographically arranged, closes the number.

4. *Publications of the Astronomical and Astrophysical Society of America*, Vol. I. Organization, Membership and abstract of papers, 1897–1909. Pp. xxvii, 347, 4to, 1910.—The dedication of the Yerkes Observatory in 1897 was the occasion for a conference of scientists which led to the establishment of this society. The present volume is the complete record of its activities since its beginning, expressed in discussions and memoirs. Their range is wide and their number great. Many are of general interest. For example, a short article on the duration of twilight in the tropics, by S. I. Bailey, shows conclusively from observations at Arequipa (altitude 8,000 feet) and at Vincocaya (altitude 14,000 feet) that the statements contained in text-books generally (even Young's) as to the brevity of tropical twilight are as inaccurate as that of the ancient Mariner ("The sun's rim dips, the stars rush out, at one stride comes the dark"). He says: "While the tropical twilight is somewhat shorter than occurs elsewhere and is still further lessened by favorable circumstances, such as great altitude and a specially pure air, it is never less, and generally much longer, than an hour."

Simon Newcomb, it goes without saying, was the leading spirit in the society until his death, and an excellent portrait of him appropriately faces the title-page, followed by one of Charles Young.

W. B.

5. *Harvard College Observatory;* EDWARD C. PICKERING, Director. Recent publications are noted in the following list (continued from vol. xxix, p. 276).

ANNALS. Vol. LIX, No. 6. Photographic Magnitudes of 153 Stars; by EDWARD S. KING. Pp. 157–186.

Vol. LXV. Journals of Zones observed with the 8-inch Meridian Circle during the years 1888–1890; by ARTHUR SEARLE. Pp. 264.

Vol. LXVI. Journal of Zones observed with the 8-inch Meridian Circle during the years 1890–1898; by ARTHUR SEARLE. Pp. 253.

Vol. LXXI, No. 1. Standard Photographic Magnitudes of Bright Stars; by EDWARD C. PICKERING. Pp. 25.

CIRCULARS. No. 153. Opposition of Eros (433) in 1910. Pp. 3.

No. 154. Determination of Absolute Wave-lengths with Objective Prisms. Pp. 4, 6 figures.

No. 155. Accurate Measurements of Photographs. Pp. 3.

No. 156. Comparison Stars for Halley's Comet. Pp. 3.

No. 157. Brightness of Halley's Comet. Pp. 3; one figure.

No. 158. Stars having Peculiar Spectra. 38 New Variable Stars. Pp. 3.

No. 159. 15 New Variable Stars in Harvard Map, Nos. 7, 10, 16, and 19. Pp. 3.

No. 160. Photographic Magnitudes. Progress to July, 1910. Pp. 6.

No. 161. Curved Photographic Plates. Pp. 3, 2 figures.

No. 162. 22 Variable Stars in Harvard Map, No. 52. Pp. 3.

No. 163. 181,325. Nova Sagittarii, No. 3. H. V. 3306. Pp. 3; one plate, 3 figures.

Sixty-fifth Annual Report of the Director of the Astronomical Observatory of Harvard College for the year ending September 30, 1910; by EDWARD C. PICKERING. Pp. 10.

6. *Publications of the Cincinnati Observatory.*—The following memoir has recently appeared: No. 17. Micrometrical Measures of Nebulæ 1905 to 1910; by JERMAIN G. PORTER, Director. Pp. 3–72. Cincinnati (Published by Authority of the Board of Directors of the University), 1910.

7. *Contributions from the Princeton University Observatory.*—The following memoir from the Princeton Observatory has recently appeared: No. 1. Photometric Researches: The Algol-System Rt Persei; by RAYMOND SMITH DUGAN. Pp. 47, with 4 tables. Princeton, 1911.

8. *R. Comitato Talassografico Italiano.*—A committee, having as its object the study of the Italian seas, was appointed in 1909, and later it was formally established by act of the Italian government. This committee, of which the Marine minister is the president, has the task of making investigations of the Italian seas from the physical, chemical, and also biological point of view. The practical questions concerning the navigation and

the fisheries will also be considered, and, further, investigations of the high atmosphere will be made in connection with the airship navigation. An annual sum of 60,000 lire is appropriated by the government, which also supplies the ships needed from the Royal navy. Four cruises in the Adriatic sea have already taken place, and a fifth cruise will soon start.

9. *International Congress of the Applications of Electricity.*—An International Congress of the Applications of Electricity will be held in Turin, from September 9 to 20, 1911. A circular from the committee of organization has been issued. Communications to it should be sent to 10 Via San Paolo, Milan.

10. *International Congress of Applied Chemistry.*—The eighth International Congress of Applied Chemistry will have its opening meeting in Washington on September 4, 1912; other meetings, business and scientific, will be held in New York from September 6 to 13. The president is Dr. W. H. Nichols, and the secretary, Dr. B. C. Hesse of 25 Broad st., New York City. Dr. E. W. Morley is honorary president.

11. *German Anthropological Society.*—The forty-second meeting of the German Anthropological Society—the fifth combined meeting of Germany and Vienna—will be held in Heilbronn, from August 6 to 9, 1911.

12. *University of Bologna.*—The University of Bologna will celebrate on the 12th of June the fiftieth anniversary of the appointment of Professor Giovanni Capellini to the chair of Geology. His contributions to geological science and his work in inspiring others in the same line are so important that the occasion should be a highly notable one. The president of the committee is Professor Augusto Righi, and the secretaries are Professors Vittorio Simonelli and Albano Sorbelli.

Obituary.

Dr. Samuel H. Scudder, the naturalist, died at his home in Cambridge, Mass., on May 17 at the age of seventy-four years. He was early (1862–4) active in connection with the Agassiz Museum of Comparative Zoology, and later with the Boston Society of Natural History. He was also assistant librarian of Harvard University in 1879–82 and paleontologist of the U. S. Geological Survey from 1886–92. He was the author of many original memoirs on insects, recent and fossil, and his valuable contribution to science brought him recognition from numerous scientific societies at home and abroad.

M. Edouard Dupont, the geologist and director of the Royal Museum of Natural History at Brussels, died March 31, at the age of seventy years.

Thomas Rupert Jones, F.R.S., the veteran English geologist, formerly Professor of Geology at Staff College, Sandhurst, died on April 13, in his 92d year.

Prof. J. Bosscha, the Dutch physicist, died on April 15, at the age of seventy-nine years.

INDEX TO VOLUME XXXI.*

*This Index contains the general heads, CHEMISTRY (incl. chem. physics), GEOLOGY, MINERALS, OBITUARY, ROCKS, ZOÖLOGY, and under each the titles of Articles referring thereto are mentioned.

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