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WITH PLATE I.

NEW HAVEN, CONNECTICUT.

1909.

RARE CINNABARS FROM CHINA.

We have still left a small lot of these remarkable Cinnabar specimens which were described and illustrated in the November issue of this Journal. Write for prices and illustrated pamphlet.

NEW ARRIVALS.

Euclase, Capo do Lane, Brazil; Terlinguite, Terlingua, Texas; Eglestonite, Montroydite, Terlingua, Texas; Patronite, S. A.; Uraninite, crystal in matrix, Portland, Conn.; Benitoite, San Benito Co., Cal.; Neptunite, Cal.; Crookesite, Hedenbergite, Sweden; Lievrite, Elba; Polybasite, Hungary and Durango, Mexico; Josephinite, Oregon; Herderite, Maine; Smithsonite, Kelley, N. M.; Californite, Tulare Co., Cal.; Cobaltite, loose crystals, and in matrix. Cobalt, Ont., and Tunaberg, Sweden; Apatite, Auburn, Maine; Vivianite, large crystals, Colo.; Vanadinite, Kelley, N. M.; Monazite, Portland, Conn.; Olivenite, Utah; Sartorite, Canton Wallis; Jordanite, Binnenthal; Mohawkite, Algodonite, Domeykite, Michigan; Crocoite, Siberia and Tasmania; Cinnabar, Cal. and Hungary; Dioptase, Siberia; Diopside, with Essonite, Ala, Piedmont; Embolite, Australia; Gypsum, twin crystals, Eisleben, Thuringia; Diamond, in matrix, New Vaal River Mine, South Africa; Brochantite on Chrysocolla, Utah; Pink Beryl, small and large, Mesa Grand, Cal.; Kunzite, small and large, Pala, Cal.; Sphene, Binnenthal, Titanite, Tilly Foster, N. Y.; Tetrahedrite, Utah and Hungary; Realgar, Hungary; Opal, Caribou River, Queensland; Octahedrite, var. Wiserine, Binnenthal; Heulandite, Iceland; Paper Calcite, Saxony; Torbernite, Eng.; Bismuth, native, Cobalt, Ont. and Conn.; Silver, native with Breithauptite and Smaltite, polished, Ont.; Emerald, loose crystals and in matrix, Ural and Bogota; Topaz crystals with rare planes, Ural; Zircon crystals, loose, Ural; Green and Cinnamon Garnets, Minnot, Maine; Vesuvianite, Poland, Maine, Italy and Tyrol; Zeolites, beautiful specimens from Erie Tunnel, Patterson and Great Notch.

CUT GEMS.

We have left over from our Christmas trade a very fine and varied lot of large and small Cut Gems, which we are offering at unheard of low prices. We name a few below :—

Garnets, green and red; Aquamarines; Zircons, all shades · Sapphires, all shades; Star Sapphires and Star Rubies; Chrysoberyl, Cats-eye; Spinels, all shades; Topaz, pink, blue, brownish and golden color; Pink Beryl; Sphene; Tourmaline, all shades; Amethyst, Siberia, royal purple color; Andalusite; Star Quartz; Peridote; Opal matrix, Mexico and Australia; Precious Opal, Australia, Mexico and Hungary; Hyacinth; Turquoise, Mexico and Persia; Kunzite; Reconstructed Rubies and Sapphires; Emeralds; Opal Carvings, such as pansies, vine leaves with bunches of grapes, and other small Opal novelties; Antique and Modern Cameos; Antique, Mosaic and other semi-precious stones.

Let us know your wants, and we will send the specimens on approval to you.

A. H. PETEREIT,

81—83 Fulton Street, New York City.

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ART. I.—*Diopside and its Relations to Calcium and Magnesium Metasilicates ;* by E. T. ALLEN and W. P. WHITE. *With Optical Study:* by FRED. EUGENE WRIGHT and ESPER S. LARSEN. (With Plate I.)

THE pyroxenes were chosen some time since as a good subject for laboratory investigation, both by reason of their geologic importance and because their comparative stability and simplicity of composition seemed to offer relatively little difficulty in their synthesis and study. Diopside is the simplest of this group of minerals, but before even this could be studied satisfactorily, a detailed investigation of both calcium and magnesium metasilicates was found necessary; a full account of which has been given elsewhere.* Here it will be sufficient to state that calcium silicate exists in two crystal forms, one of which, the mineral wollastonite (β-form), is stable up to about 1190°, when it reverts to a pseudo-hexagonal form (a-form) which melts at 1512°. The case of magnesium metasilicate is more complex. There is one form (monoclinic) strongly resembling the pyroxenes, both optically and crystallographically, which is stable up to 1365° (β-form). Here it passes over into an orthorhombic form (a-form) recalling forsterite (Mg_2SiO_4) in its habit and optical properties. It melts at 1524°. Three other forms exist, viz., the minerals enstatite, kupfferite, and a monoclinic amphibole similar to the latter. All are monotropic, and change into the β-form when heated to a sufficiently high temperature.

The question of the relation of diopside to its component salts, calcium and magnesium silicate, we undertook to settle by determinations of the melting point and specific volume

* Allen, White and Wright, this Journal, xxi, 89, 1906 ; Allen, Wright and Clement, this Journal, xxii, 385, 1906. Their form, then undiscovered, is described for the first time in these pages.

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curves, relying on very careful microscopic examinations to make sure of the solid phases which separated from the molten solutions.   Since we are concerned here with *equilibrium* conditions, it will be evident that the monotropic forms of magnesium silicate do not enter into the problem.*   In addition to this specific problem, viz., the relations existing between the calcium and magnesium silicates, we planned to study the most important properties of diopside and its transformations on heating, if any.

Many of the methods used in this investigation have been already described in previous papers from this laboratory;† others have been devised in the course of the work.

Preparation of the Mixtures.—Quartz, magnesia and calcium carbonate were mixed in the proper proportions and melted in large covered platinum crucibles.   The molten charges were chilled by dipping the crucibles into water, cracked out of the crucibles, crushed fine, and remelted to ensure thorough mixing.   All the materials were carefully examined for impurities, and we are able to state with certainty that the products contained no more than 0·1 per cent to 0·2 per cent of foreign matter, except in certain cases where the same preparation was repeatedly melted and crushed, when as much as 0·3 per cent impurity was sometimes found.

We had considerable trouble in getting magnesia sufficiently pure for our purposes.   The chief impurity is generally lime, of which all the samples examined by us contained 0·5 per cent or more.   At our request, the firm of Baker & Adamson undertook the problem of preparing pure magnesia in quantity, and succeeded in making a " basic carbonate" in which the minimum quantity of lime amounted to about ·07 per cent, or 0·15 per cent of the calcined oxide.   A sample of magnesium metasilicate prepared from one lot of this carbonate gave by direct test ·12 per cent lime.   In mixtures very high in magnesia a correction was generally made for this impurity, i. e., the proper deduction was made from the quantity of lime required by the particular mixture in hand.   For the sake of control we analyzed two of the preparations and the results are given below.

At one time during the investigation, it was suspected that some loss might be caused by the strong blast of the gas furnace in which the constituent powders were first melted together in spite of the fact that the crucible was carefully covered. The magnesia being by far the lightest of the constituents

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* Viktor Pöschl incorrectly designates the series " *enstatite*-diopside," Centr. Min., 1906, p. 572.

† This Journal, xix, 125, 1905 ; xxi, 89, 1905 ; Tschermak's Mitth., xxvi, 169, 1907.

(magnesia, calcium carbonate, quartz), its loss would be disproportionate to its weight in the mixture. But the analysis of the 60 per cent $MgSiO_3$ mixture, in which the magnesia was slightly high, shows that the suspicion was unfounded.

			Found	Cal.
1.	10% $MgSiO_3$	SiO_2	52·75	52·67
	90% $CaSiO_3$	CaO	43·52	43·33
		MgO	4·06	4·00
		Fe_2O_3 etc.	·11	----
			100·44	100·00
2.	60% $MgSiO_3$	SiO_2	56·80	56·73
	40% $CaSiO_3$	CaO	19·12	19·26
		MgO	24·11	24·01
		Fe_2O_3 etc.	·13	----
			100·16	100·00

Thermal Study.—The thermal study was carried on, as in other published work from this laboratory, by Frankenheim's method, melting point curves being used exclusively. Freezing-point curves are unreliable on account of the undercooling, which, even in substances which crystallize as readily as the metasilicates of calcium and magnesium, is often considerable. The mixture under investigation was heated in a platinum crucible, in an electric resistance furnace fed from a storage battery, the temperatures were read to tenths of a degree by a Le Chatelier thermoelement and a potentiometer, and evaluated in terms of a standard saturated cadmium cell.

Since the work here described continued over a considerable period of time, the methods used varied somewhat as successive improvements were introduced. In the earlier portion of it, charges of about 25 grams were used, and the thermoelement was protected by a porcelain tube with a platinum jacket. A control element was also employed to detect any irregularity in the heat supply.* Soon after the work was begun, the practice was also instituted of comparing the thermoelements with standards in order to correct for their deterioration,† due to contamination with iridium from the platinum crucibles and furnace coil. This has now been greatly reduced by using specially pure platinum within the furnace, but occasional comparisons with standard elements are still necessary.‡ Frequently the thermoelements were inserted together in the porcelain tube and used to read the same melting point. The

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* This Journal, xxi, 94, 1906.

† The Constancy of Thermoelements, W. P. White, Phys. Zeitschr., viii, 325, 1907.

‡ W. P. White, Phys. Rev., xxv, 336, 1907.

readings when separately corrected then seldom varied $\frac{1}{2}°$, which was about the accuracy with which any two working elements could be compared. The variations in the results, sometimes amounting to 2°, even with the more sharply melting substances (the end members, the eutectics, and diopside), were therefore due to uncertainty in locating the melting point, and not to the temperature measurements.

In the latter part of the work, charges of only $2\frac{1}{2}$ grams were used, in very small crucibles of pure platinum, in which the naked thermoelements could safely be immersed. Under these conditions and with proper precautions, the variations rarely exceeded $\frac{1}{2}°$. The small crucibles could also be more easily moved in the hot furnace, chilled in cold water, etc., and a wider range in the conditions of crystallization obtained. Furthermore, the thermal lag of the diminutive charges was very small, and complex thermal phenomena could be analyzed or separated with much greater certainty than with larger crucibles. The small crucibles were mainly used in investigating those portions of the field in which the interpretation of the phenomena had proved particularly difficult. They were used, however, in a sufficient number of cases to afford a thorough control of the earlier determinations made with 25 grams, and showed that these were accurate within their own accidental errors.

The agreement obtained between observations of the same point in both the earlier and later work is well illustrated in the following table :

TABLE I.

Agreement of Observations in Earlier and Later Work.

Temperatures in microvolts.   About 13 microvolts to 1°.

	70% MgSiO₃ : 30% CaSiO₃. 25 gr. charge.		28% MgSiO₃ : 72% CaSiO₃. 2½ gr. charge.
June, 1905	14,147	Oct. 1907	13,772
	130		776
	110		777
	138		779
	148		- - - -
	127		- - - -
Mean	14,133		13,776 .
Average deviation,	11 mv.		2 mv.
Extreme "	37 mv.		7 mv.

These particular instances were selected for illustration as being, each in its class, the one showing the largest number of strictly comparable observations. Each one is typical, and

neither is the best that could be given. Each represents three different charges.

A word as to the exact significance of the accuracy here indicated may avoid some confusion.

In comparative measurements with very small crucibles (2·5 grams) and bare thermoelements, the relative accuracy obtainable by the same observer with the same apparatus is $\frac{1}{2}°$ or better ; with the larger crucibles (25 grams) and jacketed elements, differences may reach 3°. This is shown in Table I, page 4.

The absolute value of the measurements is not established with this accuracy. Different observers, indeed, working independently with different apparatus, ought not to differ much in their results through differences in experimental methods, provided these are not positively faulty ; that is, provided the thermal junction is actually at the temperature of the melting material. This is shown by the agreement of our earlier and later results, obtained with highly differing methods, and also, perhaps more conclusively, by the agreement found between Dr. Day's special form of element[*] and the ordinary jacketed element. Differences between independent observers are, however, to be expected in the thermoelement calibration, particularly at the present time, when a long extrapolation is necessary. Practically all temperature measurements above the melting point of copper (1084° C., Reichsanstalt Scale) are now obtained by extrapolating some simple function which has been experimentally established for temperatures below that point. With the same function and different elements, temperatures usually do not vary more than 2° C. at 1,500°. With different functions, the extrapolated curves may diverge as much as 30° C. at 1,500°. An error of 0·5° in the determination of the copper point itself may cause an error of 4° in the extrapolated curve at 1,500°. All these are differences in the interpretation of the experimental measurements, which will probably continue to cause considerable differences between the results of different observers until the gas thermometer scale is extended to that temperature with sufficient accuracy, after which they can be readily recomputed to the established scale. The temperatures here given are computed from the Reichsanstalt Scale. In brief then, the *accuracy*

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[*] Carnegie Institution Publication No. 31, p. 25. Our value for magnesium silicate is 3° higher than that found by Allen, Wright and Clement, but this difference is only a little greater than the accidental variations occurring in the present work. With charges of the same size, errors in the method seem most likely to occur, if at all, as the result of a very uneven temperature distribution in the furnace or of insufficient immersion of the thermoelement in the charge. In a few cases where the platinum jacket dropped down so as to rest against the bottom of the crucible, which was cooled by contact with the pedestal below it, the melting point came about 5° too low.

of the determinations is shown by comparing the measurements among themselves. Their *interpretation* in terms of an absolute scale depends upon an agreement among observers, and will vary from time to time whenever more accurate fundamental observations are available. At the present time the Reichsanstalt Scale is generally accepted.

The melting points measured, like those obtained in this laboratory with the feldspars, and by workers in high temperatures generally, are not entirely sharp, even with substances which theoretically should melt at a strictly constant temperature. Indications that melting has already begun invariably appear on the thermal curve 20° or 30° below the melting point proper, and the region of strongest absorption of heat is distributed over an interval of from 2° to 3°. The main cause of this phenomenon in the present case probably lies neither in any unusual molecular viscosity attending the change of state* nor in experimental error of the temperature observations. It may be due to the slight impurity (·1 to ·2 per cent) which chemical analysis shows to be present, even in the most carefully prepared artificial mixtures. Similar curves are obtained with ice to which 2 per cent or 3 per cent of salt has been added, and at an absolute temperature five or six times as high the same effect should be produced by about one-thirtieth as much impurity.† The highest portion, that is, the end, of the melting interval is taken as the melting point, since this is probably the nearest attainable approach to what would be the sharp melting point of the substance unaffected by traces of impurity.

The Melting Point Curve from 0 per cent—46·3 per cent $MgSiO_3$.—The temperature-time curves were taken on a series of mixtures of the metasilicates 5 per cent to 10 per cent apart except in critical parts of the curve, where shorter intervals were chosen. The temperatures at which the heat absorptions took place are plotted in fig. 1. The results in the case of about one-third of the mixtures were controlled by repeating the observations on several different preparations, and since the thermal phenomena in certain parts of the curve were rather complicated, a considerable number of the observations were many times repeated, making in all nearly four hundred independent determinations.

By reference to the diagram (fig. 1) it will be seen that the addition of magnesium silicate to pure calcium silicate (pseudo-wollastonite) lowers the melting point rapidly, the curve fol-

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* This, of course, is not true of the feldspars, quartz, etc.

† In accordance with the Van't Hoff-Raoult formula, where Δ, the depression of the freezing point due to impurity, equals $\dfrac{·02 \ T^2}{\lambda}$.

lowing a slightly curved line to the eutectic point, 1348°, at about 28 per cent magnesium silicate. The curve then rises much more gradually to a maximum of 1380° at the composition of diopside, $CaSiO_3.MgSiO_3$, which contains 46·3 per cent magnesium silicate. Let us first consider so much of the curve by itself. The solid phases, which separated when the mixtures from 0 per cent—46·3 per cent magnesium silicate were crystallized as nearly as possible under equilibrium conditions, were proved by microscopic analysis to be only diopside and pseudo-wollastonite, making of course the proper allowance for a small mutual solubility. The latter amounted, as we shall see, to about 3 per cent diopside in the pseudo-wollastonite, and less than 3 per cent of the latter in diopside.

The end members, pseudo-wollastonite and diopside, and also the eutectic mixture, melt at a single temperature, with the reservation just made; that is, as sharply as we have yet observed with any silicate. The other mixtures show two phenomena: (1) the melting of whatever amount of eutectic is present in the mixture; and (2) as the temperature rises, the gradual solution in the melted eutectic of the excess component (diopside or pseudo-wollastonite, as the case may be), which lasts till the melting point curve ABC is reached. The temperature-time curves clearly show continuous change in character from the end members to the eutectic composition. Near the end member the predominant phenomenon is the upper point, which resembles the sharp melting of the pure component itself; the eutectic melting is of course small. It is clearly distinguishable, however, even when the mixture contains less than 1 per cent of eutectic. In mixtures farther from the end members in composition, the absorption of heat immediately above the eutectic melting is perceptible, and the highest point gradually takes on more and more the character of the end of this absorption and less and less that of a separate and independent melting point. Although, strictly speaking, this upper melting is always a solution, the temperature at which it terminates did not show, under the conditions described, any change with the rate of heating. In order to test this question, the rate was in several cases altered from 1° to 3° per minute, but the resulting effect on the upper point was less than the accidental errors of the separate determinations. As the eutectic composition is approached and the phenomenon has still more the character of a solution and less that of a melting, the upper point becomes less and less distinct.

Determination of the Eutectic Composition.—In the immediate neighborhood of the eutectic composition the difficulty of determining the upper point is still more increased by another phenomenon. The rapid temperature rise which immediately

TABLE II.
Temperature-Concentration Curve.

Weight% MgSiO₃	Upper Point	Eutectic	Inversion	Weight% MgSiO₃	Upper Point	Eutectic	Inversion
0	1510°	----	1190°	40	1374°	1347°	----
	1511	----	----		----	----	----
	1510	----	----	45	1·380°	1343	----
	----	----	----		----	----	----
1	----	----	1245	46·3	1380	----	----
	----	----	----		1381	----	----
2	----	----	1273		1379	----	----
	----	----	----		----	----	----
5	1489	1343°	----	47·5	1381	----	----
	1481	----	----		1381	----	----
	1483	----	----		----	----	----
8	----	----	1327	50·0	1381	----	----
	----	----	----		1380	----	----
10	1468	1345	----		----	----	----
	1466	----	----	55	1378	----	----
	1466	1343	----		----	----	----
	----	----	----	60	1378	----	----
20	1405	1346	----		1377	----	----
	1397	1343	----		----	----	----
	1406	1347	----	65	1377	----	----
	1407	1346	----		1378	----	----
	----	----	----		----	----	----
24	----	1350	----	70	----	1376	1363°
	----	1350	----		----	----	----
	----	----	----	72	1409	1375	----
26	----	1348	----		----	----	----
	----	1348	----	73	1408	1373	----
	----	----	----		1412	----	----
28	----	1348	----		----	----	----
	----	1348	----	75	1416	1372	1364
	----	1348	----		----	----	----
	----	----	----	80	1452	1373	1367
30	----	1348	----		1453	1375	----
	----	1349	----		1452	----	----
	----	1349	----		----	----	----
	----	----	----	90	1495	1375	1367
31	----	1349	----		1484	----	----
	----	1350	----		1487	----	----
	----	1350	----		----	----	----
	----	----	----	95	1512	1387	1362
32	----	1348	----		----	----	----
	----	1349	----	98	----	----	1360
	----	1350	----		----	----	----
	----	----	----	100	1524	----	----
36	----	1348	----		1524	----	----
	----	1348	----		----	----	----

Fig. 1.

CONCENTRATION.
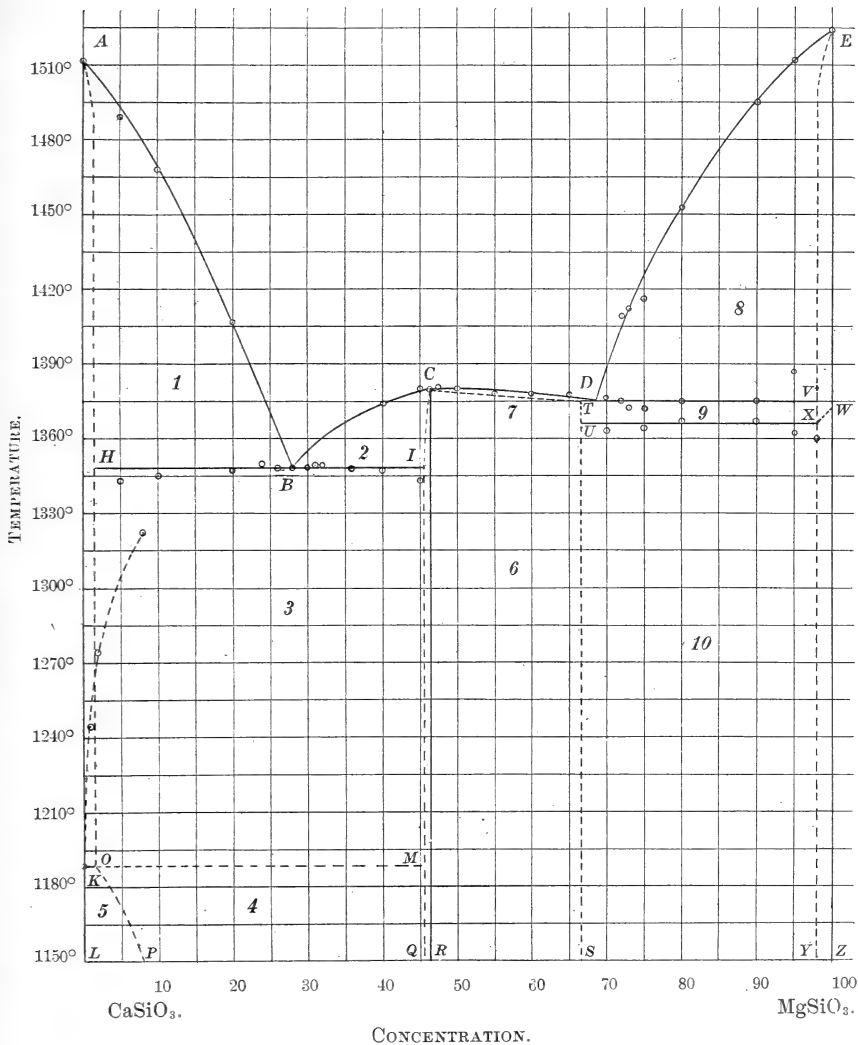
Principal Areas of the Diagram.

1. AHB a-CaSiO$_3$ + liquid.
2. BIC Diopside + liquid.
3. HIMO a-CaSiO$_3$ + diopside.
4. OPQM β-CaSiO$_3$ + diopside.
5. KOPL Mix-crystals diopside in β-CaSiO$_3$.
6. CTUSR Mix-crystals of MgSiO$_3$ in diopside.
7. CDT Mix-crystals of varying composition + liquid.
8. DEV a-MgSiO$_3$ + liquid.
9. TUXV a-MgSiO$_3$ + diopside mix-crystals.
10. UXYS β-MgSiO$_3$ + diopside mix-crystals.

follows the principal melting now extends beyond the upper point and completely overwhelms it. The difficulty of determining a small residual melting is in striking contrast to the ease with which a slight absorption of heat can be detected below the principal melting.* Owing to this masking of the upper point, a direct determination of the eutectic composition is impossible by the ordinary method; that is, we cannot distinguish within several per cent the mixture which melts leav-

Fig. 2.
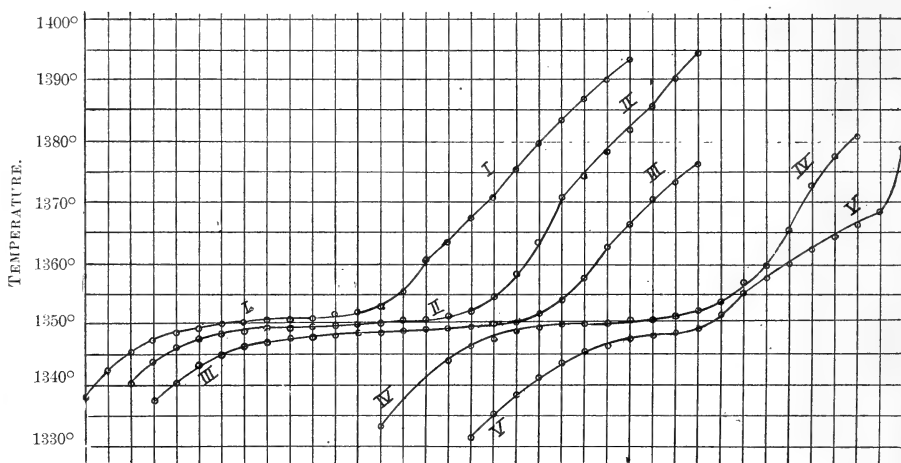
Temperature-time curves of mixtures in the vicinity of the eutectic composition (pseudo-wollastonite-diopside).
I. 24% $MgSiO_3$. II. 26% $MgSiO_3$. III. 28% $MgSiO_3$. IV. 32% $MgSiO_3$. V. 36% $MgSiO_3$.

ing no excess component, since a number of mixtures appear to do so. This is well shown by the temperature-time curves in fig. 2, which were made with especial care with reference to this very point. The upper melting can hardly be distinguished in the 24 per cent mixture, though this contains over 8 per cent of the component in excess. (The point is in fact so faint that we could hardly distinguish it from the minute irregularities in the temperature curve of the furnace were it not for the fact that it lies on the curve ABC, fig. 1, which is well defined in other mixtures farther removed from the eutectic.) For locating the eutectic two methods still remain.

* It was undoubtedly the difficulty of detecting the upper points in this region and the failure to appreciate how easily such an experimental difficulty might arise which led R. Freis (Neues Jahrb. Min., Beil. Bd. xxiii, 76, 1907) to describe a similar series of melting points as forming a curve with the two inclined portions separated by a horizontal branch of considerable extent.

The first is to extrapolate downward the liquidus curves A B and B C in fig. 1, and take the mean of the points where they intersect the eutectic line H I.   The accuracy of this extrapolation is limited by the uncertainty of the liquidus curve for some distance on each side of the eutectic composition.   We found with these particular silicates that the results agreed to

Fig. 3.

Time : ½ minute.
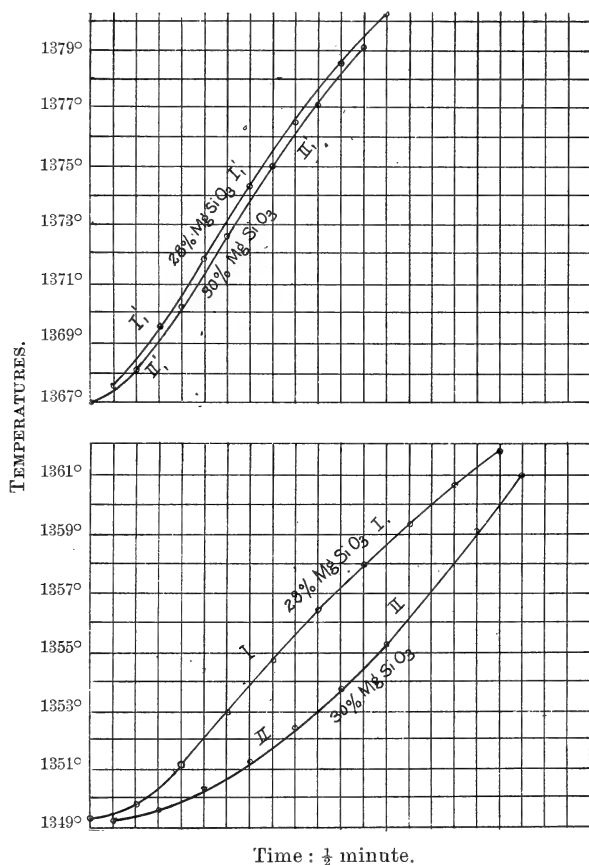
Location of the eutectic composition.
Curves I-I and II-II, 28 per cent and 30 per cent $MgSiO_3$ just above the eutectic point.
Curves I'-I' and II'-II' the same at higher temperature.

5 per cent with a probable error of not over 2 per cent in the eutectic composition.

A more accurate determination seemed for some time to involve considerable difficulty, but a satisfactory solution of the

problem was finally obtained in the following way: Two small
crucibles containing charges slightly different in composition
were put together in the furnace and brought to such a temper-
ature that the main eutectic melting was completed but the
excess component, if any, still left undissolved.   Then by sud-
denly increasing the furnace current and making alternate
temperature readings of the two crucibles at intervals of 15
seconds, the relative heat absorptions in the region immediately
above the eutectic melting point could be determined, and thus
in a very few trials of different mixtures the eutectic composi-
tion could be located.   The results of such a determination are
shown in curves I-I and II-II, fig. 3.   The temperature in
II rises more slowly than in I, because of an absorption of
heat due to the melting of the excess component.   The curves
were continued to a higher temperature to make sure that this
difference was really due to this cause and not to the relative
position of the two crucibles in the furnace or to some other
accidental circumstance.   The curves I' and II' are now paral-
lel, confirming the conclusion that their previous divergence
was due to a melting in II which is now over.   It will be seen
from this result that the 28 per cent mixture lies nearer the
eutectic than the 30 per cent.   A similar comparison of the
28 with the 26 per cent also showed that the eutectic lies
nearer the former.   These experiments are sufficient to locate
the point well within 1 per cent at the 28 per cent mixture.
The previous work had indicated that the 28 per cent was
probably the eutectic composition.   Calculated in terms of
diopside, the eutectic mixture would contain in round num-
bers 60 per cent diopside : 40 per cent pseudo-wollastonite.

Diopside.—As previously stated, the melting-point of diop-
side is a maximum on the melting point curve, which fact,
taken in connection with the microscopic homogeneity at this
composition and the occurrence of a eutectic point on either
side of it, proves that it is a compound in stable equilibrium
with its own liquid.   Abundant confirmation of this conclu-
sion is found in the form of the specific-volume curve, p. 27, as
well as in the close agreement of the composition of natural
diopside with the rational formula $CaSiO_3.MgSiO_3$.   As an
example, we give an analysis of an exceptionally pure specimen
from a metamorphosed limestone which occurs in Ham Island,
Alaska.   The composition of the *anhydrous* substance is also
given for the sake of fairer comparison.   This is justifiable,
for the water is not chemically combined, a conclusion thor-
oughly established by the fact that the substance remains
homogeneous as the water escapes.

	Diopside from Ham Island, Alaska	Cal. to the anhydrous condition	Cal. for $CaSiO_3$ $MgSiO_3$
SiO_2	54·65	55·46	53·63
Fe_2O_3	·13	·13	----
CaO	25·27	25·64	25·82
MgO	18·78	19·06	18·55
Na_2O	·03	·03	----
K_2O	·07	·07	----
H_2O	1·45	----	----
	100·38	100·39	100·00

When diopside is prepared by melting together lime, magnesia and silica in the proper proportions, it crystallizes readily, but not so rapidly as its constituents calcium and magnesium silicates, forming a dense white homogeneous mass with conspicuous cleavage. The optical constants, a full account of which is given in the second part of this paper, leave no room for doubt of the identity of the substance.

Measurable crystals was prepared by crystallizing this product from molten calcium chloride–Le Chartier's method.[*] This may be very conveniently done in platinum as described in a previous paper on magnesium silicate.[†] It is not possible, however, to perform the operation in hydrochloric acid gas, as was there done, for the diopside is then decomposed into calcium chloride, tridymite and magnesium pyroxene. The last two products were identified optically without difficulty. The calcium chloride should first be melted in the sealed crucible, traversed by a stream of dry hydrochloric acid gas. Then after the crucible has been cooled and the hydrochloric acid replaced by dry air, the crucible is unsealed and the silicate quickly introduced. In this operation some moisture doubtless gets in. Before heating again, dry indifferent gas is introduced. The crucible is heated for a number of days, the entering and exit tubes being guarded by driers. When the operation is completed, the excess of calcium chloride is removed by water. The product is usually in the form of transparent crystals of rhombic habit which sometimes attain to dimensions of several millimeters. The planes are often slightly coated with a thin film of what is probably calcium hydroxide, which doubtless comes from the decomposition of calcium chloride by the water vapor which could not be entirely excluded. It gives a strong alkaline reaction and may be readily removed with a little dilute HCl. Analysis shows that no lime is dissolved by the crystals, though they are not quite free from chlorine.

[*] Comptes Rendus, lxvii, 43, 1868.   [†] This Journal, xxii, 389, 1906.

	Found	Cal. for CaSiO₃, MgSiO₃
		Cal. for $CaSiO_3$, $MgSiO_3$
SiO_2 _____	55·59	55·62
CaO _____	25·73	25·83
MgO _____	18·61	18·55
Fe_2O_3 etc. _____	·18	____
Cl _____	trace	____
	100·11	100·00

Several products made in this way were united and tested in a mixture of methylene iodide and benzene to see if all was of uniform specific gravity. A small fraction, containing some of the larger crystals, floated, while the rest sank. These crystals seemed to differ from the rest only in porosity. The remainder were then divided into two fractions of only slightly different density and the specific gravity of each was determined by the pycnometer.

1. Lighter fraction $\dfrac{\text{Sp. gr. at } 25°}{H_2O \text{ at } 25°} = 3·270$

2. Heavier   "   "   3·275

3. Natural diopside
from Ham Island,
Alaska,   "   3·268

An idea of the expansion of the diopside in the process of melting may be obtained by comparing this constant with the specific gravity of the glass of the same composition :

$$\frac{\text{Glass at } 30°}{H_2O \text{ at } 25°} = 2·830.$$

The description and angular measurements of these crystals are to be found in Part II of this paper.

Melting Point Curve from 46·3—100 per cent $MgSiO_3$.— Referring again to fig. 1, it is seen that beyond 46·3 per cent $MgSiO_3$, the addition of it lowers the melting point gradually but very slightly, until about 68 per cent has been reached. Near this point there is an abrupt rise, the curve finally terminating at 1524°, the melting point of magnesium silicate. On the first branch of the curve (46·3–68 per cent) mix crystals of magnesium silicate in diopside separate. This conclusion was tentatively reached in the preliminary thermal work when it was found that the addition of a large percentage of magnesium silicate lowered the melting point of diopside very little, while the mixtures continued to show but *one* absorption of heat. The thermal evidence was subsequently confirmed by the specific volume curve, and by a very elaborate microscopic study.

Solid solution determined by microscopic homogeneity extends as far as 66·5 per cent $MgSiO_3$: 33·5 per cent $CaSiO_3$. The solid phases separating on the branch of the curve DE were found to be the mix-crystal just mentioned, and a-$MgSiO_3$ in all cases. All the mixtures from about 68–95 per cent $MgSiO_3$ showed an absorption of heat at 1375°. This is evidently a eutectic line and there is no doubt that we have here a case of Roozeboom's mix-crystal Type V,[*] where each of two mix-crystals *lowers* the melting point of the other to a eutectic. Points on this line to the left of the eutectic point could not be located since the liquidus curve lies only 2° to 3° higher up. The eutectic composition is about 68 per cent $MgSiO_3$: 32 per cent $CaSiO_3$ and consists therefore of about $\dfrac{32 \cdot}{33 \cdot 5}$ = 95·5 per cent of the diopside mix-crystal and about 4·5 per cent of free a-$MgSiO_3$ (in which about 2 per cent $CaSiO_3$ or 3·7 per cent of diopside is dissolved).

Inversion of $MgSiO_3$.—About 1365° pure magnesium silicate undergoes a reversible change into an orthorhombic form. The heat of transformation is small, and apparently the change does not all happen at once, but extends over quite an interval of temperature. This is the only satisfactory way of accounting for the fact that while a small absorption of heat is observed in most of the mixtures of magnesium silicate from 70 per cent on, in the pure substance and in the mixtures near 100 per cent $MgSiO_3$ it was entirely overlooked. The existence of a form stable above 1365° was proved by crystallizing a melt near the melting point, and then suddenly chilling the crystals in water. Thus the form was instantly brought into a temperature region where viscosity was great enough to prevent an inversion. The inversion temperature was determined approximately as follows : One tenth of a gram of the substance was placed in a small platinum tray shaped from a piece of platinum foil. This was suspended by a fine platinum wire inside the furnace. After the material was melted and crystallized near the melting point, the temperature was lowered to a given temperature and held there about a half hour. The furnace in which the heating was done was designed for calorimetric purposes, and had a removable bottom which was swung aside at the proper moment, when the suspension wire was instantly melted by an electric current, allowing the charge to drop into a basin of water. The results were as follows:

[*] Zeitschr. f. Phys.-Chem., xxx, 403.

1 Chilled from an initial temperature of 1346°; all orthorhombic crystals (a-form).

2 Chilled from an initial temperature of 1337°; all the crystals were orthorhombic.

3 Chilled from an initial temperature of 1324°; all monoclinic crystals (β–form).

4 Chilled again from 1324° with the same result.

After the existence of the a-form had been established, the inversion point was repeatedly sought for by the Frankenheim method and a very small minimum between 1405° and 1435° was found in many cases but by no means in all, and the point was so small that one might well have hesitated to interpret it as an inversion, had other evidence been lacking. Taken in connection with the sharp heat change which occurs in the mixtures (see below) at about 1365°, it appears that the inversion point is overstepped about 40° in both directions, which is in perfect accord with the sluggish behavior of solid silicates. The inversion point in pure magnesium silicate is represented in the diagram (fig. 1) as falling somewhat as it dissolves calcium silicate, because this is the relation which commonly holds, but it is manifestly impossible to settle the question at present.

a-Magnesium Silicate.—This form, which has already been described, crystallizes in the orthorhombic system in equant crystals on short doubly terminated prisms which resemble forsterite in habit, index of refraction and birefringence. Its specific gravity, judging from its index of refraction, varies little from that of β-magnesium silicate (3·192). It was found, by applying the floating method to a single small crystal, to be about 3·16. Fortunately, in several instances a few well-formed, separately developed crystals were found on the surface of charges of magnesium silicate which had been melted and crystallized in the furnace, though usually all was completely inverted into the magnesium pyroxene. The measurements of these crystals which are recorded in Part II of this paper *prove conclusively that this is a form entirely distinct from forsterite or enstatite.*

Inversion in the Mixtures.—The inversion line is traced in all the mixtures from 68 per cent to 98 per cent magnesium silicate and varies little from 1365.° Some typical curves showing both the inversion and eutectic points are plotted in figs. 4 and 5, curves II, V, VI, VII, and VIII. The significant feature of these curves is the gradual diminution of the heat absorption at the latter (eutectic) temperature and the gradual increase of that at the former (inversion), as we pass toward 100 per cent magnesium silicate. Thus in the 70 per cent mixture the eutectic melting is large, while in the 95 per

FIG. 4.
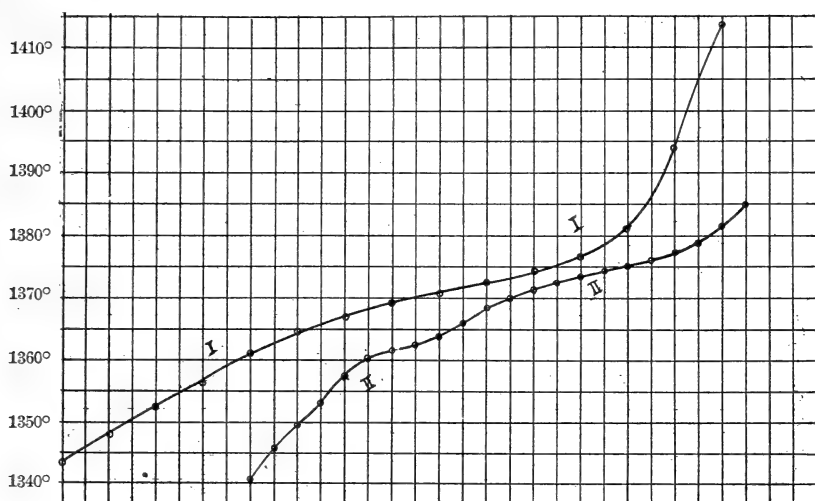
Temperature-time curves showing thermal behavior of mixtures rich in MgSiO₃.
Curve I-I, 60 % MgSiO₃.   II-II, 70 % MgSiO₃.

FIG. 5.
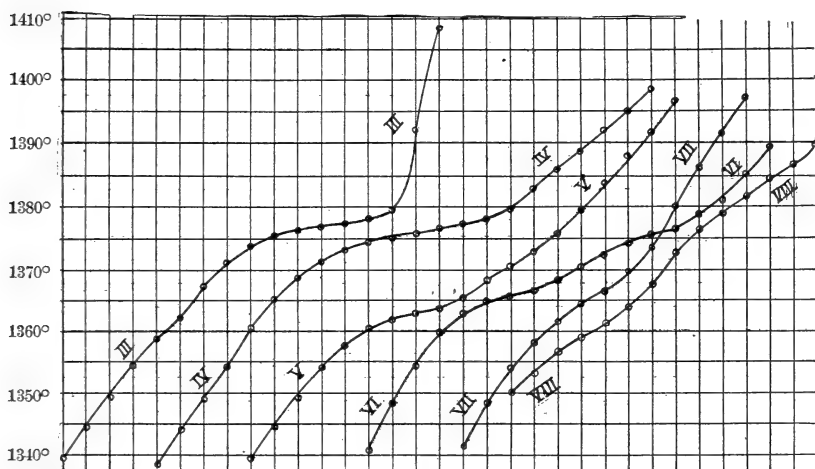
Temperature-time curves showing thermal behavior of mixture rich in MgSiO₃.
Curve III. 65 % MgSiO₃.
   "   IV. 75 % MgSiO₃ crystallized below 1300° by heating the glass.
   "   V. 75 %   "   "   not far below 1365°.
   "   VI. 80 %   "   "   "   "   "   "
   "   VII. 90 %   "   "   "   "   "   "
   " VIII. 95 %   "   "   "   "   "   "

cent it is minute and in the 98 per cent can be no longer detected ; while the inversion, small in the 70 per cent mixture, is much greater in the 90 per cent and 95 per cent mixtures. The 98 per cent mixture, where solid solution of calcium silicate begins, shows the inversion plainly but not so markedly as the 95 per cent mixture. It evidently partakes of the character of the pure silicate, which is more resistant to rapid change. Dissolved calcium silicate therefore *facilitates* the inversion of magnesium silicate, while, as we shall presently see (page 20), dissolved magnesium silicate *hinders* the inversion of calcium silicate. It is not strange that the properties of a substance should be modified by solid solution, though it is evident that the direction of such a change cannot yet be predicted, but why an excess of foreign solid should affect the inversion point of a substance is not clear. The influence of solid diopside in concentrating or sharpening the inversion of magnesium silicate, however, seems to be established.

Curves I and III show the behavior of materials which contain no free magnesium silicate and therefore show no inversion. Curve IV shows what happens when mixtures are chilled to glass and then heated. Crystallization then leads to *enstatite*, which *evolves* heat slowly over a long range of temperature. Since this evolution covers the region above 1300°, the small absorption at 1365° is effectually hidden, where, as explained, the inversion seems to be lengthened out.

Solid Solutions.—The system $CaSiO_3$–$MgSiO_3$ contains six different series of solid solutions, in only two of which is there more than a few per cent of the smaller constituent. The limit of solubility was determined by the thermoelement, by the microscope or by both when possible.

So far as thermal tests are concerned, the results refer of course to the presence or absence of a eutectic melting, i. e., the solubility at the eutectic temperature is approximately determined. The microscope, on the other hand, makes its determinations at ordinary temperatures, where presumably the solubility is generally greater. In almost all cases the solubility as determined by the microscope is a little higher, but how far this is a real difference and how far it is due to a difference in the delicacy of the methods, it is unsafe to say on account of the uncertainty in establishing equilibrium in these solid silicate solutions ; in other words, it is impossible to say whether a given solution is saturated or not. In the diagram, fig. 1, we have drawn the lines straight with a single exception, where we have more evidence that solubility increases with falling temperature.

1. Diopside in a-$MgSiO_3$. On account of the difficulties involved, this series was not investigated.

2. Diopside in β-$MgSiO_3$. The microscope detected inhomogeneity in the 3 per cent $CaSiO_3$ mixture, but none in the 2 per cent. No eutectic was observed in the latter. We may therefore put the solubility as 2 per cent $CaSiO_3$, or 3·7 per cent diopside.

3. $MgSiO_3$ in diopside. The microscope places the limit of solubility at about 66·5 per cent $MgSiO_3$: 33·5 per cent $CaSiO_3$, i. e., the quantity of diopside in the saturated mix-crystal would be $33·5/53·7 = 63·4$ per cent. In other words, diopside is capable of dissolving $37·6/62·4 =$ more than 60 per cent of its own weight of magnesium silicate. This remarkable series of mix-crystals strongly resembles diopside. The optical work described in detail in Part II shows that the extinction angle and the optic axial angle both fall about $\frac{1}{2}°$ for each additional per cent of magnesium silicate. The specific volume curve (fig. 9) shows that the solution is attended by expansion.

4. Calcium silicate in diopside. The microscope detected inhomogeneity at 44·5 per cent $MgSiO_3$ while the thermoelement detected a plain eutectic in the 45 per cent $MgSiO_3$. The limit of solubility is doubtless small, certainly less than $100 - 45/46·3 = 3$ per cent $CaSiO_3$.

5. Diopside in a-$CaSiO_3$ (pseudo-wollastonite). Mixtures containing as much as 3 per cent $MgSiO_3$ plainly showed inhomogeneity when examined by the microscope. The inhomogeneity took the form of irregular bands, irregularly distributed, which showed a distinctly lower birefringence than the rest. The 2 per cent $MgSiO_3$ solution showed traces of the above structure and gave a plain eutectic when examined thermally. The 1 per cent solution is microscopically homogeneous and gives no more than a suspicion of a eutectic. The error will be slight if we put the limit of solubility at about 1–2 per cent $MgSiO_3$, or in round numbers, 3–4 per cent of diopside.

6. Diopside in β-$CaSiO_3$ (wollastonite). In this case a thermal test is obviously useless. The microscopic analysis showed that solution ceased at about 17 per cent diopside (8 per cent $MgSiO_3$). Crystallization took place at about 1058°. The crystals of diopside and wollastonite are both monoclinic and the latter resembles diopside more closely than pseudo-wollastonite, so that it is not surprising that wollastonite should dissolve diopside in large quantity.

These solutions showed a very interesting behavior when they were heated. To understand this clearly, it should be remembered that the eutectic between pseudo-wollastonite and diopside melts at about 1348°, while wollastonite has an inversion point at about 1190°. Upon heating crystals of wollaston-

ite carrying 1 per cent $MgSiO_3$ (2·1 per cent diopside) for one hour at 1221°, no change was apparent. Heated again for two hours at 1245°, the inversion was slight. The inversion point of wollastonite appears, therefore, to be raised 40°–50° by the solution of only 2 per cent diopside. (See p. 18.)

Since time is an important factor in sluggish changes, a direct comparison was made between pure wollastonite and two mix-crystal preparations of this series by heating all three in the same furnace for the same length of time, viz., 1 hour. The temperature ranged from 1257° to 1263°, i. e., about 65° above the inversion point of wollastonite. The wollastonite was completely inverted, the 2·1 per cent solution slightly inverted, while in the 4·3 per cent solution (2 per cent $MgSiO_3$) it was doubtful if any change at all had taken place. The two solid solutions were now returned to the furnace and held an hour longer between 1273° and 1300°, about a hundred degrees above the inversion point of pure calcium silicate. The weaker solution was now found to be much changed, the stronger one less so. The 8 per cent solution of $MgSiO_3$, containing 17·3 per cent diopside, was heated for an hour at 1278° to 1280°, 90° above the inversion point of calcium silicate. A careful microscopic examination of the crystals then showed a considerable change in their appearance; a new product had separated but it did not show the characteristics of pseudo-wollastonite. Such optical properties as could be measured in fine-grained material (index of refraction, birefringence) agreed with diopside. This indicates that the solubility of diopside in wollastonite is greater at lower temperatures where the crystallization occurred, or perhaps that the solid solutions, being formed by rapid crystallization, were supersaturated. In either case the excess separates when the solution is heated to higher temperature.

Heated an hour longer at a temperature of 1298°–1303°, more diopside separated, but the signs of inversion were still doubtful. Again, the crystals were returned to the furnace and the heating continued another hour at 1327°–1343°. This time inversion was evident. These experiments show either a marked rise in the inversion temperature of wollastonite or else a great increase in molecular sluggishness caused by the dissolved diopside.

A brief discussion will make it clear under what conditions an inversion point may be raised and thus help to decide whether we have a real rise in the inversion temperature or not. By a thermodynamic method Beckman* has shown that the freezing or inversion point of a substance is changed by

* Ostwald's Lehrbuch der Chemie, vol. 2, pt. 2, pp. 38, 68.

TABLE III.

Inversion Temperature of Wollastonite-Diopside Mix-Crystals.

(Inversion point of wollastonite, 1190°.)

No. of Exper.	Composition	Time of Heating	Temper- ature	Results.
1	1% MgSiO₃ (2·1% diopside)	1 hr.	1221°	No change.
2	1% MgSiO₃ (2·1% diopside) Continuation of Exper. 1	2 hr.	1245°	Inversion slight.
	0% MgSiO₃			Completely inverted.
3	1% MgSiO₃ (2·1% diopside)	1 hr.	1257–1263°	Slightly "
	2% MgSiO₃ (4·3% diopside)			Doubtful
4	{ 1% MgSiO₃ (Continuation { 2% MgSiO₃ of Exper. 3) }	1 hr.	1273–1300°	{ Largely inverted { Much less "
5	8% MgSiO₃ (17·3% diopside)	1 hr.	1278–1280°	Separation of diopside. No inversion.
6	8% MgSiO₃ (17·3% diopside) (Continuation of Exper. 5)	1 hr.	1298–1303°	Inversion doubtful.
7	Continuation of Exper. 6	1 hr.	1327–1343°	" evident.

FIG. 6.
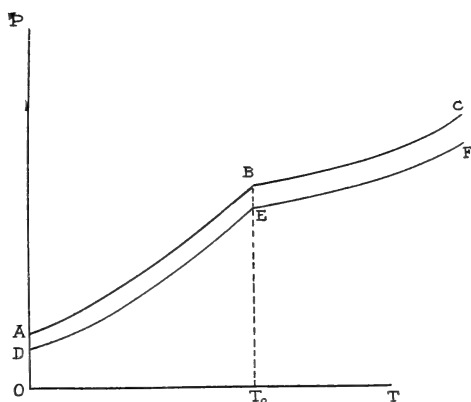
FIG. 6 shows under what conditions an inversion point remains unaltered after the formation of a solid solution.

the solution of another substance according to the equation $\triangle = \dfrac{02\ T^2}{e} (C_1 - C_2)$ where $\triangle$ = the depression in the temperature, T = the absolute temperature of the inversion point in the pure substance, l = its latent heat of fusion, C_1 = the concentration of the solution above the inversion point and C_2 = the concentration of the solution below the point.

This formula holds approximately for concentrated solutions. When $C_1 = C_2$, i. e., when the concentration of the solid solution is not changed by the process of inversion, there will evidently be no change in the inversion point; when $C_1 > C_2$, the temperature will fall, but if C_2, the concentration below the freezing point, is greater, then $\triangle$ will have the opposite sign, and the freezing point will be higher than that of the pure substance.

The same conclusion is reached by a graphic method.* In fig. 6 let AB represent the vapor pressure curve of the pure solid below the inversion point, BC the vapor pressure above it, and T_0 the inversion temperature. Now if this solid forms a solid solution, the vapor pressure of the former will be lowered according to the concentration of the solution. Suppose that this is the same above and below the inversion point, and that the vapor pressures are lowered to the same degree in both. It is evident that the new curves DE and EF will intersect at the same temperature and the inversion temperature is therefore unchanged.

In fig. 7 let us suppose that the concentrations of the two solid solutions are unequal, the one below the inversion point being the more dilute. The curve AB will be lowered to DE and BC will fall to EF by reason of the greater concentration of the second solution. DE and EF now intersect at E, at a temperature lower than T_0. By similar reasoning we conclude that when the solid solution below the inversion point is the more concentrated the inversion point will be raised. (See fig. 8.) Apparently the lower concentrations of diopside in wollastonite remain the same when the mix-crystals invert, for about 1–2 per cent $MgSiO_3$ is dissolved by the pseudo-wollastonite. In these cases, therefore, the inversion point theoretically should not change. These solutions, however, are unquestionably less changed at the same temperature than wollastonite is. We therefore conclude that the solution of diopside has increased the intermolecular friction of the crystals. It is also possible that these solutions of wollastonite-diopside which are more concentrated than 1–2 per cent $MgSiO_3$ really have a higher inversion point than 1190°. If the crystals saturated at this temperature remain more concentrated in diopside than the pseudo-wollastonite is, this must be true. A decision cannot be reached until we have some sure method of establishing equilibrium. Day and Shepherd found that solid solutions of lime or silica in calcium metasilicate inverted to wollastonite on cooling. Since the pure metasilicate does not behave so, we naturally conclude that the internal friction was lessened by the lime or silica. Magnesium

* Bodländer, Neues Jahrb. Min., Beilage Bd. xii, p. 52.

metasilicate has no such influence.   The 4·3 per cent of diop-
side in pseudo-wollastonite was cooled from 1209° to 1050°
during a period of 1½ hours without producing any change
in the crystal form.   In the diagram, fig. 1, we have drawn a

Fig. 7.
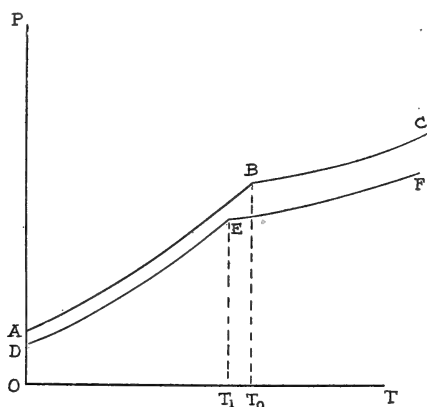
Fig. 7 shows under what conditions the inversion point of a solid is
depressed after the formation of a solid solution.

dotted line through the points where this series of solutions
was actually observed to invert, but it must not be accepted as
a true inversion line.   The inertia of these mix-crystals of wol-
lastonite causes them to exhibit a curious and variable behavior

Fig. 8.
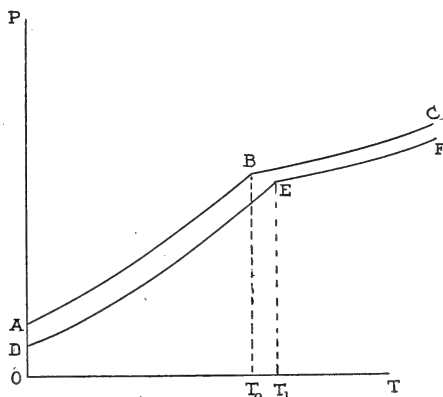
Fig. 8 shows under what conditions the inversion point is raised after
the formation of a solid solution.

when heated, which in the beginning of the work was quite confusing. The normal behavior of a solution of wollastonite containing more than 2–4 per cent of diopside, (the limit of solubility of the latter in pseudo-wollastonite) would be as follows : First, an inversion should occur somewhat above 1190°, giving crystals of pseudo-wollastonite saturated with diopside, and an excess of free diopside. At 1348° some eutectic melting would be noted, and finally, when the melting point curve is reached, another thermal point would be found. Under ordinary experimental conditions, however, where the rate of heating is about 3° per minute, solutions containing 5 per cent $MgSiO_3$ (10·8 per cent diopside) showed no melting at the eutectic temperature. Evidently no inversion had taken place. When the rate of heating was considerably slower a slight eutectic melting was noted, while if the crystals were previously held for some time at 1360°, there was a strong absorption of heat at the eutectic temperature. In the 8 per cent $MgSiO_3$ solution (17·3 per cent diopside) the eutectic failed in one instance, i. e., there was no melting at the eutectic temperature. Mixtures of saturated mix-crystals of wollastonite-diopside give, when the heating is not too slow, three points, the eutectic at about 1348°, a further melting accompanying the inversion at a higher temperature,* and finally, the point on the melting point curve where all becomes liquid. Thus the 10 per cent mixture (containing about 4 per cent of free diopside) showed heat absorptions at 1340°, 1377° and 1451°. The 8 per cent solution showed a similar behavior, indicating that some inversion may have occurred below the eutectic points. Another explanation is perhaps more probable, viz. : that the lowest point may be due to an unstable eutectic between wollastonite and diopside, since the latter was found to separate from the more concentrated solutions at the higher temperatures. If so the point lies very near the pseudo-wollastonite diopside eutectic. A fact that seems to favor the explanation is that the 10 per cent solution always gives this lowest point although it has been proved that the more concentrated solutions invert with greater difficulty. Moreover, when the 28 per cent solution was crystallized below 1190° and therefore contained no pseudo-wollastonite (a conclusion also verified by the microscope), all melted at 1358° as usual.

Specific-volume curve.—In 1890 Retgers† stated clearly two arguments to prove that diopside was a chemical compound in distinction from a mix-crystal. The first was that the minerals in nature which contain the metasilicates of calcium and

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* Since the solution of the diopside in the wollastonite crystals prevents partly or wholly the eutectic melting at the proper temperature, this melting will at once occur when the crystals are inverted.

† Ann. Ecole Polytech. de Delft, iv, p. 186, 1890.

magnesium vary comparatively little from the compositions $CaSiO_3$, $MgSiO_3$ and $CaMgSi_2O_6$; and the second, that the specific volume of diopside could not be calculated additively from the volumes of the constituents. Retgers's method of solving the question of isomorphism or isodimorphism between two substances is well known. It consists in the preparation of a suitable series of mix-crystals of the two substances and a study of the relation which their specific volumes bear to one another. He proved by many examples that the specific volumes of isomorphous mixtures (as he defined them), when plotted as a function of the composition, form a straight line. In the paper quoted above, Retgers said that this would be the best way to prove whether calcium and magnesium silicates form a double salt or are isodimorphous, if their mixtures could only be crystallized in sufficiently large individuals for specific gravity determinations. He used the floating method, which is not adapted for very small particles, and he emphasized the importance of making sure that the material is both physically and chemically homogeneous. He therefore used only transparent individuals for fear that aggregates might contain some foreign material which would escape optical detection. It has been shown in this laboratory that the specific gravities of mineral powders, if not *too* fine (100–120 mesh), can be determined with a degree of accuracy (± 001 for substances of the gravity of 3) very nearly as great as those obtained by Retgers's method. Of course, the particles should be free from air bubbles or vacua, and it must be admitted that powders require a very careful microscopic investigation to decide this point. Mixtures of calcium and magnesium silicate generally show a certain amount of "dustiness" due to very minute inclusions, or more probably to vacua. These are more numerous in the mixtures which are rich in magnesia (70–97 per cent), but not in the pure magnesium silicate itself. When large masses of material (100 grams) are crystallized slowly, the density is greater and the microscope shows that the vacua are fewer and smaller. Although the specific gravities of the mixtures crystallized in this way are still too low, we judged that they would probably be approximately comparable among themselves, and this conviction has been justified by experiment.

The specific-volume curve (fig. 9) plainly consists of three branches. A B is the locus of the volumes of mechanical mixtures of the pseudo-wollastonite and diopside (leaving out of the question the small mutual solubility). Independently of microscopic or thermal evidence, it would, of course, be impossible to say whether this line indicated a series of mechanical mixtures or a series of mix-crystals between two

isomorphous substances.   In either case the volumes would form a straight line between the two constituents.   DC is made up of diopside mix-crystals with magnesium silicate. The limit of the solubility of the latter in diopside is at about 70 to 72 per cent $MgSiO_3$ as determined by the specific volume

TABLE IV.

Specific Gravities and Specific Volumes of Mixtures of $CaSiO_3$ *and* $MgSiO_3$.

			Sp. gr.	Sp. v.
0%	$MgSiO_3$		2·912	·3434
8	"		2·965	·3373
10	"		2·947	·3362
20	"		3·046	·3283
30	"		3·111	·3215
40	"		3·201	·3125
45	"		3·229	·3096
			3·237	·3089
46·3	"		3·236	·3090
			3·241	·3086
47·5	"		3·246	·3081
50	"		3·245	·3082
			3·255	·3072
55	"		3·241	·3086
			3·241	
60	"		3·229	·3096
65	"		3·211	·3115
			3·212	
70	"		3·205	·3120
			3·198	·3127
72	"		3·196	·3129
			3·196	·3127
75	"		3·194	·3130
80	"		3·198	·3127
			3·192	·3132
85	"		....	....
90	"		3·188	·3137
95	"		3·181	·3140
100	"		3·193	·3132

Where two different numbers are given, they belong to different preparations.

curve.   The microscope sets the limit at about 66·5 per cent. The discrepancy is probably due to experimental error in the specific gravity determinations caused by the presence of bubbles in the grains   An inspection of the curve shows that the volumes of these solid solutions all lie above a line joining B and D.   They are, therefore, greater than the volumes calcu-

lated on the assumption of a purely additive relation. A sim-
ilar expansion is known in other cases.* CD contains the
volumes of mixtures of magnesium silicate and the diopside
mix-crystals. The minimum B, indicating a compound, falls at
about 49 per cent $MgSiO_3$ instead of 46.3 per cent, which is
demanded by the formula $CaSiO_3.MgSiO_3$. This is because a

FIG. 9.
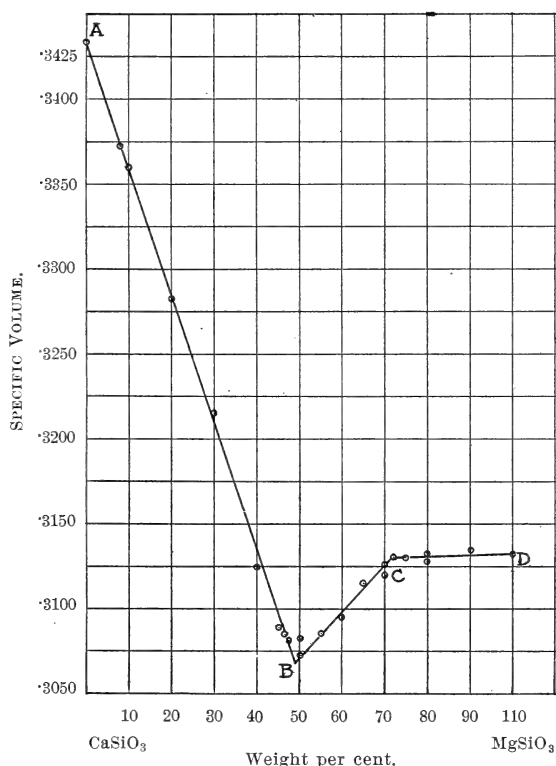
melt of the latter composition forms a crystalline mass which
always appears to contain more bubbles than the other compo-
sitions in its immediate neighborhood, so that the density of
the crystals is not only *absolutely* but also *relatively* too low.
It will be remembered in this connection that the diopside
which was crystallized from calcium chloride had a specific
gravity of 3.275, while that which was crystallized from a melt
of the composition $CaMgSi_2O_6$ had a density of only 3.24.

* E. S. Shepherd, Journ. Phys. Chem., viii, 245, 1904.

We made a number of experiments with the intention of finding whether the mix-crystals of diopside and magnesium silicate could be crystallized again from calcium chloride, or if not, what change in composition they would show with varying quantities of the chloride, but the products obtained were not only not homogeneous, but the crystals were too small to separate from one another and the microscope was unable to identify them. One difficulty in these experiments was the impossibility of entirely excluding water from the apparatus. Its reaction with the calcium chloride, of course, formed some free lime, which was dissolved by the silicate. Pure diopside, as we have seen, does not dissolve lime, but magnesium silicate does. Three grams of the latter, containing only 0·12 per cent of lime, was crystallized* from calcium chloride and analyzed after the excess of the reagent was removed. It now contained 3·04 per cent of lime, an increase of 2·92 per cent.

PART II.   *Optical Study*, by FRED. EUGENE WRIGHT and ESPER S. LARSEN.

In the foregoing pages the theoretical aspects of the Ca-Mg-metasilicate problem have been treated at length, evidence from all sources, chemical, physical, optical and crystallographic, having been brought to bear on its solution. In this general presentation of the problem, however, only the more important and decisive optical and crystallographic data have been made use of, their detailed tabulation having been reserved for a separate section. In the following paragraphs those details which are still lacking are listed, and in order to avoid repetition, general theoretical considerations have been avoided so far as possible. In the attack on the present problem the effort has been made from the very first to combine the evidence from all viewpoints and to test each conclusion by such evidence. It has been found that by this method the constant interchange of ideas and the discussion of the details of the problem have tended greatly to improve and to strengthen the final result.

For the sake of convenience the optical and crystallographic features of the three compounds of this series will be considered first, after which will follow the particular features of the intermediate preparations.

Calcium Metasilicate.—The two enantiotropic forms of this compound, wollastonite and pseudo-wollastonite, have already been described in detail in this Journal† and the evidence need not be repeated at this point. Since the publi-

* The crystals were small but well-developed.
† This Journal, xxi, 103–108, 1906.

cation of the above paper, however, better facilities for refractive index determinations have been acquired and the refractive indices of the two compounds have been redetermined. The measurements were made on polished plates of the crystalline aggregate, experience having taught that even under such conditions it is possible to determine γ and a in sodium light with the reducing attachment of the Abbé-Pulfrich total refractometer, while β can also be ascertained if the individual grains are sufficiently large. For wollastonite the new values are, $\gamma_{Na} = 1\cdot632 \pm \cdot002$; $\beta_{Na} = 1\cdot628 \pm \cdot003$; $a_{Na} = 1\cdot616 + 002$; $\gamma - a = 016$, $\gamma - \beta = \cdot004$, $\beta - a = \cdot012$. The refractive indices of pseudo-wollastonite are : $\gamma_{Na} = 1\cdot650 \pm \cdot002$; $a_{Na} = 1\cdot609 \pm 003$; birefringence $\gamma - a = \cdot041$. The birefringence of both wollastonite and pseudo-wollastonite was furthermore checked by direct measurement in the thin section ; $\gamma - a$ for wollastonite being $\cdot014$ and for pseudo-wollastonite $\cdot043$.*

Magnesium Metasilicate.—Like the calcium metasilicate, this compound has also been described in a special paper in which the optical characteristics are considered together with the other properties. Four different forms or phases were there mentioned bearing monotropic relations to each other, the monoclinic Mg-pyroxene being the one stable form. In the course of the past winter, however, still another phase has been discovered, orthorhombic in symmetry and in general aspect and development not unlike that of olivine crystals.

TABLE V.

No.	Letter	Symbol	Miller	ϕ		ρ	
1	c (?)	0	001	--	--	2°	00'
2	a	∞ 0	100	90°	00	90	00
3	b	0_∞	010	0	00	"	
4	m	∞	110	44	04	"	
5	n	∞ 2	120	23	07	"	
6	l (?)	$\infty \frac{5}{2}$	250	17	56	"	
7	k (?)	3∞	310	70	44	"	
8	r (?)	2∞	210	66	54	"	
9	s	$\bar{1}1$	$\bar{1}11$	$\bar{4}3$	20	38	58
10	e	$\bar{1}2$	$\bar{1}21$	$\bar{2}4$	58	52	11
11	p	$\bar{1}0$	$\bar{1}01$	$\bar{9}0$	00	29	09
12	o	1	111	46	48	40	21
13	i	12	121	28	30	53	10
14	(?)	$\frac{1}{3}0$	$\bar{1}03$	$\bar{9}0$	00	11	55
15	(?)	$\frac{1}{3}0$	103	90	00	12	55

* Opportunity may here be improved to correct several of the optical data in the paper on the Lime-Silica Series of Minerals (this Jour., xxii, 293–302, 1906). At top line of p. 297 read : $a = 1\cdot609 \pm \cdot003$, $\gamma = 1\cdot620 \pm \cdot002$, instead of the values given ; on p. 298, 11 lines from the top, $\varepsilon = 1\cdot554 \pm \cdot002$ and $\omega = 1\cdot544 \pm \cdot002$; on p. 299, 8 lines from bottom, $1\cdot585$ and $1\cdot621$; and 2 lines from bottom, $a = 1\cdot590$; on last line, p. 299, read $\cdot019$ instead of $\cdot025$.

The optical data of the monoclinic Mg-pyroxene form given in the above article can now be supplemented by more accurate figures in several instances; and at the same time several errors in the crystallographic data can be rectified. The β-MgSiO$_3$ is monoclinic and the observed form and measured angles are listed in Table V above.*

The reflexion signals from many of the faces were multiple and wide variations in the angles occur. The best average ratios from these values are about

$$p_0 = \cdot 58 \quad q_0 = \cdot 60 \quad e = \cdot 046 \quad \mu = 87° 26 \; ; \; \text{or}$$
$$a : b : c = 1 \cdot 03 : 1 : 0 \cdot 60 \; ; \; \beta = 87° 26' \; ;$$

values which are closely similar to those for enstatite but less so for diopside. The variations are not such, however, as to preclude isomorphic relations between the two. The plane of the optic axes lies normal to the plane of symmetry and not in the plane of symmetry as in most pyroxenes†; the bisectrix c is inclined to the vertical axis c, 21·8°. The optic axial angle was measured on the universal stage and by means of the two screw micrometer ocular. Care was taken to select favorable sections and the probable error in each case was not large. The average of all good determinations by both methods is $2V = 53 \cdot 5° \pm 1°$, or $2E = 96°$. The overlapping of the twinning lamellae often causes abnormal variations in this optic axial angle and it proved a difficult matter to find suitable sections. Etch figures on the cleavage face were also obtained and will be considered later, together with the etch figures of the other members of this series.

The a-MgSiO$_3$, to which reference has already been made, crystallizes readily and is obtained by quenching the crystallized melt from temperatures above 1365° to prevent its inversion to the β-form. Once obtained it can be held for apparently an indefinite period at ordinary temperatures without inversion to the more stable β-form. The crystals are orthorhombic in symmetry and in certain positions bear strong resemblance to the characteristic crystal habit of olivine. On the surface of a melt held at 1510° and then chilled rapidly, several crystals, water-clear and sharply bound crystallographically, occurred, and three of them ($1 \times \cdot 5 \times \cdot 2^{mm}$) were measured

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* Compare with Table II on page 393, vol. xxii, 1906, this Journal, in which several letters were unfortunately transposed, although the relations are correctly represented in the gnomonic projection plat on the same page.

† The relations of the different pyroxenes, particularly of the magnesium iron group, have been recently discussed in an interesting paper by W. Wahl (Die Enstatit-augite, Tschermak's Miner. Petrogr. Mittheil., xxvi, 1–131, 1907), who proposes the name clino-enstatite for the β-MgSiO$_3$ or magnesium pyroxene. The suggestion is a good one and may well be adopted, the two latter terms being long and cumbersome.

on the goniometer. The reflexion signals were not of the best and the angles of the table can be considered only approximately correct, an error of $\pm 15'$ being easily possible.

TABLE VI.*

No.	Letter	Miller	Symbol		ϕ	ρ
1	b	010	0∞	$0°03'$		$90°00'$
2	m	110	∞	40 08		90 00
3	k	011	01	0 01		25 09

From the angles the crystallographic constants can be calculated: $p_0 = 0.40$ $q_0 = 0.47$
or $a : b : c = 1.19 : 1 : 0.47$.

The crystals are often tabular and prismatic in shape after 010 as indicated in fig. 10. In other cases the prism zone is less prominent and the crystals are of equant development. The forms b, m, and k FIG. 10. were observed on all three crystals. Cleavage after 100, good.
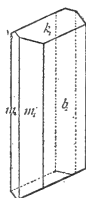
The plane of the optic axes is the cleavage plane 100 and the acute bisectrix is c. The optical orientation is, therefore, $a = b$; $b = c$; and optical character $+$. The refractive indices were determined by the immersion method in refractive liquids; $a = 1.641 \pm .003$; $\beta = 1.648 \pm .003$; $\gamma = 1.663 \pm .003$; $\gamma - a = .022$; $\gamma - \beta = .015$; $\beta - a = .007$. The birefringence $\gamma - \beta = .016$ was furthermore measured directly on a tabular crystal 0.182^{mm} thick by use of the Babinet compensator. The optic axial angle is large and was measured with the two-screw micrometer ocular on two sections showing an optic axis in the field of vision. The average of the two values thus obtained ($2V = 59.5°$ and $61.0°$) is about $2V = 60.3°$ and $2E = 111°$. The axial dispersion is fairly strong, $2\,V\rho > 2Vv$.

* The angles in the table are the averages of the different values obtained. These measurements were made on January 17, 1906, and since that time no suitable crystals for goniometric measurement have again been observed. Although the original notes stated definitely that these "crystal angles do not coincide with those of enstatite" while "the optical relations do not correspond with those of olivine," and this same form was observed at that time in at least seven different preparations, its importance was not realized and its presence was ascribed to impurity. In later experiments practically no chilling was done and not until the thermal data indicated to Dr. A. L. Day the presence of a high-temperature phase, enantiotropic to the first, were quenching experiments again resumed and with them the true significance of the a-MgSiO$_3$ became apparent.

In several of the larger crystals of the a-MgSiO$_3$ a character-
istic arrangement of inclusions and lines of growth was observed
and strongly resembled the hourglass structure of certain
pyroxenes, the hourglass portions of each crystal showing
abnormal interference phenomena, due either to incipient
changes into the β-form or to peculiar intergrowths or possibly,
but not probably, to strain phenomena.

The a-form is readily distinguished from the β-form by its
lack of polysynthetic twinning, parallel extinction and stronger
birefringence; from olivine and enstatite by its cleavage and
the position of the optic axial plane relative to the cleavage.

It is of interest to note that the a-MgSiO$_3$, which is unstable
below 1365° and cannot be obtained except under very special
conditions, has not been observed in nature, thus establishing,
as in the case of pseudo-wollastonite, a high temperature limit
for the formation of certain minerals.

Diopside.— This third compound of the series is an excellent
crystallizer and can be formed in a number of different ways
and at different temperatures. The best crystals were obtained
by heating glass of the composition CaMgSi$_2$O$_6$ in a flux of
CaCl$_2$ in an atmosphere of dry HCl at 1000° for one week. The
crystals varied in size up to 2^{mm} in diameter, were water-clear
and of simple crystallographic habit. Three crystals were
measured on the goniometer with reducing attachment. The
reflexion signals obtained were not of the best and the values
of Table VII are the averages of the observed angles. A
number of other crystals were selected and mounted on the
goniometer, but the reflexion signals from their faces were
often multiple and unsatisfactory, and not suited to improve
the results already obtained from the three measured crystals.

TABLE VII.

No.	Letter	Miller	Symbol	Artificial Diopside		Natural Diopside	
				φ	ρ	ϕ	ρ
1	b	010		0 00	90 01	0 00	90 00
2	m	110		43 30	90 00	43 33	90 00
3	s	$\bar{1}11$	−1	$\bar{2}4$ 51	33 04	$\bar{2}5$ 07	33 04
4	x	$\bar{2}21$	−2	$\bar{3}5$ 12	55 20	$\bar{3}5$ 22	55 19
5	λ (?)	$\bar{3}31$	−3	$\bar{3}9$ 17	66 17	$\bar{3}8$ 19	66 04

For the sake of comparison, the angular values ϕ and ρ for
the same forms on natural diopside (Goldschmidt, Winkelta-
bellen, p. 283) are included in this table. From these angles
the average value of $p_0 = {\cdot}539$; $q_0 = {\cdot}568$; $e = {\cdot}276$, and $\mu =$
73° 59'; or $a : b : c = 1{\cdot}096 : 1 : {\cdot}591$. For natural diopside,
$p_0 = 0{\cdot}5390$; $q_0 = 0{\cdot}5670$; $e = 0{\cdot}2731$; $\mu = 74°$ 09'; or

$a : b : c = 1.0934 : 1 : 0.5894$. Both the angular values and the calculated crystallographic constants prove the close resemblance of the artificial diopside crystals to the natural mineral, the differences observed being within the limits of error possible with the quality of reflection signals obtained from the artificial crystals. Except for the form λ, which was observed only once, the crystal habit is simple and requires no comment. Twinning after 100 is common and one of the three crystals measured was thus twinned, the twinning plane dividing the crystals into two nearly equal halves. Polysynthetic twinning after 100, however, occurred only rarely and is not characteristic.

FIG. 11.

Prismatic cleavage after 110 is good; in diopside crystallites from the melt indications of a parting after a dome or basal pinacoid face at an angle of about 66° with the prismatic cleavage cracks were also recorded.

The refractive indices were measured on polished plates of the crystalline material on the total refractometer in sodium light:

$$\gamma_{Na} = 1.694 \pm .002 ; \quad \beta_{Na} = 1.671 \pm .002 ; \quad \alpha_{Na} = 1.664 \pm .002$$
$$\gamma - \alpha = .030 ; \quad \gamma - \beta = .023 ; \quad \beta - \alpha = .007$$

Direct determinations of the birefringence were also made in the thin sections with the result: $\gamma - \alpha = .030 \pm .002$ (average of three measurements on good sections). The optic axial angle was measured on a number of different sections both with the universal stage and with the two-screw micrometer ocular. The average of four good determinations is: $2V = 59°.3 \pm 1°$; $2E = 114°$. The optical axial dispersion is weak, $2V\rho > 2V_v$. The plane of the optic axes is the plane of symmetry (010).

Extinction angles were measured both on the clinopinacoid and the prism face 110. On 010 $c : c = -38°.5 \pm 1°$. On 110 $c : c = -32°.9 \pm 1°$. The position of total extinction was ascertained in each case by use of the new bi-quartz wedge plate[*] and the values should be correct within 1°. Extinction angles were also measured for different faces in the prism zone. Suitable crystals, held in a specially constructed device,[†] were immersed in a liquid of the refractive index β and the extinction angle read for different angles of revolution of the crystal from its position of zero extinction when the orthopinacoid is normal to the axis of the microscope.

[*] This Journal, xxvi, 377-379, 1908.   [†] This Journal, xxvi, 388, 1908.
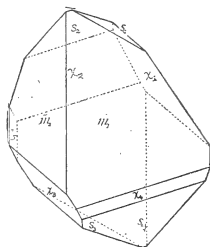
ϕ^*	E	E_1
$0°$	$0°$	$0°$
$10°$	$-13°$	$-12°\cdot5$
$20°$	$-20°\cdot9$	$-21°\cdot7$
$30°$	$-27°\cdot1$	$-27°\cdot9$
$40°$	$-32°\cdot2$	$-31°\cdot9$
$43°30'$	$-32°\cdot9$	$-32°\cdot5$
$50°$	$-34°\cdot3$	$-34°\cdot6$
$60°$	$-35°\cdot5$	$-36°\cdot4$
$70°$	$-37°\cdot2$	$-37°\cdot6$
$80°$	$-38°\cdot5$	$-38°\cdot3$
$90°$	$-38°\cdot5$	$-38°\cdot5$

* ϕ=angle of prism face with orthopinacoid 100.

These figures indicate that for the first 40° from the ortho-pinacoid the extinction angle rises very rapidly while for faces near the clinopinacoid the variations are very slight.

For the sake of comparison the theoretical values of the extinction angles indicated by the Michel-Lévy formula* are listed under column E_1.

From the melt diopside crystallizes readily, usually in the form of radiating prismatic individuals intricately intergrown and overlapping. A characteristic microscopic feature is the presence of fine bubble-like inclusions or cavities throughout the crystallized mass. These cavities are either tubular in shape and parallel in a general way the prismatic elongations of the crystallites; or they appear cutting across the sections in an irregular way not unlike the cavities in a section of worm-eaten wood. The cavities are probably due to the shrinkage accompanying the crystallization of diopside from the silicate melt.—Such air spaces in the crystals from $CaCl_2$ fluxes were only rarely observed and are not characteristic of the same.

The Intermediate Compositions.—In studying the prepara-tions of this series intermediate in composition between the compounds, the microscopic analysis has been directed along two principal lines : (1) To ascertain whether or not the prod-uct is homogeneous ; (2) to determine as accurately as pos-sible the optic properties of the one or more components in each preparation. Experience with both thermal and optical data has shown that in certain instances limits of homogeneity cannot be detected within one or two per cent optically and the optical determinations of the limits of solid solution in this series given below may easily be in error therefore one or two per cent.

* Les Mineraux des Roches, p. 11, 1888. In this formula the following values were used : V=$29°\cdot6$, $\gamma=0°$, ext. angle=$38°\cdot5$; or $\mu=8°\cdot9$, $\nu=68\cdot1$; $u + v = 77°$.

When out of the melt of a readily crystallizing substance, minute quantities of a second substance crystallize, they are usually so completely hidden in the mass of the first crystals that the process of finding them microscopically is not unlike that of "finding the needle in a haystack," particularly when the optical properties of the two substances are closely similar. It has been found by experience that the best method for detecting inhomogeneity is to immerse the powdered material (finely divided by tapping the substance in a mortar) in a liquid of the refractive index of the predominating substance ; in this the minute particles of the second substance can be seen at a glance, if its refractive index be different from that of the first. For this purpose, a set of refractive liquids of indices ranging from 1·450 to 1·790 has been used, the refractive index of each successive liquid differing from the foregoing by ·005. The refractive indices of these liquids were determined directly on an Abbé-Pulfrich total refractometer and their constancy checked every three months at least.* The liquids are kept in small dropping bottles (30^{cc} capacity) with ground glass stopper and ground glass cap, and the refractive indices of the liquids change either very slightly or not at all in three months.

In ascertaining the different optic properties of the members of this series, the following methods have been found most serviceable and seem best adapted to work of this character: Refractive indices were measured by use of refractive liquids after the immersion method of Schroeder van der Kolk. Wherever possible, especially on homogeneous preparations,

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* The following is the list of liquids used in the preparation of this set. (On an average the change in refractive index of a liquid is about ·001 for a change of 3° C. in temperature.)

Refractive Index.	*Liquids used.*
1·450 to 1·465	Mixtures of chloroform and carbontetrachloride.
1·470 to 1·495	Mixtures of turpentine and xylol.
1·500 to 1·505	Mixtures of xylol and monochlorated benzene.
1·510	Aethyliodide.
1·515 to 1·520	Mixtures of cedar oil and clove oil.
1·525	Monochlorated benzene.
1·530	Mixtures of cedar oil and clove oil.
1·535	Mixture of aethylbromide and monochlorated benzene.
1·540 to 1·550	Mixtures of clove oil and cinnamic aldehyde.
1·555	Nitro-benzol.
1·560	Benzene monobromated.
1·565 to 1·615	Mixtures of clove oil and cinnamic aldehyde.
1·620 to 1·635	Mixtures of benzene mono-chlorated and a-monochlorated naphthaline.
1·640 to 1·655	Mixtures of a monochlorated naphthaline and a-monobromated naphthaline.
1·660 to 1·740	Mixtures of a-monobromated naphthaline and methylene iodide.
1·740 to 1·790	Mixture of methylene iodide and sulphur.

the refractive indices were measured directly on the total refrac-
tometer, experience having shown that with polished plates of
the crystallized mass of substance the γ and a limiting refrac-
tive index lines can usually be distinguished if the reducing
attachment be used.   In such cases where the maximal and
minimal indices are determined from aggregates of crystals
rather than from one crystal, it is of course not possible to
determine also the refractive index β.   Optic axial angles
were determined by use of the two-screw micrometer ocular
and also by the modified universal stage* of Fedorow.   Extinc-
tion angle measurements were made with the aid of the bi-
quartz wedge plate,† care being taken to select favorable
sections in each case.   Direct determinations of the birefrin-
gence in the thin section or in flat crystal grains were accom-
plished by measuring the thickness of the plate or grain with
the micrometer screw of the microscope (model Fuess) and
then ascertaining the path difference of the emerging waves
by means of a Babinet compensator.   By this method only a
fair degree of accuracy can be obtained because of the

FIG. 12.
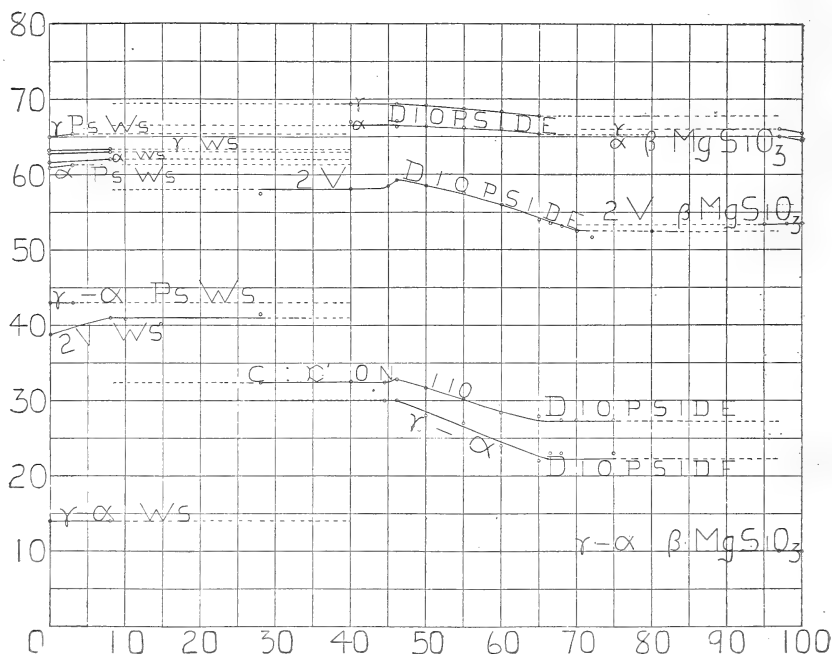
difficulty of determining the thickness of the plates accu-
rately. This error was reduced so far as possible by taking
the average of a number of measurements of thickness
on the same section and by grinding the sections thicker
than usual.

The optical data prove that wollastonite can take up in solid
solution about 17 per cent of diopside, while pseudo-wollaston-
ite can absorb only about 4 per cent of diopside in solid solution ;
that in diopside only a small amount of the calcium metasil-
icate, not over 5 per cent, can enter into solid solution, while
mixed crystals containing up to about 39 per cent of $MgSiO_3$
in diopside can exist ; the maximal solid solution of diopside
in β-$MgSiO_3$ is not great and does not exceed 5 per cent.
These relations were ascertained both by observing the limit of
homogeneity of the preparations and by observing the changes
in the different optic constants of the preparations.

In fig. 12 the optic constants are represented graphically and
the limits of solid solution are indicated by the breaks in the
curves. The optical data from which these curves were drawn
are included in the following table (VIII).

Although every effort was made to reduce the probable error
of the values listed in this table, the very nature of the mate-
rial precluded accuracy of a very high order. The refractive
indices given in the table may be considered exact within
$\pm$·003 ; the direct determinations of birefringence within
$\pm$·003, especially when checked by refractive index determi-
nation ; the optic axial angles are not all of the same order of
accuracy,—that of pseudo-wollastonite being the least satisfac-
tory, with β-$MgSiO_3$ next ; in general the probable error does
not exceed $\pm 1°$; the extinction-angle determinations on 110
probably vary less than 1°· from the true values.

Table VIII as well as fig. 12 prove conclusively that diopside
is a compound, and that the limits of solid solution for
the different members of the series is that indicated above.
Beginning with wollastonite, the refractive indices, the birefrin-
gence and the optical angle of the pure compound increase with
increasing admixture of $MgSiO_3$ up to about 8 per cent $MgSiO_3$,
after which the curves are practically horizontal, thus marking
the limit of crystal miscibility with diopside. In the sections
free diopside was observed first in the preparation containing
10 per cent $MgSiO_3$.—For pseudo-wollastonite the refractive
indices, the birefringence and the optic axial angle increase
slightly only up to about 2 per cent $MgSiO_3$, and the exami-
nation of the preparations proved that beyond this limit inho-
mogeneity exists and diopside is present.—The limits of solid
solution of $CaSiO_3$ in diopside were difficult to determine optic-
ally with any degree of certainty. The data indicate only
slight solid solution, probably not below 45 per cent $MgSiO_3$,
or not over 2 per cent of calcium metasilicate. In the prepa-

TABLE VIII.

Composition % MgSiO₃		a	β	γ	γ−a*	γ−a	γ−β	γ−β'	Opt. character	Optical axial angle 2V	Dispersion	Extinction angles c:c' on 110
0	Wollastonite	1·616	1·628	1·632	·014	·016	·004	·012	—	38°·8	ρ > v	----
0	Pseudo-wollastonite	1·609	--	1·650	·043	·041	--	--	+	7°·5	--	----
1	"	--	--	--	--	--	--	--	--	10°·0	--	----
3	"	1·612	--	1·654	·043	·042	--	--	--	---	--	----
5	"	--	--	--	--	--	--	--	--	10°·5	--	----
5	Wollastonite	--	--	--	--	--	--	--	—	38°·0	--	----
7·95	"	1·620	1·630	1·634	·014	·014	·004	·010	—	41°·0	--	----
7·95	Pseudo-wollastonite	--	--	--	--	--	--	--	+	7°·0	--	----
10	Wollastonite	--	--	--	--	--	--	--	—	40°·8	--	-- -
10·74	"	--	--	--	--	--	--	--	—	40°·2	--	----
28	"	--	--	--	--	--	--	--	—	41°·5	--	
28	Diopside	--	--	--	--	--	--	--	+	57°·5	ρ > v	−32°·4
40	"	1·670	--	1·694	--	·024	--	--	--	58°·1	--	−32°·5
44·5	"	--	--	--	·030	--	--	--	--	---	--	−32°·4
45	"	--	--	--	--	--	--	--	--	58°·5	--	----
46·12	"	1·664	1·671	1·694	·030	·030	·023	·007	+	59°·3	--	−32°·8
50	"	1·664	--	1·692	--	·028	--	--	--	58°·5	--	−31°·7
55	"	1·662	--	1·684	·027	·022	--	--	--	57°·5	--	−30°·2
60	"	1·660	--	1·684	·024	·024	--	--	--	56°·0	--	−28°·4
65	"	1·654	--	1·678	·022	·024	--	--	--	54°·0	--	−27°·9
66·5	"	--	--	--	·023	--	--	--	--	53°·6	--	----
68	"	--	--	--	--	--	--	--	--	53°·2	--	−27°·4
70	"	--	--	--	--	--	--	--	--	52°·5	--	−27°·4
72	"	--	--	--	--	--	--	--	--	51°·7	--	----
75	"	--	--	--	·023	--	--	--	--	---	--	--27°·4
80	"	--	--	--	--	--	--	--	--	52°·5	--	----
90	"	--	--	--	--	--	--	--	--	---	--	----
95	"	--	--	--	--	--	--	--	+	53°·4	--	----
97	β-MgSiO₃	1·650	--	1·660	--	·010	--	--	+	---	--	----
98	"	--	--	--	--	--	--	--	--	53°·5	--	----
100	"	1·645	1·647	1·655	·009	·010	·008	·002	+	53°·5	--	----
100	a-MgSiO₃	1·641	1·648	1·663	--	·022	·015	·007	+	60°·3	ρ > v	----

* γ−a in this column was determined directly by measurements on plates in the thin section.

rations between 40 and 45 per cent peculiar phenomena were observed and no satisfactory tests of homogeneity could be made.—Between diopside and pure magnesium metasilicate mixed crystals extend from diopside up to about 66 or 67 per cent MgSiO₃ of the series. The appearance of all preparations between pure diopside (46·12 per cent MgSiO₃) and 67 per cent MgSiO₃ is that of diopside in the thin section so far as the optic properties are concerned. The refractive indices, the birefringence, the extinction angles and the optic axial angles all decrease gradually but noticeably, and the sections appear homogeneous under the microscope except for the minute air spaces. The crystallized melt changes noticeably moreover in appearance from the large, bright and glistening

aggregates of diopside to dull, lusterless, white granular masses of much finer grain and higher $MgSiO_3$ content.

Beyond the 68 per cent the preparations appear inhomogeneous, the β-$MgSiO_3$ appearing in increasing amounts as its composition is approached. In the preparations ranging from 68 to 90 per cent $MgSiO_3$ in composition, β-$MgSiO_3$ appears almost without exception intergrown with the diopside and usually occupies the center of the large diopside sections. The β-$MgSiO_3$ is invariably twinned polysynthetically after 100 and on sections approximately normal to the prism axis, the prismatic cleavage lines can be seen cutting across both the diopside and the β-$MgSiO_3$, thus indicating the close crystallographic symmetry of the two compounds. In such sections the β-$MgSiO_3$ is characterized by its weak birefringence and by the position of its optic axial plate parallel with the twinning lamellae, while for the enclosing diopside substance the optic axial plane is at right angles to the twinning lamellae.—The limit of crystal miscibility of diopside in β-$MgSiO_3$ is above 98 per cent $MgSiO_3$, since preparations of that composition are clearly inhomogeneous. The optic properties of the β-$MgSiO_3$ change slightly between 98 and 100 per cent $MgSiO_3$, but only enough to indicate very slight solid solution, probably not over 2 per cent of diopside.

Etch figures.—Proof of the fact of solid solution for compositions ranging from pure diopside to about 67 per cent $MgSiO_3$ was also gained by etching the crystals with hydrofluoric acid.

At the present time isomorphism is a much discussed subject and its final definition has not yet been agreed upon. Emphasis has been placed on similarity of the crystal form of the two end members, on analogous chemical composition, on complete miscibility, and on the fact that for some of the physical properties, as specific volumes, the properties of the intermediate mixtures are additive functions of those of the end members. This last assumption of Retgers has been questioned recently, * while the qualification of analogous chemical composition has long been considered unnecessary by certain investigators.

Briefly stated, the tendency seems to exist for crystallizing substances to absorb, during the process of crystallization, large or small amounts of other material. The more closely similar the absorbed material is to the absorbing crystal in crystal structure, dimensions and tendencies, the greater the amount in general which can be thus taken up. In certain instances, the properties of two substances are so similar and their molecular volumes so nearly equal, that the solid solution or crystal miscibility extends from the one compound without break to the second, and the physical properties vary continuously throughout the series. In such a case of complete miscibility no doubt can exist as to the isomorphic relations of the two end

* B. Gossner, Zeitschr. Kryst., xliv, 417–519, 1908.

members.   But in case the crystal miscibility is incomplete or limited the term isomorphism has not yet been defined with adequate precision nor the criteria therefor developed with sufficient sharpness to permit one to state in every actual case whether or not isomorphism does exist.   It seems proper, however, to speak of the two compounds in the first case as completely isomorphous, while in other instances the isomorphism is incomplete or limited.   In the case of incomplete isomorphism, criteria such as crystallographic similarity, additive character of certain physical properties in the intermediate mixtures, chemical analogy are then relied on to prove isomorphism.

In the present series, the diopside and β-MgSiO$_3$ are of the same crystal system and somewhat similar in crystallographic properties.   Limited miscibility has been shown to exist and the physical properties prove that the two are incompletely isomorphous.   This being the case, it is reasonable to suppose that their internal crystal structure is similar, that the distribution of the effective crystallographic forces is analogous. In the intermediate mixtures, therefore, the distribution of the forces is represented, approximately at least, by the resultants of the crystallographic forces of the end members in their proper intensities.   One of the best methods for studying the distribution and relative intensity of crystallographic forces is by means of etch figures.   On the above assumption, the etch figures of the intermediate members should be intermediate in character between those of the end members, diopside and β-MgSiO$_3$.[*]

After considerable experimentation on the conditions best suited to produce favorable results, both with respect to the etch figures and the handling and photographing of the exceedingly small crystals, this statement has been substantiated.   The etch figures on 110 were produced by immersing cleavage pieces from the different preparations in hot commercial hydrofluoric acid (heated over a steam bath in a platinum crucible) for 40 seconds and then stopping the reaction by plunging the crystal into cold water.   The crystal was then mounted on the condenser lens attachment of the universal stage[†] and examined in strong reflected arc light and turned until the proper cleavage face, 110, was normal to the axis of the microscope.   The etch figures on 110 thus obtained were not of equal size or development for the different members of the series.   The largest and best developed etch figures are those of diopside (Plate I, photomicrographs *a* and *b*), while the least favorable are those of β-MgSiO$_3$, which are exceedingly difficult to obtain under

[*] The value of etch figures in determining isomorphism has been strongly advocated by Retgers (Zeitschr. f. Phys.-Chem., xvi, 35, 1895) and notwithstanding the objections which have been raised to this criterion, it does apply in certain series.   In the present case of limited isomorphism the etch figures sustain the contention of Retgers.

[†] This Journal, xxiv, p. 342, and fig. 7, p. 332, 1907.

any conditions and are excessively small. The photomicrographs (Plate I), *a–f*, illustrate the changes in the shape of the etch figures thus produced on 110 in preparations ranging from diopside to pure β-MgSiO$_3$. The etch figures on diopside (*a* and *b*) are long spindle-shaped pits with an upper blunt termination. On an average their length is four times the width and the angle *a* between the two sides at their point of junction at the lower extremity is about 18°. These etch pits are similar in every detail to those on 110 of natural diopside from Ala,[*] Piedmont. Etch pits on the face 010 were also observed and likewise resembled those on 010 of the natural mineral.—The etch pits on 110 of the preparation 50 per cent MgSiO$_3$ (*c*) are very similar to the figures on diopside, the angle *a* between the two sides at the lower extremity being slightly greater perhaps. On crystals of the composition 55 per cent MgSiO$_3$ (*d*) the etch pits are noticeably wider and the angle *a* has increased to about 35°. This angle *a* gradually increases until at the limit of solid solution it measures approximately 50° (*f*). The relation of the length of the etch pits to their width changes from about 4 : 1 in diopside to 3 : 1 in the 55 per cent and about 5 : 3 at the limit as represented by the etch figures of the 75 per cent preparation, which were chosen in place of those of the 67 per cent because of the sharper definition of the particular figures photographed. The transitional changes in the shape of the upper portion of the etch figures are also characteristic. The etch figures on the cleavage faces of β-MgSiO$_3$ (*e*) are exceedingly small and triangular in shape ; the angle *a* measures 55°–60° and the relation of length to width is about 3 : 2. Other details of the etch figures appear in Plate I and the evidence from all viewpoints tends to strengthen the assertion, that in this case of limited or incomplete isomorphism the character of the etch figures does change continuously with increasing MgSiO$_3$, and in the direction of the type of the etch figures of pure β-MgSiO$_3$.

It is of interest to note that the β-MgSiO$_3$, the low temperature form, takes up very little if any diopside in solid solution. This may be due to the fact that the high temperature-, *a*-form, is orthorhombic and therefore would have less tendency to take up the diopside molecule.

On the calcium side of diopside the crystal miscibility in the series is very slight, diopside taking up only small amounts of the calcium metasilicate. Wollastonite, on the other hand, can absorb up to 17 per cent of diopside and still remain homogeneous, whereas pseudo-wollastonite takes only 4 per cent at most of diopside in solid solution. No satisfactory explanation has been found to account for these differences in the behavior of the different compounds of this series.

* Compare R. A. Daly, Proc. Amer. Acad. of Arts and Sciences, xxxiv, 373–428, pl. iv, No. 18, 1899.

In Part I of this paper, the fact of eutectic mixtures and its bearing on the present problem are shown to be of prime importance.   In the case of alloys eutectic textures are definitely recognized and it is natural to expect such textures in silicate melts.   In the latter, however, power and rapidity of crystallization, combined with viscosity, frequent absence of stable equilibrium, and other factors, tend usually to veil effectively such textures which might otherwise develop. Indications of probable eutectic textures were occasionally recorded in this series, but as a rule the crystallization apparently takes place so rapidly with strong undercooling that normal, theoretical conditions of equilibrium do not exist.

It is also of interest to note that throughout this series the melts of the pure compounds are, as a rule, of coarser grain than the intermediate compositions and of more vitreous luster.   The intermediate mixtures frequently resemble porcelain in appearance.   This change in aspect undoubtedly results from the decrease in granularity and lack of continuity of the single crystallites.

The inversion of the a- and β*-$MgSiO_3$.*—With pure $MgSiO_3$- melts the thermal data show practically no heat effect at the temperature of inversion of the β- into the a-form and vice versa, and only after the admixture of several per cent of diopside does the thermal effect produced by the inversion appear.   The quenching experiments of Dr. A. L. Day, however, proved definitely that the a-$MgSiO_3$ did exist, and attempts were then made to fix the temperature of inversion by use of a specially constructed thermal microscope.*   (Fig. 13, *a* and *b*.)

* Constructed in the workshop of the Geophysical Laboratory after plans by Dr. Arthur L. Day and the writer.   The details of construction of the electric resistance furnace are given in fig. 13*b*, two important features of which were suggested by Dr. Day, namely, the enclosing of the whole in a suitable water jacket and the splitting of the thermoelement wires to serve as a support for the preparations.   By this latter device the purity and temperature of the preparations even at high temperatures is insured.   The microscope is fitted with revolvable nicols ; at the base of the furnace there is a thin metal slide, A_3, by means of which part or all of the field can be shaded and the characteristics of the light emitted and transmitted by the body studied with respect to effects of polarization.   A plate at high temperatures may become often self-luminous and it is then necessary to adopt special devices to detect transmitted polarized light and with this end in view the optical system of the microscope has been arranged.   With it, also, the character of the emitted light alone can be examined with respect to polarization effects if such exist.   At high temperatures the white heat of the furnace tends to veil the interference phenomena unless the transmitted light be of greater intensity, and this condition has been met by using an electric arc as source of light.   With this furnace the birefringence of quartz has been measured up to 1300° and it is proposed to study the optical changes in several minerals at different temperatures in this way.—Temperature readings are made either roughly on a direct reading Siemens and Halske voltmeter or accurately by use of the potentiometer.—The water jacketing of the furnace permits its use on any microscope in which the distance between the stage and the objective can be made great enough, the optical system remaining thereby unchanged.

FIG. 13, *a*.
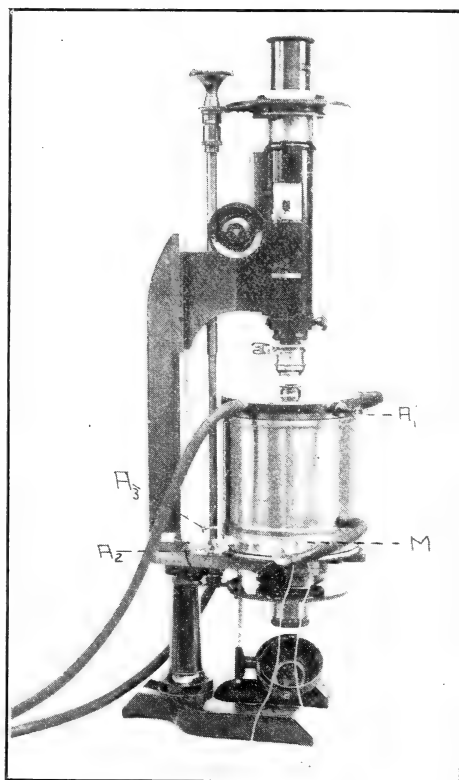
FIG. 13, *b*.
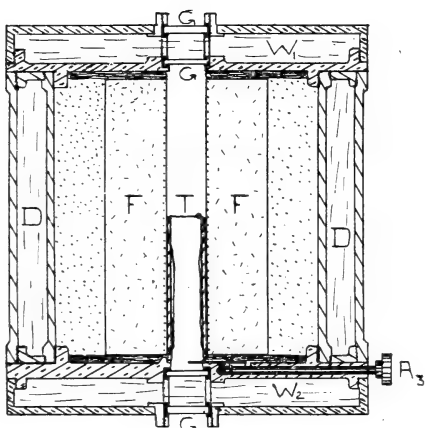
FIGS. 13, *a* and *b*.--Microscope equipped with electric resistance furnace. With the exception of the base and the upper tube, which were taken from a Fuess universal stage microscope, this thermal microscope was constructed in the workshop of the Geophysical Laboratory. The microscope is fitted with revolvable nicols and a low power 3-inch objective. The furnace rests directly on the stage of the microscope and can be revolved through small angles. Its different parts are shown in cross section in fig. 13*b* (one-half actual size). The water jacket consists of three parts ; W_2, base ; D, side cylinder, and W_1, cap. Each of these parts is complete in itself and by means of rubber tubing (fig. 13*a*) the water is made to pass through W_2, then D and finally W_1. At G in both W_1 and W_2 glass plates are introduced and allow light rays to be transmitted without permitting the heat to reach the objective and lower condenser system. The circulating water is sufficient to keep these plates cool. In the first experiments air bubbles from the water collected between the plates and seriously disturbed the clearness of vision. This difficulty was overcome by means of rubber plungers fastened to A_1 and A_2 (fig. 13) which could be passed back and forth in front of the plates and the bubbles brushed aside. By means of the rod A_3 with its attached brass plate, transmitted light from any part of the field can be shut off and the effects of emitted light alone studied. The furnace itself consists of a tube F (fig. 13*b*) 7.5^{cm} long, 4.5^{cm} outside diameter and 1^{cm} inside diameter, wound on the inside with fine platinum wire $.35^{mm}$ diameter. The thermoelement wires are supported by the porcelain tube T, which rests directly on the asbestos paper covering the upper plate of W_2. The thermoelement wires are introduced into the furnace at M (fig. 13*a*) and the furnace wires on the opposite side of the microscope. The sides of the furnace, F, are surrounded with magnesia powder and the ends capped with asbestos paper, to prevent loss of heat from radiation so far as possible.

Better results were obtained by another method, in which single,water-clear crystals of β-$MgSiO_3$ (about $.2 \times .2 \times 1^{mm}$) were mounted in cedar oil on the universal stage and turned until the clinopinacoid was normal to the line of vision and the twinning planes appeared as sharp lines. After photographing in this position (magnification 100 diameters) the crystal was placed in a specially prepared platinum basket and heated in an electric resistance furnace to a specified temperature, either above or below that of the β-$MgSiO_3$ inversion. After cooling, the crystal was again photographed under precisely the same conditions as before heating. The study of a long series of negatives prepared in this way has brought out several interesting points : In the inversion of a single crystal of β-$MgSiO_3$ to the *a*-form, no great volume change is involved nor even a great redistribution of the molecules. This is evident from the fact that after reversion from the *a*- to the β-$MgSiO_3$ the original crystal is intact and its faces still fairly sharp. Twinning planes are still present though usually in different positions, each lamella extending the entire length of the crystal as before heating. On such paramorphic change, inversion into one form and reversion to the original, it might be expected that, as in crystal aggregates formed by precipitation, many crystal nuclei would be formed,* and that on reversion each one of the new nuclei would produce at least one separate individual of the original form, with the result

* This actually happens on the inversion of wollastonite into pseudo-wollastonite. This Journal, xxi, 107, 1906.

that instead of a single crystal or a regularly twinned crystal, the aggregate of irregularly oriented individuals would result. In case, however, the molecular redistribution was slight, the inversion might proceed in regular fashion throughout the entire crystal and the effect of inversion and reversion be chiefly one of shifting of the ever present twinning lamellae. And this is the exact state of change in the β-$MgSiO_3$ crystals. Rarely the subdivision of a crystal into several irregularly bounded parts was noted and usually only the shifting of the lamellae. It was also of interest to observe that occasionally a shifting of the twinning lamellae took place in crystals heated to temperatures slightly below the inversion point. Because of this property, no decisive determinations of the inversion point could be made and recourse was taken to sudden chilling experiments—the preparations being first melted, the temperature then lowered and kept at a specified point for one hour, after which the preparation was dropped into cold water and chilled almost instantly. The a-$MgSiO_3$ thus obtained clearly showed the effect of incipient change even under these conditions, the major part of the powder being full of minute dustlike particles or cavities and as a result was semi- or subtransparent, and only now and then were clear portions of the a-form observed. Whenever the a-$MgSiO_3$ was held at temperatures slightly below the inversion point and then quenched, the entire preparation consisted essentially of the twinned β-form alone in clear transparent individuals, the dusty effect as well as the a-$MgSiO_3$ aggregates having practically disappeared except for an occasional clear crystal of the same.

Summary.

1. The end members of the system $CaSiO_3$–$MgSiO_3$ both exhibit enantiotropy. The inversion point in the former is about 1190°. The a-form, pseudo-wollastonite, is unknown in nature. The β-form is the mineral wollastonite. The β-form of magnesium silicate is the magnesian pyroxene occurring in meteorites and in intergrowths with enstatite and has recently been called clino-enstatite.[*] At about 1365° it is transformed into an orthorhombic form quite distinct from enstatite and unknown in nature.

2. Only one stable compound appears, viz., $CaSiO_3.MgSiO_3$, identical with diopside. It melts at 1380° and has a specific gravity of 3·275. It was obtained in well-formed, measurable crystals extremely pure, when crystallized from molten calcium chloride.

3. A eutectic occurs between diopside and pseudo-wollastonite at the composition 60 per cent diopside : 40 per cent calcium silicate. It melts at 1348°. A second eutectic occurs at about 68 per cent $MgSiO_3$: 32 per cent $CaSiO_3$. It is com--

[*] W. Wahl, Die Enstatit-augite, Tschermak's Mitth., xxvi, 1–131, 1907.

posed of about 95·5 per cent of a mix-crystal containing about 62·5 per cent of diopside, 37·5 per cent magnesium silicate, and 4·5 per cent a-$MgSiO_3$. Its melting temperature is 1375°. Microscopically eutectic textures were observed rarely if at all.

4. Six solid solutions appear in this system. Only two of them contain more than three or four per cent of the lesser component, and only these will be mentioned here.

a. β-calcium silicate (wollastonite) forms a saturated solution of wollastonite containing about 17 per cent diopside (8 per cent $MgSiO_3$) : 83 per cent $CaSiO_3$, when crystallization takes place in the neighborhood of 1050°, i. e., wollastonite is capable of dissolving about $\frac{17}{83} = 20$ per cent of its own weight. This series of solutions is interesting from the fact that the inversion point of pure calcium silicate (1190°) appears to be raised by the addition of $MgSiO_3$, up to 100° in the most concentrated solutions. This is probably largely, if not wholly, an *apparent* rise in the inversion point due to viscosity, for, as is well known, an inversion point should be raised only when the concentration of the solution below the point is greater than that above, while here there is a rise in the weaker solutions which suffer no change in concentration when they invert. Again, the concentration of solutions just below the inversion point cannot be determined with accuracy on account of the difficulty of establishing an equilibrium in solid silicate solutions.

b. Diopside dissolves about 60 per cent of its own weight, forming a solution which contains 66·5 per cent $MgSiO_3$: 33·5 per cent $CaSiO_3$. This saturated solution is very similar to diopside in all its properties. Its melting point is only 3° lower (i. e., the maximum heat absorption falls there, the melting interval is unknown). The specific gravity changes very little ; the optic data show slight but noticeable changes : the refractive indices, the birefringence, the optic axial angle and the extinction angles all falling continuously with the addition of $MgSiO_3$ from diopside up to the limit of solid solution at 66·5 per cent $MgSiO_3$.

5. In the series of limited solid solution between diopside and clino-enstatite, the effect of the addition of $MgSiO_3$ to diopside is, furthermore, clearly shown by etch figures on the prismatic cleavage faces. On passing from diopside to the limit of solid solution at about 66·5 per cent $MgSiO_3$, the shape of the etch pits changes gradually, their character, on preparations of intermediate composition, being intermediate between those of the two compounds, diopside and pure β-$MgSiO_3$, thus proving that actual solid solution does exist in the series, and that the effects of the end members are felt crystallographically in the solid solutions of the same.—For the observation, under the microscope, of changes which take place in substances at high temperatures, a special micro-

scope, fitted with electric resistance furnace, fig. 13a, has been constructed and found useful in the study of these etch pits.

6. The specific-volume curve consists of three well-defined branches, the first of which is the locus of the volumes of mechanical mixtures of pseudo-wollastonite (a-$CaSiO_3$) and diopside; the second, that of the solid solutions of magnesian pyroxene (β-$MgSiO_3$) in diopside; and the third the locus of the volumes of mixtures of saturated mix-crystals just mentioned, and the free magnesian pyroxene. The volume of the solid solutions is *greater* than the sum of the constituent volumes. There is a sharp minimum on the curve at the composition of diopside $CaSiO_3.MgSiO_3$. On account of the presence of minute bubbles in the crystals and the comparatively small difference between the specific gravity of diopside and that of the magnesian pyroxene, the critical points on the curve are several per cent in error.

7. A method for the more accurate determination of the composition eutectics is described; also a method for the approximate location of inversion points in inert substances. The accidental variations between different determinations of the melting point of a sharp melting silicate seldom amount to 1° up to 1500°. This is the accuracy available for comparative measurements. The absolute accuracy of a determination is less than this on account of the present limitations of the absolute scale.

The authors wish to express to Dr. Arthur L. Day their hearty thanks for valuable assistance in connection with the study of the a-magnesium silicate.

Art. II.—*The California Earthquake of 1906 ;* * by G. K.
Gilbert.

THREE days after the California earthquake of April 18,
1906, Governor Pardee appointed a commission for its scien-
tific investigation. No funds were at his disposal to defray the
expenses, but provision was made later by the Carnegie Insti-
tution, and the Institution is publishing the reports. Volume
I, in two parts with atlas, has recently appeared, and a second
volume is to follow.

Volume I is by Andrew C. Lawson, chairman of the com-
mission, and includes contributions from a large number of
collaborators. After an introductory account of the geology
and morphology of the Coast Ranges, it treats at length of the
physiographic features and physical changes associated with
the earthquake, of the distribution of intensity, and of the
directions of vibratory motion. The marine phenomena, the
composition of the main shock, the sequence of after shocks,
and various minor topics are presented, and account is given of
earlier severe earthquakes in the same region.

The earthquake was of the tectonic class, and was occasioned
by a slipping on the plane of an old fault. The fault outcrops
at the surface, and there was a visible displacement of consid-
erable amount. The line of outcrop trends NW.–SE., and
the fault plane is vertical. There was, however, very little
vertical displacement, the differential movement being almost
wholly horizontal. The country adjacent to the fault on the
SW. side moved bodily toward the NW., and the country
on the NE. side moved toward the SE. The changes did
not tend to increase the height of a mountain or the depth of a
valley but merely to distort the land horizontally. The amount
of displacement was measured in two ways, (1) by observation
of the dislocation of roads, fences, etc , traversed by the fault,
(2) by the remeasurement of a net of triangulation previously
made by the Coast Survey. Fences and roads were usually
offset from 8 to 15 feet, and the results from triangulation
showed relative dislocation of about the same amount for

points near the fault line. For points at greater distance the changes were less. The discussion of the data, by J. F. Hayford and A. L. Baldwin, led to the conclusion that the absolute movement was greater west of the fault than east of it, and in both directions diminished with distance from the fault, the diminution being most rapid in the immediate vicinity of the fault.

This earthquake is practically unique, among the small group that have been broadly studied, in that the stress couple to which the fault may be referred lay in the horizontal plane. The main associated distortions were distortions in ground plan, with little vertical complication. They were, therefore, exceptionally adapted for measurement by the method of triangulation, and the results actually obtained are more systematic than any previous results of the same character. It is, therefore, peculiarly unfortunate that they were qualified by a lack of chronologic unity in the trigonometric surveys preceding the fault, which were strung along through several decades. This fact made it impossible to discriminate between deformation at the time of rupture and progressive deformation during accumulation of strain before rupture; and if progressive deformation took place before rupture, the precision of the adjusted triangulation was thereby impaired. Nevertheless the results invite the careful attention of geophysicists. To the reviewer the distribution of dislocation, and especially the existence close to the fault, on each side, of a belt of maximum distortion, seems clearly not that which would obtain if the fault passed completely through a solid crust to a liquid substratum. And it appears also that, on the assumption of continuous solidity from the surface downward, the geodetic results might yield to adequate analytic treatment a conception of the order of magnitude of the vertical distance to which the fault penetrated.

The surface outcrop of the fault was definitely traced from San Juan to Point Arena, a distance of 190 miles. At Point Arena it passes under the sea, and there is doubt as to its further course. A fault made at the same time on a more northerly part of the coast may be its continuation, after inflection, or may be on an independent line; but in either case the total length of dislocation was about 270 miles.

At all points the fault follows a peculiar topographic feature to which the name *San Andreas rift* was given; but the rift is more extensive than the fault of 1906, having been traced to the Salton basin, several hundred miles southeast of San Juan. In its larger expression the rift is a trough, a trough coinciding in general trend with the Coast Ranges, but crossing various mountain ridges obliquely, or even following their crests.

In detail it comprises many small ridges and hollows, approximately parallel but otherwise irregularly disposed, and evidently caused by splintery dislocation. Streams zigzag more or less about the ridges, and the hollows contain many small ponds and marshes. There are reports of long cracks which appeared in different parts of the rift in connection with various earthquakes of the last century, and it is inferred that each of these cracks was the surface expression of a fault-slip similar to that of 1906. It is further inferred that the rift as a whole marks the outcrop of a long fault or fault zone, separating two crustal tracts which are slowly moving past one another, with gradual accumulation of strain and stress, and occasional relief by local slipping when the stress at some point overpowers the adhesion on the fault plane. The physiography of the rift is illustrated by numerous excellent photographs, and by a local contour map by F. E. Matthes. Although the rift has been mentioned in various writings of earlier date, its description in this volume practically adds a type of surface configuration to physiographic science.

In the discussion of the intensity of the shock, a distinction is recognized between the elastic wave propagated from the origin through the crust, with gradually diminishing magnitude, and the phenomena of emergence, conditioned by the nature of the surface formation. The intensity observed at the surface, and expressed chiefly by damage to buildings and other structures, is called "apparent intensity," and this only is mapped. The general map shows a long narrow belt of high intensity, following the fault, with peninsulas and outlying islands where destructive effect was enhanced by the presence of incoherent formations; but this elongation is less characteristic of the lines limiting the areas of low intensity. The outer line, touching the most remote points of sensible tremor, traverses southern Oregon, central Nevada and southern California. In view of the ideas recently advanced by W. H. Hobbs, there is a careful review of the relation of local intensity to the known major faults of the region, about forty in number. In three cases it was thought possible that some portion of the movement of dislocation was diverted from the main (San Andreas) fault to the planes of intersecting faults. A special intensity map of San Francisco, by H. O. Wood, shows with great detail the grades of violence; and its comparison with a geologic map brings out forcibly the intimate relation between effective intensity and the underlying formation.

The subject is further elucidated by the report of an experimental study by F. J. Rogers. By mechanical arrangements similar to those employed by the Japanese commission in investigating the principles of earthquake-proof construction, har-

monic horizontal motion was given to an open box containing some loose material such as sand. A block resting on and anchored to the upper part of the sand, so as to share its motion, was found not to have harmonic motion, but motion of a distinct type which varied with the conditions of the experiment. Under certain conditions the amplitude of its motion was greater than that of the motion of the box, and its maximum acceleration—the factor corresponding to earthquake intensity—very much greater. These novel experiments are not only valuable in their immediate results, but of signal importance as indicating a line of study which should develop a complete theory of the phenomena of the emergence of earthquake waves.

The marine phenomena were in àccord with the terrestial in that they indicated no bodily movements of the ground except in a horizontal sense. Vessels at sea experienced a shock; there were boilings of water near the shore; a small seiche was started in San Francisco bay; a wave several feet high washed the east shore of Tomales bay, a narrow sheet of water traversed by the fault; but there was no great sea wave such as accompany vertical dislocations of the ocean bed.

The main shock, which was of about one minute duration, was reported by many observers as consisting of two parts, or having two maxima, but by others as continuous. Considering the improbability that movement was synchronous and similar over the entire plane of rupture, it is to be assumed that the vibration had different characters at different places, but the observations are not discussed with reference to geographic distribution. There are many records of preceding or accompanying sounds, all of low pitch. The after shocks were of normal character, diminishing with time in frequency and average strength, and continuing for at least ten months. The report enumerates more than 100 in the first 24 hours; about 300 in the first month; and for succeeding months, 71, 24, 44, 28, 14, 11, 13, 15, 21, 2, 3, 1, 2. The record is recognized as fragmentary, and the actual number of sensible shocks was probably much larger. There was somewhat voluminous testimony to the occurrence of visible undulations of the surface of the ground, the speed of which was much slower than that of the elastic waves in rock.

Cracks opened in many places near the fault; from several of these were large temporary discharges of water or of water and sand; the circulation of underground water was seriously and permanently deranged, springs being destroyed, created or changed in volume; landslides and earthflows were precipitated in great number. Alluvial lands slumped toward stream channels, and soft ground was in some localities left with a wavy surface.

The volume closes without discussing the subject of future earthquakes in the San Francisco region, but furnishes material pertinent to that discussion by publishing accounts of the earthquakes of 1868, 1865 and 1857. The fault in 1857 was on the southern part of the San Andreas rift, and the fault in 1865 may have been on the same rift near the southern end of the fault of 1906. The fault in 1868 was on a parallel rift east of the southern arm of San Francisco bay. In each case the distribution of intensity in San Francisco was substantially the same as in 1906, the character of the ground having more influence than the direction of the origin.

The second and closing volume of the report will be by H. F. Reid, and will treat of the theory of the seismogram.

ART. III.—*Descriptions of Tertiary Insects;* by T. D. A. COCKERELL. Part V.

SOME NEW DIPTERA.

Lasiosoma mirandula sp. nov. (Mycetophilidæ : Sciophilinæ).

Expanse 16^{mm}; length of body about 10^{mm}, of wing 7^{mm}; abdomen reddish, with the hind margins of the segments rather broadly blackened, its whole surface with minute appressed hairs; legs pale brown, the femora minutely hairy; wings wonderfully preserved, strongly rufescent, with a purple or pink tinge, nervures darkened. By the dusky wings and the short prostrate hairs on abdomen it agrees with the living *L. pallipes* (Say), but it is considerably larger than Say's species. The venational features are as follows: the costal thickening extends a short distance beyond the tip of the ultimate branch of the radius (third vein); *subcosta,* much as in the fossil *Sciophila hyatti* Scudd., *does not distinctly reach the costa,* but is evanescent after the little vein which passes from it to the radius, meeting the beginning of the inferior branch of the latter; small vein from costa to subcosta distinct, oblique, forming an angle of 45° with each, and placed a moderate distance (about $\frac{2}{3}$^{mm}) from base of wing; branches of radius as in *Sciophila,* with the same little cell formed in the fork by R$_{2+3}$ running up to join R$_1$: media, as usual, weaker than radius, and forking almost immediately after leaving the radio-medial cross-vein, so that the stem before the fork is shorter than the cross-vein, although the latter is short and not very far from vertical; cubitus forking not far from base as in *Sciara;* anal with its apical portion wanting, as in *Ceroplatus.* In Williston's tables (N. A. Diptera, 3d ed.) this runs exactly to *Lasiosoma,* and seems to accord well with that genus.* The living American species are northern.

Hab.—Florissant, Colorado, in the Miocene shales, Sta. 14 (*S. A. Rohwer*, 1907).

Holotype in Peabody Museum (Yale).

Tetragoneura peritula sp. nov. (Mycetophilidæ : Sciophilinæ).

Length 4^{mm}; wing 3$\frac{3}{5}$, antenna 1$\frac{2}{5}$^{mm}; dorsum of head, thorax and abdomen dark brown, the rest of the body pallid; legs long and slender; wings hyaline, with brown nervures.

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* It differs, however, from Handlirsch's figure (Foss. Ins., pl. vi) of *Lasiosoma* in the shorter subcosta, not ending on costa, and also in the more vertical radio-medial cross-vein. Handlirsch's figure does not show any cell in the forks of the radius, so it may not be of this genus.

Antennæ with about 16 joints, the middle joints much broader than long (about 102 μ broad, and 76 long) ; scutellar region with two very long stout bristles, 459 μ long, the other bristles of thorax much shorter ; thorax very strongly convex above ; legs and abdomen with extremely fine hairs ; hind tibiæ with a row of short black bristles, about 93 μ long. Venation : subcosta reaching to about the middle of the wing, that is to say, *not abbreviated*, and ending in a very broad V, the upper branch extending to the costa, and the lower to the radius ; radius normal, its lower branch leaving it a short distance before the termination of the subcosta, and emitting, shortly after that termination, the oblique cross-vein to R_1 which really represents R_{2+3} ; R_{4+5} normal, ending very near apex of wing ; oblique radio-medial cross-nervure very long, about three times as long as the nearly vertical first section of lower branch of radius ; media with a long fork ; cubitus not distinctly preserved (it ought to be forked).

Hab.—A few miles north of Rifle, Colorado, in rocks of Eocene age, probably of the Green River Group, but possibly Wasatch. Type in collection of Dr. S. M. Bradbury. This cannot be identified with any of Scudder's fossil Mycetophilidæ. Professor O. A. Johannsen very kindly examined my sketch and notes, and suggested the generic reference. He writes as follows :

" The subcosta in most of the species thus far described is short, and ends either free, or in R ; in one species described by Walker it ends in the costa ; in one species of Meunier it is long, though ending in R. As only about sixteen species (including fossils) are known of this genus, and these quite rare, its limitations are difficult to define. I should be inclined to call your fossil *Tetragoneura*, though acknowledging it as somewhat aberrant" (litt. Aug. 19, 1908). The known fossil species of *Tetragoneura* number seven, all from Baltic amber, described by Meunier. As the amber is of Oligocene age, the species now described is the oldest known.

Alepidophora g. nov. (Bombyliidæ).

A genus with elongate, subcylindrical abdomen, looking not unlike a bee. In Williston's tables (N. Am. Dipt., 3d ed., p. 216) it runs to 29, and has very much the build of *Lepidophora lepidocera* (*appendiculata*), except that it is not at all scaly, the wings are very much shorter, and so far as can be seen, the mouth-parts are not elongated. The anterior tibiæ (the only ones visible) are not bristly, as they are in *Sphenoidoptera*. In the hairy abdomen it differs from *Paracosmus ;* but the course of the second vein is as in *Paracosmus*, not as in *Metacosmus*.

By the characters of the abdomen and venation it is excluded from *Aphoebantus* and the related *Epacmus* and *Eucessia*.

The characters of the venation are as follows :

(1.) Second vein ($R_{(2+3)}$) *arising at the same point as the third*, and about 390 μ basad of discal cell. Near its end it curves upwards, and ends on costa at an angle even more obtuse than that presented by *Pantarbes* (Williston, l. c., p. 212).

(2.) Third vein $R_{(4+5)}$ robust, gently curved, with its lower branch (R_5) forming a gently curved but nowhere angled line ; upper branch (R_4) leaving it at right angles, and after 255 μ bent at a right angle, but emitting a short vein (rudiment of the cross-vein) in a straight line with the second section, so that the whole branch represents a ⊤ resting on the third vein, and having one of its sides prolonged and bent upwards to reach the costa. The end of the branch is not bent nearly so much as the end of the second vein, and its inner angle with the costa is not very much greater than a right angle. In general, all this is much as in *Pantarbes*, except as to the rudimentary cross-vein directed basad (in *Pantarbes* the cross-vein is complete and directed upwards).

(3.) Radio-medial cross-vein much beyond middle of discal cell (about 760 μ from its apex), and 255 μ long.

(4.) First posterior cell open at apex, the opening about 120 μ wide.

(5.) Discal cell long and rather narrow (its length about $2\frac{2}{3}^{mm}$), shaped as in *Systrophus* (the bounding nervure having the same curves), except that it is much longer.

(6.) Second posterior cell narrow (306 μ) at base, and extremely broad at apex (i. e. on margin) ; third posterior broad at base, and narrowed apically ; fourth (morphologically fifth) very broadly open, formed as in *Pantarbes*, but longer ; its base is 476 μ from base of discal cell.

(7.) Anal cell rather widely open.

Alepidophora pealei sp. nov.

Length 12^{mm} ; of wing 6$\frac{1}{2}$; of abdomen about 8 ; width of abdomen 3$\frac{2}{5}^{mm}$; head and thorax black ; abdomen dark reddish-brown ; wings hyaline, nervures brown, costal region (between costa and radius) reddened ; as preserved, the abdominal segments appear as widely separated dark chitinous bands, with broad colorless intervals between, these intervals being about half the size of the chitinous rings. Eyes with facets of two sizes, the smaller about 22 μ diameter, the larger about 42 μ ; the two kinds seem to be about equally represented, the division apparently longitudinal, and not abrupt. Tarsi with scattered strong bristles. Third abdominal segment slightly bristly or hairy, fourth with a conspicuous patch of dark hairs on each side, fifth and sixth moderately hairy, the hairs dark.

Hab.—Florissant in the Miocene shales, 1908.　On the same slab, close to the fly, are the leaves of *Fagus longifolia.*　While I was preparing the above description, Dr. A. C. Peale, the discoverer of the Florissant shales, visited my laboratory.　It is with much pleasure that I dedicate the species to him.

Holotype in Peabody Museum (Yale).

Pachysystropus gen. nov. (Bombyliidæ).

Rather large, cylindrical-bodied, with a strong projecting proboscis ; antennæ with a sharp apex, constructed essentially as in *Geron ;* hind femora stout and hairy.　In Williston's table (N. Am. Diptera, 3d ed.) it runs straight to *Dolichomyia* (the eyes are not very distinct, but I feel sure not holoptic),

FIG. 1.

Pachysystropus rohweri Ckll.

but the venation agrees better with that of *Systropus*, differing, however, as follows :

(1.) The lower half of the cross-vein from the bend of R_4 to R_{2+3} is present, and very distinct, though the upper half is wanting.　This vein is absent in *Systropus* (though the abrupt bend remains to indicate where it was), but is complete in *Pantarbes* and *Exoprosopa.*

(2.) The first posterior cell is closed just before the margin of the wing, a condition approximately intermediate between that of *Systropus* (in which it is open) and *Pantarbes.*

(3.) The anal cell is closed just before the margin, as in *Ocondocera* (N. Am. Dipt., f. 82).　The venation is very well

preserved, and the existence of only three posterior cells is certain. The anal cell in the S. African *Systropus crudelis* (as figured by Sharp) is like that of *Pachysystropus*.

Pachysystropus rohweri sp. nov. Fig. 1.

Black or dark brown, the wings hyaline, with dark nervures; apical half of area between radius and costa fuliginous; length (excluding proboscis) $13\frac{1}{2}^{mm}$; proboscis rather stout, a little over 3^{mm} long; antennæ $2\frac{2}{3}^{mm}$, the last joint very sharp-pointed, 663 μ long; width of thorax 4^{mm}; of the parallel-sided abdomen about $2\frac{1}{3}^{mm}$, its apex not swollen; lateral anterior corners of first three abdominal segments (especially the second) projecting at an acute angle; fourth and fifth segments with dark hair at sides; hind femora about 4^{mm} long, stout, the posterior side with much long dark hair; length of wing $8\frac{3}{4}^{mm}$; base to anterior cross-vein $5\frac{2}{3}^{mm}$.

Hab.—Florissant, in the Miocene shales, Sta. 9. (*S. A. Rohwer*, 1906.)

Holotype in Peabody Museum (Yale).

Callimyia (?) *hypolitha* sp. nov. (Platypezidæ).

A small stout-bodied fly with long wings; as preserved, the head and thorax are dull black; the abdomen conspicuously shining, dark reddish-brown, with the hind margins of the segments black; wings hyaline, nervures pale.

Length of body $4\frac{1}{2}^{mm}$, of wing $4\frac{1}{3}$; length and width of abdomen each about $2\frac{1}{4}^{mm}$, but the apex is not visible (apparently turned downwards); thorax robust; head broad, but not quite so wide as thorax.

Venation, as preserved (the subcosta, radius and branches, and anterior cross-vein are visible), exactly as in *Callimyia* (Willst., N. Am. Dipt., 3d ed., p. 242, f. 2) except that I cannot demonstrate any spinulosity on the radius, but the veins are so nearly the color of the rock that this might well be invisible. The first posterior cell is widely open, as in *Callimyia*. The subcosta ends on the costa at about the middle.

Hab.—Near Rifle, Colorado, in Eocene rocks; the locality and other particulars being the same as already given for *Tetragoneura peritula.*

Only two Tertiary Platyperidæ have been previously described; *Oppenheimella baltica* Meunier, from amber; and *Callimyia torporata* Scudder, from the Green River beds of Wyoming. *C. hypolitha* is a much larger species than *C. torporata.*

Since writing the above I have found the reverse impression of *C. hypolitha*, showing the anterior branch of the media

very distinctly. The media turns *downwards* near its distal end, and the first posterior cell is more widely open than in *Callimyia.* This downward bend is to the apical corner of the discal cell, which forms a somewhat acute though large angle, and from that point onwards the media is directed straight to the margin. (The margin and immediate vicinity at this place are not visible.) This arrangement of the media, etc. resembles that of *Ocydromia* (Empididæ). Scudder's *C. torporata* also has the very widely open first posterior cell.

Leptis florissantina sp. nov. (Leptidæ).

A small, slender species, beautifully preserved, with expanded wings. Length 8^{mm}; wing 7; expanse 15^{mm}; width of head 2^{mm}, of the abdomen 1½. Antennæ not well preserved, but the third joint seems to be large, much as in *Hilarimorpha;* I cannot see the styles. Eyes very widely separated above; head broader than long; thorax small; head and thorax black; wings hyaline, without spots, veins dark reddish-brown; abdomen parallel-sided, a little broadened to the obtuse apex, the basal two segments pallid, the others largely dark (perhaps originally wholly dark). Venation as in *Leptis;* compared with *L. mystacea* Macq. (Williston, N. A. Dipt., 3d ed., p. 157) the following slight differences are found :
(1.) Costa not or barely arched near base.
(2.) Wings narrower.
(3.) The second vein ends nearer apex of wing, beyond level of middle of cell in forks of third.
(4.) Bases of second and third posterior cells about half a millimeter back of level of base of cell in forks of third vein.
(5.) Anterior cross-vein (radio-medial cross-vein) nearer to middle of discal cell. The anal cell is barely closed, just on the margin of the wing; there may be an infinitesimally small opening.
Hab.—Florissant, in the Miocene shales, Station 13 B (*S. A. Rohwer*, 1908). Four species of *Leptis* have been described from amber.

Tipula heeriana n.n.

Tipula lineata Heer. Ins. Oen. II, p. 194, t. 15, f. 4 (1849).—Miocene of Radoboj (not *T. lineata* Scopoli, Ent. Carn., p. 320).
Tipula lineata Heer, Scudder, Proc. Am. Phil. Soc., 1894, p. 9.

Limnophila meunieri n.n.

Limnophila gracilis (Lw., as *Tanysphyra*, Scudder, Proc. Am. Phil. Soc., 1894, p. 21 (nom. nud.); Meunier, Ac. Sc. Nat. (9) iv, p. 382, t. 14, f. 9 (1906).—Baltic amber (not *L. gracilis* Wiedemann, Auss. Zw. 1, p. 28).

Art. IV.—*The Electrolytic Estimation of Lead and of Manganese by the Use of the Filtering Crucible;* by F. A. Gooch and F. B. Beyer.

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

In a former paper* we have shown that the filtering crucible may be put to advantageous use in an electrolytic cell for the treatment of deposits not compact and adherent enough to be handled rapidly and conveniently by ordinary methods of electro-deposition. Four devices were described : I, a closed cell in which the perforated platinum crucible is adapted to use as an electrode and to filtrations after interruption of the electric current; II, a closed cell in which the perforated platinum crucible is used as an electrode and in subsequent filtrations without interruption of the current; III, a cell in which the perforated platinum crucible is adjusted to a filtering flask for continuous filtration during electrolysis; IV, a cell in which a perforated porcelain crucible with included electrode of platinum is arranged, like the platinum crucible of III, for continuous filtration during electrolysis. It was shown that by either of the devices described reasonably rapid and accurate electrolytic determinations of copper may be made without the use of rotating motors or expensive apparatus of platinum. In testing these devices, copper sulphate was electrolyzed, with an error ranging between $+0.0003$ grm. and -0.0003 grm. upon approximately 0.1274 grm. of copper or 0.5000 grm. of the sulphate. The duration of the electrolysis was about thirty minutes in the processes involving continuous filtration and forty-five minutes in the processes in which filtration was begun after electrolysis was completed. The metallic copper deposited upon the cathode was partly compact, partly spongy. In the work to be described the apparatus has been tried in the more difficult determinations of manganese and lead as the dioxides formed upon the anode in very imperfectly adherent condition.

The Determination of Lead as the Dioxide.

In depositing lead dioxide† electrolytically, solutions containing nitric acid are employed ; precautions must be taken in regard to concentration of acid, strength of current and temperature; and the liquid is siphoned off before interruption of the current. With the rotating cathode making 600 revolutions a minute and a sand-blasted platinum dish for the anode, Exner obtained in ten to fifteen minutes adherent

* This Journal, xxv, 249, 1908.
† Smith, Electro-analysis, p. 101, edition of 1907.

deposits with a current $N.D._{100}$=10 amp. and 4·5 volts, acting
upon 125^{cm3} of solution containing 20^{cm3} of concentrated nitric
acid.

In some of our preliminary trials of electrolysis in the closed
cell with subsequent filtration it was found that when the con-
centration of nitric acid amounted to 10^{cm3} in 60^{cm3} of liquid,
with a current of 4 amperes ($N.D._{100}$=10 amp.) and 6 volts,
two sources of error appeared. In the first place, the depo-
sition of metallic lead upon the cathode was often noticeable;
and secondly, it appeared to be impossible to make the precipi-
tation of lead dioxide complete so long as that substance was
allowed to float in the liquid. Similar results were obtained
in experiments in which urea
was added to the liquid for the
purpose of obviating the sol-
vent action of dissolved oxides
of nitrogen upon lead dioxide.
In the experiments with this
form of apparatus the stirring
of the asbestos felt by gas
evolved upon the bottom of the
crucible used as an anode, as
well as the deposition of oxide
on the outer surface of the
crucible, was prevented by tak-
ing the precaution to moisten
the asbestos, from the outside,
with a drop of nitrobenzene
which, being insoluble in
water, prevents the contact of
the aqueous electrolyte with
the electrode surface under-
neath the asbestos. An increase
of nitric acid to the proportion
of 30^{cm3} in 100^{cm3} of solution
served to prevent the deposi-
tion of lead upon the cathode,
but to prevent the re-solution of lead dioxide it was found
to be necessary to use the process of continuous filtration,
so that the deposit might be compacted upon the felt, and
after deposition was complete to replace the acid liquid by
a solution of ammonium nitrate without interruption of the
current. After washing out the nitric acid with the solution
of ammonium nitrate the final washing was completed with
water. The form of apparatus employed, shown in figure 1,
and the manner of using, were fully described in the former
article to which reference has been made.[*] In Table I are

FIG. 1.

* This Journal, xxv, 249, 1908.

given the results of experiments following this procedure, and, for comparison, the result of an experiment, (1) in which it was found that, though electrolysis was continued by the circulating process until the filtrate contained no lead, traces of lead dioxide went into solution after the amount of electricity which passed had been diminished by the gradual dilution with water used in washing to replace the electrolyte. Tests for lead in filtrates and washings were made by neutralizing with ammonium hydroxide and adding ammonium sulphide, or acetic acid and potassium chromate.

TABLE I.

Electrolysis with Continuous Filtration.

$Pb(NO_3)_2$	Vol.	HNO_3 conc. cm^3.	Current			Time min.	PbO_2 found grm.	Theory for PbO_2 grm.	Error grm.
			Amp.	ND_{100}	Volt				
				A					

With no ammonium nitrate in electrolyte or in wash-water.

(1) 0·2023	50	15	2	5	4	5			
			4	10	5	130	0·1460	0·1436	—0·0024

B

With ammonium nitrate in electrolyte and in wash-water.

(2) 0·2022	50	15	2	5	4	40			
			4	10	5	100	0·1459	0·1462	+0·0003
(3) 0·2014	50	15	2	5	4	5			
			4	10	5	115	0·1454	0·1458	+0·0004
(4) 0·2001	50	15	2	5	4	5			
			4	10	5	115	0·1444	0·1442	—0·0002
(5) 0·2006	50	15	2	5	4	5			
			4	10	5	115	0·1448	0·1446	—0·0002
(6) 0·2046	50	15	2	5	4	5			
			4	10	5	115	0·1477	0·1472	—0·0003

C

With ammonium nitrate in wash-water only.

(8) 0·2020	50	15	2	5	4	5			
			4	10	5	115	0·1458	0·1460	+0·0003
(9) 0·2037	50	15	2	5	4	5			
		4	4	10	5	115	0·1470	0·1473	+0·0003

From the results of the experiments described, it appears that good analytical results may be obtained with the filtering crucible used as an electrolytic cell if nitric acid be present to the proportion of 30^{cm^3} of the concentrated acid in 100^{cm^3} of solution, the liquid kept in continuous filtration until the electrolysis of the lead salt is complete, the acidic liquid replaced by a solution of ammonium nitrate so that the electric current passing shall not fall off until the nitric acid has been removed,

the final washings made with water, and the deposit weighed after drying at 200°. The time required for the complete deposition of 0·15 grm. of lead dioxide under the conditions described is about two hours.

The Determination of Manganese.

For the electro-deposition of manganese as the dioxide various processes have been described.[*] With stationary electrodes solutions containing nitric acid, sulphuric acid,

Fig. 2.
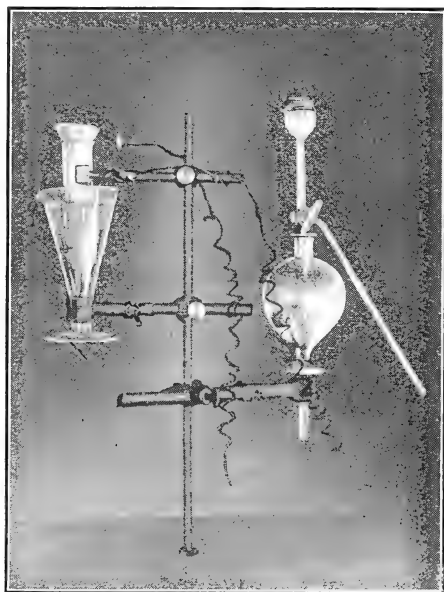
acetic acid, formic acid with or without a formate, or ammonium acetate alone, with chrome alum, or acetone, have been employed. For use with the rotating anode, solutions containing ammonium acetate with chrome alum or alcohol have been advocated.[†] In all these processes hydrated manganese dioxide is deposited upon a large anode which is preferably a roughened platinum dish of considerable capacity.

The experiments to be described have been made to test the utility of the electrolytic filtering cell in the determination of manganese as the dioxide. The procedure adopted was the

[*] Smith's Electro-analysis, edition of 1907, p. 134 et seq.
[†] Koester, Zeitschr. Electro-chem., x, 553, 1904.

simplest. Fifty-centimeter portions of a solution of pure manganese sulphate, standardized by evaporation of measured portions and gentle ignition of the residue over a radiator,* were treated, in each case, with six drops ($0 \cdot 17^{cm^3}$) of concentrated sulphuric acid and electrolyzed in the filtering cell with a current of 2 amperes ($\text{ND.}_{100} = 5$ amp.) and 20–10 volts, the voltage decreasing as the solution became heated. In one set of experiments the process of continuous filtration during electrolysis, for which the adjustment of apparatus is shown in figure 1, was employed: in a second set of experiments the closed cell, shown in figure 2, was used during the electrolysis and the adjustment for filtration made subsequently as previously described.† The time required for the deposition of $0 \cdot 1860$ grm. of the dioxide was one hour and three-quarters in the former process: a period varying from two hours and ten minutes to two hours and fifty minutes is required in the latter process. Tests with hydrogen dioxide and ammonia showed that the deposition was complete in the process of continuous filtration and practically so in the closed-cell process. The closed-cell process naturally requires less attention during the electrolysis, and so it is advantageous to run the process for a period, perhaps two hours, with the closed cell and then to adjust the apparatus for filtration during further electrolytic action in order that floating particles of the dioxide may be drawn to the felt and completeness of precipitation may be assured. In this way the advantage of the circulating process may be obtained with less attention to manipulation than is required when the filtration is continuous from the start. The deposit was washed with water after interruption of the current, first dried at 200° for ten or fifteen minutes and weighed, and thereafter ignited to low redness in the spreading flame of a large burner.‡ Results of experiments with the cell arranged for continuous filtration, and of experiments in which the closed cell was used until the electrolysis was nearly over, are given in the accompaning table.

The results are evidently as good as could be expected of any process which involves the weighing of manganese dioxide brought to condition by heating. The degree of oxidation of the oxide thrown down under the conditions which obtain apparently approximates closely to that of the ideal oxide represented by the symbol $MnO_2.H_2O$, formerly assigned by Rüdorff§ to the electrolytically formed oxide, and differing in that respect from the electrolytically deposited oxide which was studied by Groeger.‖

* This Journal, v, 209, 1898. † This Journal, xxv, 249, 1908.
‡ This Journal, v, 214, 1898. § Zeitschr. angew. Chem., 1892, 6.
‖ Zeitschr. angew. Chem., 1895, 253.

TABLE II.

Solution of MnSO₄ taken cm³	H₂SO₄ conc. cm³	Current			Theory for MnO₂ grm.	MnO₂ weighed as MnO₂ grm.	MnO₂ weighed as Mn₃O₄ grm.	Error grm.
		Amp.	ND.₁₀₀	Volt				

(Note: the Current heading spans the Amp. / ND.₁₀₀ / Volt sub-columns.)

A

Electrolysis with continuous filtration.

Solution of MnSO₄ taken cm³	H₂SO₄ conc. cm³	Amp.	ND.₁₀₀	Volt	Theory for MnO₂ grm.	MnO₂ as MnO₂ grm.	MnO₂ as Mn₃O₄ grm.	Error grm.
(1) 50	0·17	2	5	20 — 12	0·1860	0·1862		+0·0002
							0·1858	—0·0002
(2) 50	0·17	2	5	20 — 12	0·1860	0·1856		—0·0004
							0·1856	—0·0004
(3) 50	0·17	2	5	20 — 12	0·1860	0·1843		—0·0017
							0·1872	+0·0012

B

Electrolysis in closed cell with subsequent filtration.

(4) 50	0·17	2	5	20 — 12	0·1860	0·1860		0·0000
							0·1853	—0·0007
(5) 50	0·17	2	5	20 — 10	0·1860	0·1856		—0·0004
							0·1856	—0·0003
(6) 50	0·17	2	5	18 — 10	0·1860	0·1853		—0·0007
							0·1858	0·0002

Somewhat greater regularity in results might be expected if the manganese dioxide could be converted to manganous sulphate and weighed as such, but experiments made with this end in view were unsuccessful. The application of gaseous sulphur dioxide proved to be ineffective and sulphuric acid attacked the asbestos felt during ignition, causing a permanent increment of weight. The substitution of spongy platinum for asbestos in the filtering crucible, as suggested and used by Monroe,* served to obviate the difficulty due to the action of the sulphuric acid upon the filtering medium, but the process of removing the necessary excess of sulphuric acid by gentle heating over radiator was exceedingly slow and, if pushed, liable to errors of mechanical loss. To weigh as either form of oxide, in this process, is therefore better than to attempt the conversion to manganese sulphate.

The processes demonstrated for the electrolytic deposition of lead dioxide and manganese dioxide with the use of the filtering crucible are obviously inferior in point of convenience to the more rapid processes which demand the use of large and special platinum containers and rotating motors, but in absence of such apparatus they may serve a useful purpose.

* Chem. News, lviii, 101.

Art. V.—*The Specific Radio-Activity of Thorium and its Products;* by G. C. Ashman.

The radio-activity of thorium compounds and minerals was discovered by Schmidt[*] and independently by Mme. Curie[†]; Strutt[‡] also found that all thorium minerals examined by him showed radio-active properties. Debierne[§] discovered actinium while working up uranium ores containing thorium. The similarity of the chemical properties of actinium and thorium led to the suggestion by a number of chemists that the activity of thorium is not due to thorium itself but to slight traces of actinium, since actinium is very difficult to separate from thorium and the other rare earths. This view is hardly tenable in the light of the fact that thorium and actinium give emanations with totally distinct properties: their rates of decay are widely different, and their products are in no way identical. In 1902 Hofmann and Zerban[‖] announced that they had obtained an inactive thorium preparation from a Brazilian monazite sand, and that thoria prepared from various minerals, although active at first, became inactive after a few months. Baskerville and Zerban[¶] also claimed they had separated from a South American mineral thoria which was perfectly inactive. A little later Hahn[**] and Ramsay[††] extracted from the mineral thorianite a radio-active preparation several thousand times more active than thorium itself and yielding a proportionately larger amount of thorium emanation. This discovery made it appear possible that the activity of thorium might be due wholly to radiothorium since the latter possesses an extreme tendency to retain its association with that element. Papers bearing on this question were published simultaneously by Boltwood,[‡‡] by Dadourian,[§§] and by McCoy and Ross[‖‖]. The concordant results of these three independent investigations proved conclusively that the intensity of the radio-activity associated with thorium in any mineral is directly proportional to the thorium content of the mineral. This work, together with the preparation of radiothorium from thorium minerals by Hahn and

[*] Ann. d. Phys., lxv, 141, 1898.
[†] C. R., cxxvi. 1101, 1898 ;
[‡] Proc. Roy. Soc., London, lxxvi, 88 and 312, 1905.
[§] C. R., cxxix, 593, 1899 ; cxxx, 206, 1900.
[‖] Ber. d. Chem. Ges., xxxv, 531, 1902.
[¶] J. Amer. Chem. Soc., xxvi, 1642. 1904.
[**] Ber. d. Chem. Ges., xxxviii, 3371, 1905.
[††] J. de chim. phys., iii, 617, 1906.
[‡‡] This Journal, xxi, 409, 1906.
[§§] Ibid., xxi, 427, 1906.
[‖‖] Ibid, xxi, 433, 1906.

Ramsay, and the demonstration that the extracted radiothorium produced thorium-X and the subsequent products left no doubt that radiothorium was produced by the disintegration of thorium, but the question still remained whether this disintegration of thorium itself was accompanied by a-rays; that is, whether thorium *itself* was radio-active. McCoy and Ross found that all of the activity of a thorium mineral, not due to uranium, remained in the pure thorium dioxide, separated by Neish's method: the measurements were made at the end of a month to allow the accumulation of the maximum amounts of thorium-X and subsequent products. Pure thorium dioxide made from commercial samples of thorium nitrate had about half the normal activity. This was at first thought to be due to the removal of part of the radiothorium in the technical process of purification. McCoy and Ross attempted to separate radiothorium completely from thorium, but found it apparently impossible to do so. Hahn found that the activity of commercial samples varied with the age of the material; the activity was smallest for samples three to nine years old. A sample twelve years old had greater activity. To explain these results, Hahn[*] suggested that there is a rayless intermediate product, mesothorium, having a period of about seven years, between thorium and radiothorium; that this is separated in the process of extraction of thorium from minerals, and that the radiothorium, which has a period of two years, decays with time, causing the observed fall of activity of commercial samples. Some observations by Boltwood[†] tended to confirm this view. Later quantitative experiments by McCoy and Ross showed that the hypothesis was in good agreement with the facts and that the period of mesothorium was five and one-half years; this value has since been confirmed by Hahn[‡] by new quantitative measurements. Hahn also compared the activities of old and new thorium by means of the a-rays, the β-rays, and the emanation; the variation with age in activity of the emanation is greater than the variation in the a-ray activity. The removal of thorium-X caused a greater proportional decrease in the activity of new than in old thoria. The activity of radiothorium, when freed from thorium-X, was decreased to a smaller fraction of its original value than that of any ordinary thorium preparation similarly treated. These facts led Hahn to conclude that thorium itself has a typical a-ray activity; but he gave no estimate of its intensity.

Rutherford and Soddy[§] had observed that in the case of thorium precipitated with ammonia, its final or maximum

[*] Phys. Zeitschr., viii, 277, 1907.
[†] This Journal, xxiv, 93, 1907.
[‡] Phys. Zeitschr., ix, 246, 1908.
[§] Phil. Mag., iv, 378, 1902.

activity after one month was about four times the initial activity. McCoy and Ross* found the ratio of final to initial activity to be approximately 2·5 for various samples of thoria prepared from a commercial nitrate. The corresponding ratio for thoria prepared from minerals was about 3·2. The authors at that time considered this to prove conclusively that thorium is itself active, and estimated that the specific activity of thorium dioxide was between 100 and 130. The work here described was undertaken at the suggestion of Professor McCoy with the object of determining the *a*-ray activity of thorium itself with accuracy. A brief preliminary mention of my results was made in the paper of McCoy and Ross.

The activity of thorium itself is found from the experimental data as follows: The activity of new thorium freed from the easily separated products thorium-X emanation, thorium A, thorium B, and thorium C, is due to Th + Rt. But in the course of a month the products (Pr) accumulate in equilibrium amounts, and the activity is then due to Th + Rt + Pr. The activity of old thorium freed from the products is due to Th + xRt, where x is the fraction of the equilibrium amount of radiothorium in the sample; and after an interval of one month the activity is due to Th + x (Rt + Pr). These four relations lead to four equations by means of which the four unknown quantities, activity of Th, Rt and Pr, and the fraction x may be found. McCoy and Ross explained that the uncertainty of the data upon which their estimate was based was due to the fact that by the large number of precipitations with ammonia, which were necessary to remove the separable products, Th-X, etc., large quantities of silica and other impurities from the glass and reagents were introduced into the thorium. A further disadvantage of the ammonia method arises from the fact that Th-A, with the comparatively long period of 11 hours, is precipitated with the thorium. This makes it necessary to carry out 12 to 15 precipitations in the course of three or four days in order completely to remove the separable products.

Schlundt and Moore† found that in the precipitation of thorium by fumaric acid, according to Metzger's method for the analytical separation of thorium from other rare earths, Th-A as well as Th-X remains in the solution to a very large extent, while Th-B is carried down with the thorium. This method would therefore seem to offer an easier way to separate the active products of thorium than the precipitation with ammonia; but it had the disadvantage of requiring an expen-

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* J. Am. Chem. Soc., xxix, 1709, 1907.
† J. Phys. Chem., ix, 682, 1905.

sive reagent and the necessity of working in alcoholic solutions.
Schlundt and Moore* also found that precipitation with nitro-
benzoic acid removed some form of radio-active matter from
thorium but they did not identify the products separated.
The extensive use of meta-nitrobenzoic acid by McCoy and
Ross† in the analysis and purification of thorium minerals sug-
gested also the use of this reagent as a substitute for fumaric
acid.   It was found that the first precipitate of thorium with
meta-nitrobenzoic acid lost its activity at a much greater rate
than would correspond to the period of thorium-A.   The
minimum activity was reached in four or five hours, then an
increase due to the growth of thorium-X and its products set
in.   When the precipitate was dissolved and the thorium
reprecipitated at the end of two hours the activity was dimin-
ished still further ; and it was found that two additional pre-
cipitations at intervals of two hours gave finally pure thorium
dioxide free from thorium-X and all its subsequent products.
The activity of the oxide prepared by this method began
immediately to increase.   On account of the convenience of
working in aqueous solutions and the ease and rapidity with
which filtration takes place, the nitrobenzoic acid method
offers many advantages over the fumaric acid method, and
leaves nothing to be desired concerning purity of the product
and completeness of separation.   The precipitation with nitro-
benzoic acid was carried out in the following manner :   The
solution of thorium nitrate, containing approximately 2 grams
of thoria, was nearly neutralized with dilute ammonia, methyl
orange being used as indicator, a slight excess of a saturated
solution of nitrobenzoic acid was slowly added, and the mix-
ture kept at a temperature of 80° for a short time.   The pre-
cipitate of thorium nitrobenzoate was filtered from the solution
and washed well with water.   Two hours later it was dissolved
in dilute nitric acid, diluted to about 300^{cc}, almost neutralized
with ammonia and the thorium then reprecipitated by the
addition of 400^{cc} more of the nitrobenzoic acid solution.   The
fourth thorium precipitate was rapidly filtered from the solu-
tion, placed directly in a platinum crucible and ignited first
over a Bunsen flame and finally at the highest attainable tem-
perature of the blast lamp for ten minutes.   Four lots of
thorium oxide were thus prepared ; two from " old " material,
two from thorite.   Oxide "A" was from sample "A" of
thorium nitrate described by McCoy and Ross.‡   It had been
precipitated 100 times with ammonia and was known to be
poor in radiothorium.   It was repurified by the nitrobenzoic

* Loc. cit.
† J. Am. Chem. Soc., xxix, 1709, 1907.
‡ J. Am. Chem. Soc., xxix, 1712, 1907.

acid method and converted into the oxide by ignition. Oxide
" B " was from sample " B " of thorium nitrate described by
McCoy and Ross. It had been precipitated 40 times with
hydrogen peroxide and contained about one third of the
equilibrium amount of radiothorium. It was twice purified
by Neish's method, and finally by four precipitations with
nitrobenzoic acid, made at intervals of two hours, Samples
" C " and " D " were oxides made from thorite from Arendal,
Norway. Nine grams of the finely powdered mineral were
digested for a number of hours with concentrated hydro-
chloric acid. The chlorides were dissolved in hot water and
filtered from the insoluble residue. The thorium was then
precipitated with a boiling solution of oxalic acid and washed
free from the excess of the acid. The precipitated oxalates
were decomposed by boiling them for ten minutes with fifteen
grams of potassium hydroxide in 30^{cc} of water. The thorium
hydroxide was washed free from alkali and dissolved in dilute
nitric acid. From this solution the thorium oxide was obtained
free from thorium-X and all subsequent products by four
precipitations with nitrobenzoic acid in the manner described.

The thoria thus prepared was made into films, 7^{cm} in
diameter, as quickly as possible by Boltwood's method,[*] paint-
ing the paste onto a metal disc with a camel's-hair brush.
Owing to the rapidity with which the activity of the thoria
increased, the slower sedimentation process,[†] which yields
more uniform films, could not be used. However, the error
due to lack of uniformity was doubtless negligible since one
set of films, " D_1," made by the sedimentation process gave the
same maximum specific activity, 948, as did the painted films
from the same material ; see Table I. Activity measurements
were made in the manner described by McCoy and Ross,[‡] and
with the same electroscope.[§] From five to eight films were
made from each sample ; the films were made thin, 0·2 to 7 mg.
per square cm., in order to avoid errors due to the evolved
emanation in the case of material containing the equilibrium
amount of Th-X.[‖]

In order to find the activity of the thorium oxide at the
time zero, i. e., at the moment when thorium-X and its prod-
ucts were completely removed from it, the activity of each
film was measured at intervals of a few hours during the first
day after its preparation. The increase of activity with time
was plotted and the activity at time zero found by extending
the curve back to the ordinate for zero time as illustrated in

* This Journal, xxv, 269, 1908.
† McCoy, J. Amer. Chem. Soc., xxvi, 391, 1905.
‡ Loc. cit.   § This Journal, xxvi, 521, 1908.
‖ McCoy and Ross ; this Journal, xxi, 433, 1906.

the accompanying curve, which represents a film of sample
" D." The activities are in terms of the U_3O_8 standard, which
had an activity of 35·0 units. This correction was necessary
as the time intervening between the last precipitation of the
thorium and the first activity measurement was usually one to
two hours.

Fig. 1.

Time in Hours.
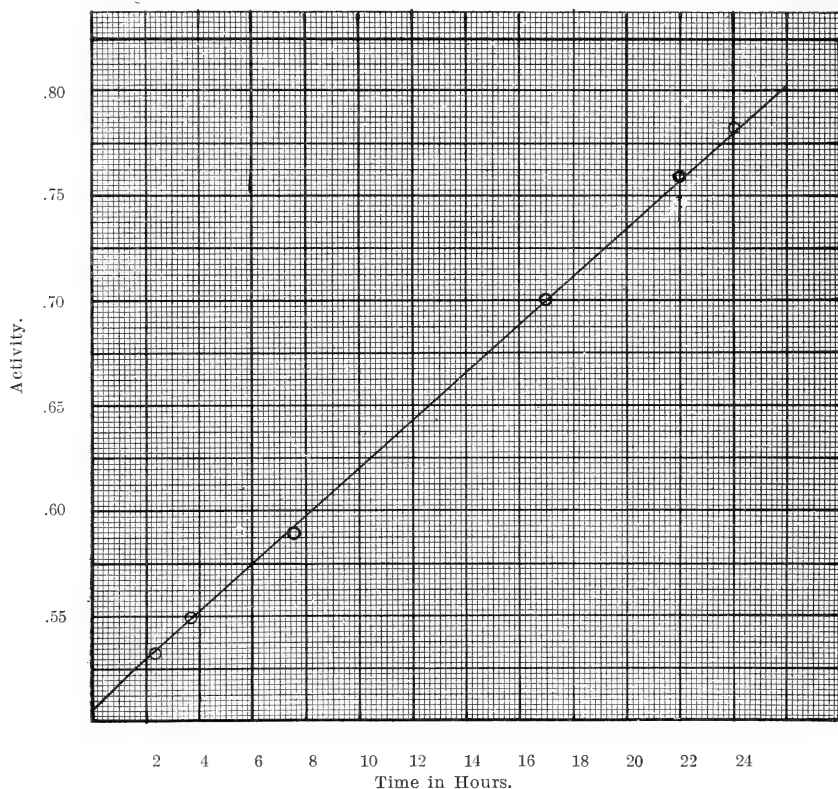
Table I gives the results obtained from the four samples of
oxide.

TABLE I.

Sample	Date of preparation*	Minimum activity	Date of Measurement of maximum activity	Maximum activity
"A"	Aug. 28	167	Oct. 1	400
"B"	Oct. 19	167	Nov. 21	380
"C"	Aug. 29	286	Oct. 4	921
"D"	Oct. 23	292	Nov. 23	948
"D "	Oct. 23	——	Nov. 23	948

* All dates refer to the year 1907.

From these figures the specific activity of thorium alone can be calculated. The average value of the specific activity of thorium dioxide plus radiothorium and its products given by samples " C " and " D " is 939. That of thorium plus radiothorium obtained from the same samples is 289. Therefore that of the products alone is 650. From samples "A" and " B " the value of the activity of Thx (Rt + Pr) is found to be 390. That of Th + x (Rt) is 167 : therefore xPr is 223 and x = 0·3446. Since Th + Rt = 289 it follows that Rt = 185, and therefore the specific activity of thorium dioxide is 104, or that of thorium is nearly 119.

Taxing the period of mesothorium as 5·5 years and that of radiothorium as 737 days, McCoy and Ross* have shown that it is possible to calculate the activity of a sample of thorium dioxide at any time, t, after the separation of all the mesothorium, thorium-X and its products. The maximum activity of sample "A," Oct. 1, 1907, was 400. On Feb. 27, 1908, 149 days later, it was 346. In this interval of time the radiothorium present on the former date would decay to $e^{-149\lambda_2} = 0\cdot869$, where λ_2 is the disintegration constant of radiothorium, and the products of radiothorium would disappear in the same proportion. The specific activity of thorium dioxide itself is 104. If no radiothorium had been formed from the new mesothorium produced from thorium during the interval of 182 days between the date of preparation of the oxide, Aug. 28, 1907, and Feb. 27, 1908, the activity would have been 0·869 (400 − 104) + 104 = 361. The activity of the equilibrium amounts of radiothorium and all its products is 835. Now some radiothorium must have been produced from the mesothorium formed from thorium during the interval 182 days ; the activity thus gained, according to the formula of McCoy and Ross, would be

$$836 \left\{ 1 - \left[\frac{\lambda_2}{\lambda_2 - \lambda_1} \left(e^{-\lambda_1 t} - e^{-\lambda_2 t} \right) \right] - e^{-\lambda_2 t} \right\} = 4.$$

The calculated specific activity on Feb. 27, 1908, is therefore 361 + 4 = 365. The observed activity was 346. Table II gives the activities observed and calculated of samples "A," " B " and " D " on various dates since their preparation.

TABLE II.

Sample	Date of preparation 1997	Date and max. activity 1907		Date and activity 1908 Obs. Cal.			Date and activity 1908 Obs. Cal.		
"A"	Aug. 28	Oct. 1	400	Feb. 27	346	365	Aug. 26	308	336
"B"	Oct. 19	Nov. 21	380	Feb. 27	346	359	Aug. 29	308	331
"D"	Oct. 23	Nov. 23	948	Apr.	841	854	Aug. 28	767	765

* Loc. cit.

It is seen that in the case of sample " D " the observed and calculated activities agree quite closely. The discrepancies are probably due mainly to errors of experiment. In samples "A" and " B " the calculated activity is somewhat greater than the observed activity, for which there is no adequate explanation. The quantitative changes with time in the activity of thorium and its products would be effected to a slight extent by the presence of actinium or ionium* in the thorium extracted from uranium-bearing minerals ; but, as the percentage of uranium in the mineral used was not determined, the magnitude of this effect can not be calculated.

The more important results of this investigation may be given as follows : An expedient method for separating thorium and radiothorium from the other disintegration products of the element has been described. Additional evidence has been obtained which supports the view that thorium on disintegrating emits an *a*-radiation. The specific activity of thorium is about 119 ; this is 11 per cent of the activity of the same thorium when equilibrium amounts of its disintegration products are present. Of the remaining activity 20 per cent is due to radiothorium and 69 per cent to Th-X, and subsequent products. The activity ascribed to thorium itself is too much in excess of the activity of the ionium associated with thorium in minerals to warrant the conclusion that the observed activity of thorium is due wholly or largely to the presence of ionium. The earlier conclusions of Hofmann, and of Baskerville and Zerban, that thorium itself is inactive, were without doubt due to the fact that the methods used were not sufficiently refined to detect the low activity of the element free from its short-lived active products, and other radio-active impurities.

* Boltwood, this Jour., xxv, 269, 1908.

Kent Chemical Laboratory,
University of Chicago,
October, 1908.

Art. VI.—*Coronas with Mercury Light;* by C. Barus.

1. *Preliminary Survey.*—The inferences of the preceding papers* gave promise that on judiciously using monochromatic light as the source of illumination, the optical nature of the coronas might be fully brought out. Such light must be strictly homogenous and at the same time very intense. Hence the usual methods of obtaining it are unsatisfactory. The strong green line of a mercury lamp, however, fulfills the requirements admirably, and this was therefore used. The results show that the green disc and the first green ring alternately vanish as the result of the interference phenomenon superimposed on the diffraction phenomenon. If therefore the nucleation of a highly charged medium is systematically reduced, a series of angular diameters may be obtained both for the green disc and the inner or outer edge of the first green ring. From the loci of these values the position of the *first diffraction minimum* for green light may be inferred, and the size of droplets computed from the usual equation for small opaque particles.

If the reduction of the nucleation is accomplished by successive partial exhaustions, all of them identical, while filtered air is allowed to enter the receiver systematically between the exhaustions, the nucleations of any two consecutive exhaustions should show a constant ratio. Allowances must, however, be made for the subsidence during the later fogs and for time losses, if any. This is the method used hitherto in my work and the results seem to have been trustworthy.

In the case of mercury light, however, it is now possible to compare the latter with the former (diffraction) method of obtaining the diameters of particles, with a view to throwing definite light on the optical phenomenon. Subsidence methods are out of the question for large coronas, as these are invariably fleeting in character and pass at once into smaller coarse coronas.

The results of the two methods may be regarded as coincident as long as not more than 300,000 nuclei per cubic centimeter, or diameters of particles not smaller than $\cdot0003^{cm}$ are in question. For larger numbers and smaller diameters the divergence rapidly increases. Indeed, for particles larger than the size given, the optical loss per exhaustion exceeds the exhaustion ratio, a result which is satisfactorily explained by the cotemporaneous subsidence of these relatively large particles. For particles smaller than the limit in question, the loss

* This Jour., xxv, p. 224, 1908; xxvi, p. 87, 1908; xxvi, p. 324, 1908.

computed by the optic method is larger than the exhaustion loss, as if fresh nuclei were produced, or rather made available at each exhaustion. It is this result which the present paper purposes to bring out in detail and to consider in its bearings on the optical phenomenon.

2. *Apparatus.*—The fog chamber was of the usual pattern, cylindrical in form, with its axis horizontal. The clear walls being of blown glass showed some refracting disturbances, not however of serious character. The fog chamber was connected with a large vacuum chamber by a short, wide passage way, though width is of little consequence here. The cylinder was lined with wet cloth, closely adhering, except at the narrow horizontal windows for observation.

For exhaustion this stopcock was suddenly opened at the beginning of the first second, closed after five seconds and the corona quickly measured. Filtered air was then at once introduced and the next exhaustion made at the beginning of the sixtieth second. This rhythm is essential. The isothermal value of a drop of pressure $[\delta p_2]$ was carefully predetermined. It fixes the ratio, y, of the geometric progression of nucleation, since

$$y = (p - \pi - [\delta p_2]) / (p - \pi)$$

where p is the barometric pressure and π the vapor pressure at the given temperature. If the cock were left open for a longer time than five seconds, $[\delta p_2]$ would increase to the limit δp_3.

The goniometer was of the usual type, the eye being at the center or apex, while two needles on radii 30^{cm} long registered the angular diameter of the coronal discs or annuli. Formerly the whole instrument was placed on the *near* side of a fog chamber, the eye being about 30^{cm} from the nearest wall. It conduces to much greater sharpness of vision, however, and admits of a measurement of larger coronas, *caet. par.*, if the eye is placed all but in contact with the nearer wall and the needles (or in this case preferably the inner edges of round rods) beyond the further wall. In such a case the refraction errors are also diminished. In addition to these advantages I may mention the decidedly increased (about 25 per cent) value of the aperture obtained. These excessive apertures show, however, that the ordinary diffraction equation for coronas is not fully applicable ; for aperture varies with the position of the eye along the line of sight. It is often surprising how large a corona can be measured by the second method in a small fog chamber, scarcely six inches long. The distance between lamp and chamber is kept about $D = 250^{cm}$.

3. *Equations.*—The equations needed in the present work are derived in my last Report,[*] and need merely be summarized

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[*] Carnegie Publications, No. 96, 1908, Chapters I, III (equat. 1 to 12).

here. If y is the exhaustion ratio, the nucleation n_z of the zth exhaustion in terms of the original nucleation n_0 will be

$$n_z = n_0 y^z (1 - S/s_0^2) (1 - S/s_1^2) \dots (1 - S/s_{z-1}^2)$$

where S is a subsidence constant and s the chord of the angular diameter of the coronal disc on a radius of 30^{cm}.

To find S, two consecutive values of s suffice, or

$$S = s_z^2 (1 - s_{z+1}^3 / y s_z^3)$$

approximately. The diameter of particles, d, is in terms of n,

$$d^3 = 6m / \pi n$$

If $\lambda = 54 \cdot 6 \times 10^{-6}$ cm. is the wave length of green mercury light and θ the angular radius of the first green minimum of the coronas

$$\sin \theta = \cdot 61 \lambda / (d' / 2). \quad \text{Since } \sin \theta = s / 2R,$$

R being the radius of the goniometer of which s is the chord, d' the diameter of fog particle (the primes referring to optic measurements)

$$d' = \cdot 004 / s$$

for mercury light. Hence, optically, the nucleation

$$10^{-6} n_z' = 29 \cdot 8 \, ms^3,$$

where m grams of water are precipitated per cubic centimeter on exhaustion, and found in the exhausted fog chamber.

4. *Data with green mercury light,* $10^6 \lambda = 54 \cdot 6^{cm}$.—Omitting the correlative data with white light and removing all tables for lack of space, the charts figure 1 contain results obtained with a mercury arc lamp as the source of light. Different annuli are measured and the chords, s, on a radius of 30^{cm} are distinguished by accents, as follows:

s' is the chord of the green disc,
s'' is the chord of the inner edge of the first green ring,
s''' is the chord of the outer edge of the first green ring.

The edges are fairly sharp. Hence

$$s = (s' + s'') / 2$$

may be taken as the chord of the first green minimum. Optically the diameter of the particle is then $d' = \cdot 004/s$.

The water precipitated per cubic centimeter, m, differs with the drop of pressure, $\delta p_3/p$, and the temperature. In the successive parts of the chart the data are

Parts I, II,	$10^6 m = 4 \cdot 1$ grams,	$n' = 122 \, s^3$ (omitted)
Parts III, IV,	$= 4 \cdot 12$ grams,	$n' = 123 \, s^3$
Parts V–VIII,	$= 4 \cdot 02$ grams,	$n' = 120 \, s^3$

where n' is the optical value of the number of nuclei per cubic centimeter.

In parts I–IV the angular diameter, s', of the green discs

Fig. 1.
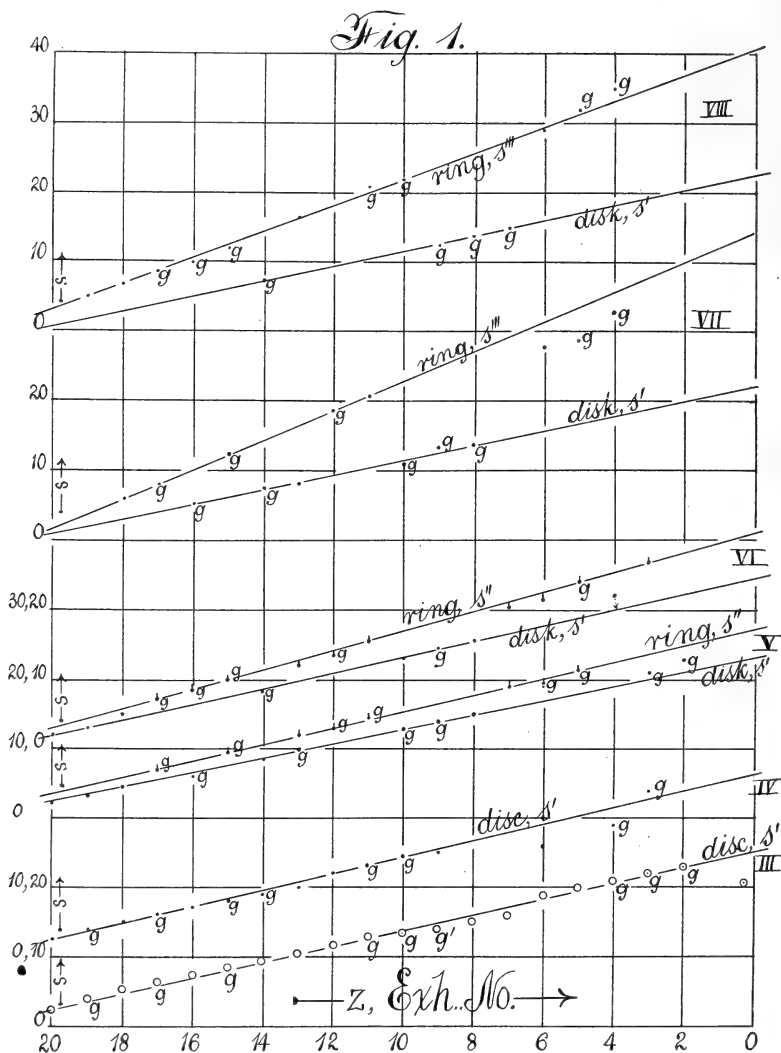
only were measured. The diameter s of the corresponding first minims may, however, be obtained by using the method of reduction found in parts V and VI where $s = {\cdot}44 + {\cdot}85\ s'$.

In parts V and VI the data for s' and s'', the angular diam-

eter of the inner edge of the first ring, are both observed, while in parts VII and VIII data for s' and s''', the outer diameter of the first ring, appear.

In parts I and II (omitted) the goniometer was in front of the fog chamber, and in series I a two-minute interval between exhaustions was (exceptionally) introduced. The result is not good; for a sudden break of the curve appeared after the seventh exhaustion, probably due to the time losses in the extra minutes. The reason, however, is by no means obvious. In series II, for one minute intervals there was no break and the locus passing through the points for green discs (the others, not marked g, are here and elsewhere to be disregarded) is persistently straight throughout. The curves show

For series I, $ds / dz = 1{\cdot}00$, and
For series II, $ds / dz = {\cdot}80$,

suggesting a time loss in the first case.

Compared with the preceding table, the values of ds/dz should be in the ratio of red and green minims, or

$$ds_r / dz : ds_g / dz = {\cdot}95 / {\cdot}80 \text{ correspond to } \lambda_r / \lambda_g = 63{\cdot}0 / 54{\cdot}6 \; ;$$

the last ratio, $1{\cdot}15$, is somewhat short of the former, $1{\cdot}19$.

In series III and IV the pins of the goniometer are behind the fog chamber, the eye being at the front wall. In series III the relation,

$$s' = 2{\cdot}30 + 1{\cdot}15 \; (19\text{—}z)$$

is remarkably well sustained throughout; and in series IV

$$s' = 2{\cdot}50 + 1{\cdot}13 \; (18\text{--}z)$$

gives a good account of the green coronas, if the dull cases are ignored.

The most interesting results are given in parts V and VI of figure 1, and in the subsequent paragraphs the computations have been fully carried out. In these cases the chords on a radius of 30^{cm} of the edge of the green disc, s', and the inner edge of the first green ring, s'', were successively observed. Figure 1 contains both pairs of curves and their linear character is again astonishing. We may write

Part V, $s'=2{\cdot}0+1{\cdot}10 \; (19-z)$,   Part VI, $s'=2{\cdot}0+1{\cdot}13 \; (18-z)$,
$\quad s''=3{\cdot}4+1{\cdot}21 \; (19-z)$, $\quad s''=3{\cdot}3+1{\cdot}30 \; (18-z)$,
$\quad s={\cdot}59+1{\cdot}06s'=-{\cdot}56+{\cdot}96s''$, $\quad s={\cdot}50+1{\cdot}07s'=-{\cdot}44+{\cdot}93s''$,

where the minimum is located midway-between s' and s'', both of which are fairly sharp.

From both series the mean value

$$s = {\cdot}55 + 1{\cdot}06 \; s' = -{\cdot}50 + {\cdot}93 \; s''$$

may be derived, for the general reductions in this and other cases where s' is observed. The individual data are omitted.

With the given value for s the optical data for the diameters of the particles, $d' = \cdot004/s$ and for the nucleation, $n' = 120\ s^3$, were computed.

The subsidence constant

$$S = s_z^2 \left(1 - s_{z+1}^3 / y\ s_z^3\right)$$

was obtained from the observations between $z = 13$ and $z = 19$, and a mean datum, $S = 12$, accepted as most satisfactory. It is then possible to compute n_o, the original nucleation, as

$$n_o = n_z / \{y^z (1 - S/s_o^2) \ldots (1 - S/s_{z-1}^2)\}$$

from each of the groups of values specified. The mean results are

$$\text{Part V,} \quad n_o = 4\ 540\ 000$$
$$\text{Part VI,} \quad = 3\ 430\ 000.$$

Knowing n_o, the series of data for the nucleation $n \times 10^{-3}$ follow; from these the diameter $10^4 d = 199\ n^{-\frac{1}{3}}$ of fog particles and the apertures $s = \cdot004/d$ are finally computed. In other words n and d are the data obtained in view of the occurrence of geometric series of nucleations with allowance for subsidence.

All these results have been constructed graphically in figures 2 and 3, for parts V and VI of the above charts respectively. The observed and computed apertures s are first given; then the observed are optically computed d' and the computed d from sequences appear, and finally the observed or optic n' and the computed nucleation n from sequences. The corresponding data coincide very closely after 9 to 11 exhaustions, i. e. for moderately small coronas: but in the case of large coronas and nucleations, there is marked systematic divergence. A discussion of these results will be given presently.

Finally, parts VII and VIII of fig. 1 contain measurements of the chord of the angular diameter (radius of goniometer of 30^{cm}) of the outer edge of the green disc s' and the outer edge of the first ring s'''. The minimum may be deduced from s', since $s = \cdot54 + 1\cdot06s'$ has been accepted. From s the optic value of diameter of fog particle d' and the nucleation n' have been computed. The apertures are very fully given in figure 1, in relation to the number z of the exhaustion. The curves are again linear in character, but in case of the outer edge s''', the insufficient size of my fog chambers and the greater vagueness of definition interferes with close measurement. The results are

Part VIII $s' = 1\cdot00 + 1\cdot07\ (18 - z)$, part VII $s' = \cdot50 + 1\cdot13\ (17 - z)$,
$\quad\quad\quad s''' = 3\cdot00 + 1\cdot93\ (18 - z)$, $\quad\quad\quad s''' = 1\cdot50 + 2\cdot13\ (17 - z)$,
$\quad\quad\quad s = 1\cdot61 + 1\cdot14\ (18 - z)$, $\quad\quad\quad s = 1\cdot08 + 1\cdot20\ (17 - z)$.

As a rule s''' is less than twice s'. The data for s' and s are obtained alternately as the figure shows, the green color passing from the disc of the first ring and returning again, in succession.
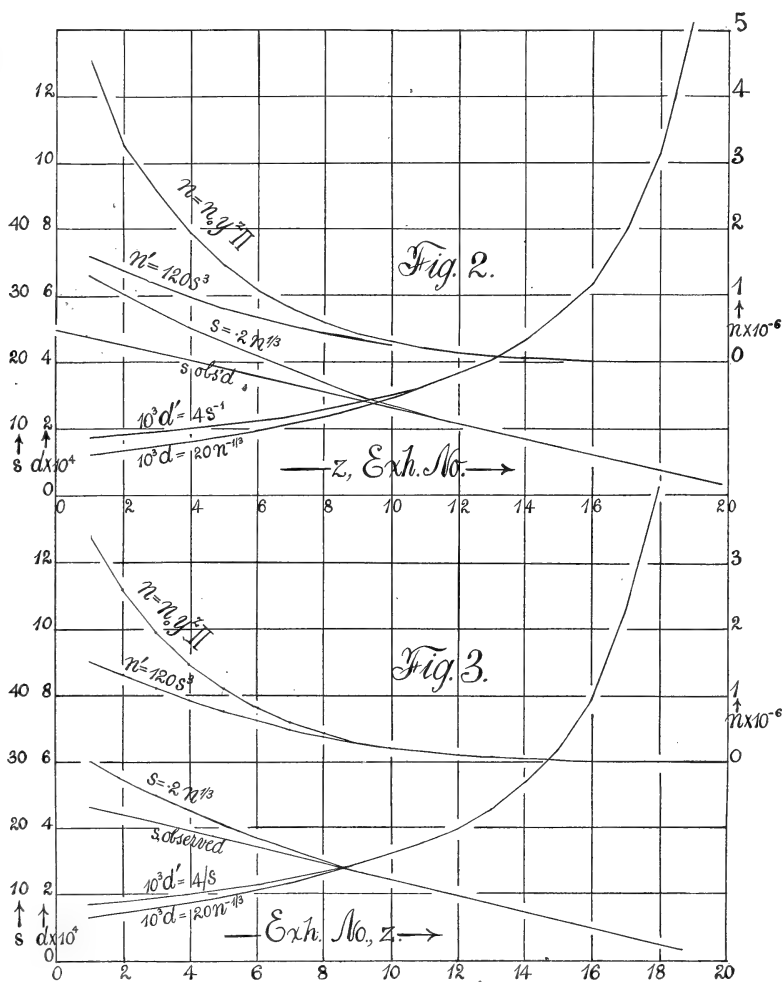
Inferences.

5. *Interference and diffraction.*—The tables and chart show in the first place, that the disc and first ring of the coronas are alternately of a vivid green, other colors being dull because the remaining lines of the mercury spectrum are faint. At inter-

vals neither disc nor ring are quite green. Hence there is a periodic term impressed on the diffractions, which may be identified as an interference similar to the case of the lamellar grating referred to in another paper.*

When monochromatic light is used it is necessary, therefore, to observe both the edge of the disc and the inner edge of the first ring; for neither appear vividly at the same time. The chord s on a radius of 30^{cm} for the minimum in terms of the corresponding chords s' and s'', of the first and second edges specified, may then be written.

$$s = \cdot 55 + 1 \cdot 06 \; s',$$
$$s = -\; \cdot 50 + \cdot 93 \; s''$$

Probably the ratio s/s' and s/s'' should be constant and the absolute term in these equations is an error of observation; but as it is small, little depends upon it, millimeters only being significant.

If we summarize all the observations for ds/dt, the agreement as a whole is in keeping with the nature of the observations and reasonably satisfactory. Thus, in

Series I, II, $d's/dz = \cdot 90,$ } $s = \cdot 44 + \cdot 85 \; s'$ (goniometer in front),

$$
\begin{array}{ll}
\text{III,} & 1\cdot15, \\
\text{IV,} & 1\cdot13, \\
\text{V,} & 1\cdot10, \\
\text{VI,} & 1\cdot13, \\
\text{VII,} & 1\cdot13, \\
\text{VIII,} & 1\cdot07, \\
\end{array}
$$
$s = \cdot 54 + 1 \cdot 06 \; s'$ (goniometer behind), mean $ds'/dz = 1 \cdot 12$.

The feature of these data is the occurrence of linear loci for s and z nearly throughout the extent of the curves. It is as difficult to even conjecture a reason for this, as it is easy to find reasons against it. The presumptive equation for s is

$$s = \cdot 004 \; (\pi/6m)^{\frac{1}{3}} \; n^{\frac{1}{3}}, \propto 3\sqrt{n}$$

and for n'_z if Π denotes the product,

$$n_z = n_0 \, y^z \Pi.$$

Hence,

$$s = \cdot 004 \; (\pi n_0/6m)^{\frac{1}{3}} \; (y^z \, \Pi)^{\frac{1}{3}}$$

if we disregard the subsidence correction for large coronas

$$ds/dz \propto y^{z/3}$$

in which there is no suggestion of a sustained constancy of the coefficient ds/dz such as the experiments show.

To come to some conclusion as to the cause of the discrepancy between the optic value of the nucleation n' and the presumable value n (geometric progression), we may compare the

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* This Journal, xxv, p. 224, 1908.

successive value $n'_{z+1}/n'_z = s^3_{z+1}/s^3_z$ in their relation to $y = \cdot 771$ the exhaustion applied. The table shows that for very large coronas $n'_{z+1}/n'_z > y$, whereas for very small coronas $n'_{z+1}/n'_z < y$. For the intermediate coronas (g_3), i. e., from the seventh to the tenth exhaustion among twenty, the ratio is nearly equal to y. Ratios smaller than y may be reasonably interpreted as due to subsidence and the constant S is actually of the order of values to be computed from the viscosity of the medium and the size of the vessels and fog particles. Within this range (coronas smaller than g_3) the optic and the presumptive nucleation may in fact be brought into agreement.

In case of the large coronas, however, subsidence is virtually absent and the occurrence of $n'_{z+1}/n_z > y$ calls for some apparent production of nuclei at each exhaustion, which is altogether improbable. Therefore, fig. 2 and 3, compare n' and n, whence $n\text{-}n'$ shows the number of nuclei not registered by condensation.

For, no matter whether condensation on a given group of nuclei occurs or not, no matter how many nuclei have failed of catching a charge of water, the identical removal of nuclei by partial exhaustion must take place. Such removal is independent of condensation, and would occur in a dry atmosphere under similar treatment. Consequently y cannot be too large. It may be too small not only from subsidence, but from time losses (decay), or as the result of the purification of air due to turbulent motion across a solid or liquid surface. Consequently n may be regarded as an inferior limit of the nucleation with a probably close approximation to the true value. A comparison of n and $n\text{-}n'$ would, in such a case, show the percentage of nuclei of irregular size which have failed of capture, the number being $n\text{-}n'$.

At the same time it must always be recalled, that no adequate theory of coronas exists and that therefore the meaning of n' is obscure. We must in any case place a part if not all the discrepancy between n and n' within the province of such a theory as is evidenced by the dependence of aperture on the position of the eye. The need is particularly manifest for the large coronas, in which there is accentuated superposition of interference and diffraction. Small coronas may be tested by coincident results obtained from subsidence and the agreement is then well within the errors of observation.

Brown University,
    Providence, R. I.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *An Attempt to Produce a Compound of Argon.*—Assuming that any compound which argon might form would be endothermic, and would hence require a large amount of energy and a high temperature for its production, and assuming also that such a compound would need to be quickly cooled in order to prevent its decomposition, FISCHER and ILIOVICI have passed electric sparks, as well as the electric arc, between poles of cadmium in liquid argon. Cadmium was selected for these preliminary experiments on account of the fact that Kohlschütter and Müller had found that the pulverization of cadmium by the electric discharge was abnormally great in argon gas, as compared with other gases. The argon was prepared from atmospheric air by the absorption of the other gases by means of calcium carbide. An elaborate apparatus was devised for carrying out the experiments, in which it was found necessary to keep the argon at a pressure near that of the atmosphere, for liquid argon boils at $-189 \cdot 6°$ C. under a pressure of 760^{mm}, while it solidifies only $2 \cdot 70$ below this point, and below a pressure of 500^{mm} liquid argon does not exist. As a result of the passage of electric sparks and the arc through this liquid there was produced a new compound, cadmium nitride, due to traces of nitrogen in the argon used. This nitride, which was mixed with pulverulent metallic cadmium in the product produced by the arc, gave off nitrogen when heated in a vacuum, and this nitrogen was found to contain a considerable amount of argon. The authors consider this argon as due to adsorption, but propose to continue their experiments under different conditions.—*Berichte*, xli, 3802.

H. L. W.

2. *Explosive Crystallization.*—Having occasion to evaporate a solution containing a sulphate and a thiosulphate enclosed in a bell-jar under a diminished pressure of about 20^{mm}, WESTON found that an apparent explosion violent enough to break the bell-jar had occurred during the night, when the liquid had become very concentrated. Soon afterwards he attempted to crystallize two solutions of a sulphite, which were probably supersaturated, under the same conditions. In this case he saw a part of the contents of one of the dishes violently ejected so that the dish was broken, the other dish was upset, and the whole apparatus was so shaken that the glass plate upon which the bell-jar rested was broken. The author is of the opinion that crystallization was suddenly induced on the surface of the basin with a consequent sudden increase in the vapor-pressure of the surrounding liquid, which under the very low pressure existing in the bell-jar

caused the liquid to boil violently. It appears to the reviewer that this explanation overlooks the chief cause of the sudden boiling, namely, the great amount of heat that is set free by the sudden crystallization of a large amount of salt from a supersaturated solution. This sudden warming under low pressure and the presence of much solid salt in the liquid explain satisfactorily these interesting accidents. — *Chem. News*, xcviii, 27.   H. L. W.

3. *Constituents of Ytterbium.*—AUER VON WELSBACH, whose work on the rare earths is well known, particularly his splitting up of old didymium into neodymium and praseodymium, has succeeded in obtaining two earths from ytterbium. This was done by long continued fractionation, particularly of the ammonium double oxalates. He has named the new elements, Aldebaranium and Cassiopeium, Ad and Cp. Their distinguishing feature is in their spark spectra. Their reactions are those of ytterbium, and they cannot be distinguished from one another by any chemical reactions. They form only one oxide, the sesquioxide, which is stable at a red heat. All the salts are colorless if the acid is not colored. The atomic weights found were 172·90 for Ad and 74·23 for Cp. The cassiopeium was not obtained absolutely free from the other earth, but it is the author's intention to repeat the separation with a larger amount of material in order to obtain purer cassiopeium, which he designates as the last in the series of rare earths. It will take six or eight years to complete this tedious task. — *Monatshefte*, xxix, 2.   H. L. W.

4. *A New Form of " Tin Infection."*—It has been known for a long time that metallic tin at low temperatures is subject to a physical change which renders it grey and very friable. For instance, it is said that the tin buttons on the uniforms of Napoleon's soldiers in the Russian campaign fell to pieces. This behavior was formerly attributed to the simple action of low temperature, but in recent times it has been shown that it is due to a recrystallization which can be communicated to any piece of tin at a low temperature, by contact with an affected piece of tin, or, as it may be termed, by inoculation. It has been recently observed by VON HASSLINGER that a piece of tinware soldered with tin which had been stored for two years in a place which was always heated in winter showed a dull surface, a crystalline structure under the microscope, and a friability corresponding to the change that usually takes place only at low temperatures. It was found further that this material was capable of inoculating unchanged tin, either in the form of ordinary tin plate, tin foil or cast tin, at such temperatures as 7°, 19° and 37° C. The growth of the infected spots of nearly circular form was at the rate of from 3 to 5^{mm} per day, but it was noticeable that this growth became slow as it extended farther from the inoculated center.— *Monatshefte*, xxix, 787.   H. L. W.

5. *The Heat Evolved by Radium.*—A new determination of this constant has been made by VON SCHWEIDLER and HESS, with the result that 118·0 gram-calories per hour were found. Previ-

ous observers have obtained results varying from 100 to 134 in the same terms. The material used consisted of 1·0523g. of radium-barium bromide, corresponding to ·7951g. of radium. The method used was that previously employed by Angström for the same purpose. It consisted in placing the radium in a calorimeter, and keeping a second, exactly similar, calorimeter at the same temperature by an electrically heated wire of known resistance. The elevation of temperature thus produced in the calorimeters amounted to 5·5° C. At first only 40 per cent of the expected heating was produced, probably on account of the escape of some emanation before the beginning of the experiment, but this increased from day to day. The radium employed was in equilibrium with its decomposition products of short period, but its contents of the products from radium D to radium F was uncertain.—*Monatshefte*, xxix, 853.   H. L. W.

6. *Positive Rays.*—W. Wien arranged an apparatus which enabled him to transmit the canal rays some distance through a capillary tube which was exhausted by means of charcoal and liquid air to a low vacuum. He concludes from his observations that the particles in the canal rays which are least influenced by a magnetic field are those which carry the light emission. Moreover, the condition of equilibrium of particles of equal weight—which may be destroyed by a magnetic field—reasserts itself during the length of path of the rays. The length of this path increases with higher potentials.—*Physik. Zeitschrift*, No. 22, Nov. 1, 1908, pp. 765–767.   J. T.

7. *Spectral Intensity of Canal Rays.*—The observers of the Doppler Effect in canal rays in hydrogen agree that the displacement observed is a band which is separated from the hydrogen line by a space showing no band. J. Stark and W. Stenberg select the method of viewing the hydrogen line at right angles to the direction of the canal rays, in order to determine its changes in intensity. No Doppler effect of course is seen, but the photometric measures indicate the changes in velocity of the positive particles. They state that the intensity of the canal rays depends upon their velocity. They also find a minimum intensity in the Doppler effect.—*Ann. der Physik.*, vol. xxvi, 1908, pp. 918–926.   J. T.

8. *Canal Rays.*—J. Stark discusses the bearing of modification of the electromagnetic theory of light upon the phenomena of canal rays, especially Planck's theory of electrical resonators, and Einstein's discussion of *Lichtquantenhypothese*, and believes that this latter hypothesis must stand or fall with further observations of the canal rays.—*Physik. Zeitschrift*, No. 22, Nov. 1, 1908, pp. 767–773.   J. T.

9. *Potential Measurements in the dark Cathode Space.*—W. Westphal has confirmed Prof. J. J. Thomson's theory that the cathode rays are due to impacts of positive particles impinging through the cathode space upon the cathode, and shows, also, that measurements of this potential by means of sounding wires

does not introduce an appreciable error. He finds that Poisson's equation is applicable to electric discharges through a gas.—*Ann. der Physik,* No. 13, 1908, pp. 571–588. J. T.

10. *The Elements of Physics; Vol. II, Electricity and Magnetism ;* by E. L. NICHOLS and W. S. FRANKLIN. New edition, pp. vii + 303, with 196 figures. New York, 1907 (The Macmillan Co.).—This edition of the second volume of Nichols' and Franklin's Elements of Physics has been entirely rewritten. No statement is made here, however, concerning a new edition of the other volumes, nor have we seen any announcement elsewhere.

The most salient feature of the new edition is the discarding of the traditional treatment of electrostatics, beginning with electrostatic attraction and the definition of the electrostatic unit of charge. The authors say: "It seems better to approach this subject from the standpoint of the ballistic galvanometer, inasmuch as, when so developed, the theory of electrostatics is a logical continuation of the foregoing theory of the electric current." "Most students begin electrical theory at both ends and never reach the middle."

The columns of mechanical and electrical analogies at the end of Chapter VII and at the beginning of Chapter XVI are interesting and complete. At the close of the book a list of 145 well-selected problems is given. The volume as a whole is attractively executed and reflects credit both on the authors and on the publishers. H. S. U.

11. *A Text-Book of Physics ;* edited by A. W. DUFF. Pp. xi + 680, with 511 figures and 225 problems. Philadelphia, 1908 (P. Blakiston's Son & Co.).—This volume is a new departure in the writing of college text-books, in that seven experienced teachers have contributed to its production. The various divisions of the subject and the authors responsible for them are as follows : Mechanics, pp. 1-177, written by A. W. Duff; Heat, pp. 179-281, by K. E. Guthe; Wave Motion and Sound, pp. 283-328, by W. Hallock; Light, pp. 329-474, by E. P. Lewis; Electricity and Magnetism, pp. 475-630, by A. W. Goodspeed; Conduction of Electricity through Gases and Radio-Activity, pp. 631-666, by R. K. McClung.

An obvious danger attendant upon each contributor writing about his special field is that of his treating the subject at such length as to weaken in the student's mind the contrast between the fundamental facts and those of less significance. In other words, too much detail tends towards a dead level of the special branch under discussion. This danger does not seem to have been successfully avoided, in spite of the fact that the sections written by each author were freely criticized by his six collaborators. This objection is especially pertinent to the chapters on Light. In the preface the suggestions are made: "Some may find the material included in the book too extensive for a single course. If so, a briefer course can be arranged by omitting all of the parts in small print together with as much of those

in large print as may seem desirable." This is unquestionably true from the theoretical standpoint, but we have found by experience that, in general, much culling out of paragraphs is not conducive to the best results on the part of the student.

The processes of the differential and integral calculus are used only in the small-print paragraphs and the notation of infinitesimals occurs very infrequently in the large-type articles. Nevertheless, several useful formulæ, which in their less rigorous, algebraic clothing are very useful in numerical examples, occur only in the small-print paragraphs in conjunction with the more rigorous, calculus expressions for the same laws.

The problems are not numerous and are grouped at the ends only of the chief divisions of the entire subject to which they appertain. The percentage of rather poorly drawn, shaded figures is appreciably greater in this volume than is usually the case with recent books of college grade. H. S. U.

II. Geology.

1. *Publications of the United States Geological Survey,* GEORGE OTIS SMITH, Director.—Recent publications of the U. S. Geological Survey are noted in the following list (continued from p. 402 of vol. xxvi) :

TOPOGRAPHIC ATLAS.—Thirty-five sheets.

FOLIO No. 161. Franklin Furnace Folio, New Jersey. Description of the Franklin Furnace Quadrangle ; by A. C. SPENCER, H. B. KÜMMEL, J. E. WOLFF, R. D. SALISBURY, and CHARLES PALACHE. Pp. 27, with 6 maps, columnar sections, 15 figures.

BULLETINS.—No. 347. The Ketchikan and Wrangell Mining Districts, Alaska; by FRED EUGENE WRIGHT and CHARLES WILL WRIGHT. Pp. 210 ; 12 plates, 23 figures, 3 maps in pocket.

No. 349. Economic Geology of the Kenova Quadrangle, Kentucky, Ohio, and West Virginia ; by WILLIAM CLIFTON PHALEN. Pp. 158, 6 plates, 21 figures.

No. 351. The Clays of Arkansas ; by JOHN C. BRANNER. Pp. 247 ; 1 plate, 20 figures, 1 map in pocket.

No. 352. Geologic Reconnaissance of a Part of Western Arizona ; by WILLIS T. LEE. With notes on the Igneous Rocks of Western Arizona; by ALBERT JOHANNSEN. Pp. 96 ; 11 plates, 16 figures.

No. 355. The Magnesite Deposits of California ; by FRANK L. HESS. Pp. 67, 12 plates, 4 figures.

No. 357. Preliminary Report of the Coalinga Oil District, Fresno and Kings Counties, California ; by RALPH ARNOLD and ROBERT ANDERSON. Pp. 142, 2 plates, 1 figure.

No. 362. Mine Sampling and Chemical Analyses of Coals tested by the United States Fuel-testing Plant, Norfolk, Va., in 1907 ; by JOHN SHOBER BURROWS. Pp. 23.

No. 369. The Prevention of Mine Explosions, Report and Recommendations; by VICTOR WATTEYNE, CARL MEISSNER and ARTHUR DESBOROUGH; with letter of transmittal by J. R. GARFIELD. Pp. 11.

Also 341-A. Advance chapter on the Coal Fields of North Dakota and Montana from Bulletin 341, Contributions to Economic Geology, 1907, Part II.

Further, Mineral Products of the United States, 1896-1907. Tabulated on large sheet ; also numerous advance chapters from Mineral Resources of the United States, 1907 ; and

WATER-SUPPLY PAPERS.—No. 219. Ground Waters and Irrigation Enterprises in the Foothill Belt, Southern California ; by WALTER C. MENDENHALL. Pp. 180, 9 plates, 16 figures.

No. 220.—Geology and Water Resources of a Portion of South-Central Oregon ; by GERALD A. WARING. Pp. 86, 10 plates, 1 figure.

No. 222. Preliminary Report on the Ground Waters of San Joaquin Valley, California ; by WALTER C. MENDENHALL. Pp. 52, 1 plate.

2. *Canada : Geological Survey.* A. P. Low, Director, Ottawa.—Recent publications from the Geological Survey of Canada, including the Department of Mines, are included in the following list : (See p. 239, vol. xxvi.)

Seventeen maps, giving plans and sections of the Gold Districts of Nova Scotia.

Preliminary Report on a Part of the Similkameen District, British Columbia; by CHARLES CAMSELL. Pp. 41, with folding map.

Department of Mines, R. W. BROCK, Acting Director.

Report on a Portion of Conrad and Whitehorse Mining Districts, Yukon ; by D. D. CAIRNES. Pp. 38, 8 plates, folding map.

Preliminary Report on a Portion of the main Coast of British Columbia and adjacent Islands included in New Westminster and Nanaimo Districts; by O. E. LEROY. Pp. 56, 4 plates, 6 figures, folding map.

Report on a Recent Discovery of Gold near Lake Megantic, Quebec ; by JOHN A. DRESSER. Pp. 13, folding map.

Report on the Landslide at Notre-Dame de la Salette, Lièore River, Quebec ; by R. W. ELLS. Pp. 10, 7 plates.

3. *North Carolina Geological and Economic Survey,* JOSEPH HYDE PRATT, State Geologist.

Economic Paper No. 14. The Mining Industry in North Carolina during 1906 ; by J. H. PRATT. Pp. 142, 20 plates, 5 figures. Raleigh, 1907.

Bulletin No. 16. Shade Trees for North Carolina ; by W. W. ASHE. Pp. 72, 10 plates, 18 figures. No. 17. Terracing of Farm Lands ; by W. W. ASHE. Pp. 72, 6 plates, 2 figures. Raleigh, 1908.—The total value of the mineral productions of North Carolina, in 1906, was some $3,000,000, having increased from $1,800,000 since 1901. The most important items, making up two-thirds of the whole, are clay and coal. Following these are

mica ($218,000), copper ($136,000), gold ($122,000) and monazite ($126,000). The present report, by Dr. Pratt, gives an account of the mining industries of the state, particularly as related to gold, mica and monazite.

The accompanying bulletins discuss the introduction of shade trees in the cities of the state, and the methods of terracing farm lands. This latter subject is particularly important in a region where the prosperity of the community depends so largely upon the preservation of the natural soil, which, when left to natural processes, soon suffers destructive erosion and is permanently lost.

4. *Report of the State Geologist of Vermont for 1907-8.* Pp. 302, with 59 plates.—In the first portion (pp. 1–57) of this volume, the state geologist, Professor G. H. Perkins, treats of the mineral resources of the state, of which marble forms the bulk. In 1906 marble worth nearly four and one-half million dollars was produced, and of granite about four million dollars. T. Nelson Dale describes the Granites of Vermont; H. E. Mervin, Some Late Wisconsin Shore Lines; C. H. Hitchcock, the Geology of the Hanover, New Hampshire, Quadrangle; G. H. Perkins, the Geology of Franklin and Chittenden Counties; George E. Edson, the Geology of the Town of Swanton; and C. H. Richardson, the Geology of Newport, Troy and Coventry.

An interesting discovery is the finding at St. Albans of a Middle Cambrian fauna with Paradoxides. The fine skeleton of a Pleistocene whale, *Delphinapterus vermontanus*, long shown at the State Museum, is here described and illustrated at great length by the state geologist. Professor Richardson seems to have fossil evidence indicating that the highly metamorphosed sedimentaries lying between the eastern foothills of the Green Mountains and the valley of Lake Memphremagog are of Cambro-Ordovician age. The fossils appear to be crushed graptolites.

C. S.

5. *Thirty-second Annual Report, Indiana Department of Geology,* W. S. BLATCHLEY, State Geologist. Pp. 1231, with 22 maps and 55 plates. Indianapolis, 1908.—Nearly 300 pages are devoted to a description of the soils of 17 counties of Southern Indiana by Messrs. Shannon, Lyons, Snider, Ward and Ellis. The vast oölitic limestone industry is described at length by the state geologist and associates. There are also the annual reports of the inspector of mines and natural gas. The chapter on the petroleum industry in 1907 states that since 1891 there have been sunk for oil 24,297 wells into the Trenton limestone and of these 15,210 were producing last January. Last year the total shipped output was nearly five million barrels of 42 gallons each, bringing about 88 cents per barrel.

About one-half of the book is devoted to "The Stratigraphy and Paleontology of the Cincinnati Series of Indiana," by Prof. R. E. Cumings. Sixty-seven local sections are described in detail and the fossils listed for each bed. This is followed by a general discussion of the Cincinnatian series. The greater part of the

work is devoted to redescriptions of the 422 species collected, most of which are illustrated on 55 plates. The final paper by D. Reddick describes the mushrooms of Indiana.   c. s.

6. *Illinois State Geological Survey, Year-Book for 1907 ;* H. Foster Bain, Director. Bulletin No. 8, 374 pp., 23 pls., 32 figs. with map. Urbana, 1907.—A number of papers contained in this report have been already published (this Journal, xxiv, 447, xxv, 353–354, xxvi, 166). The remaining papers deal chiefly with economic subjects, including cement materials, clay industries, petroleum, artesian wells, lead and zinc, concrete, land reclamation, and valuable studies relating to the alteration of coal, with detailed investigations in certain areas.   H. E. G.

7. *New Zealand Geological Survey,* J. M. Bell Director. *The Geology of the Cromwell Subdivision, Western Otago Division ;* by James Park. Bull. No. 5 (new series). Pp. 86, pls. 20, maps 10, geol. sections 6. Wellington, New Zealand, 1908.—The geological section of the Cromwell area includes, in the Paleozoic system, two series : the Maniototo series of mica and chlorite schists which have an extreme thickness of 30,000 feet and a remarkably uniform schistosity, sills and dikes being almost completely absent over the wide area of five survey districts ; and the Kakanui series of upper schists which are less metamorphosed. The Pliocene is represented by the Manuherikia series of shales and clays, containing valuable seams of lignite. The region has been glaciated, as indicated by the moraines and extensive terraces and river gravels. All the glacial and fluviatile deposits are gold-bearing, and the principles underlying the concentration of gold in these gravels are discussed. Petrographic descriptions are given of the following rocks: Chlorite and mica-schist, greywacke, serpentine, hypersthene-diorite, feldspar-porphyrite, mica-gneiss, biotite-granite, augite-hypersthene-diorite, augite-diorite, hornblende-schist, hornblende-camptonite, sandstone, and chemical analyses are given of altered greywacke, serpentine, mica-schist, and chlorite-schists. Physiographically, the region is a part of the central Otago peneplain, now deeply dissected into " high table-top mountain ranges intersected by deep water courses and separated from each other by river valleys or cleft in twain by profound gorges". Mr. Park enters into an extensive discussion of the origin and development of the block mountains, with their intervening basins.   H. E. G.

8. *Report on the Eruptions of the Soufrière in St. Vincent in 1902, and on a Visit to Montagne Pelée in Martinique. Part II. The Changes in the Districts and the Subsequent History of the Volcanoes ;* by Tempest Anderson. *Petrographical Notes on the Products of the Eruptions of May, 1902, at the Soufrière in St. Vincent ;* by John S. Flett. Phil. Trans. Roy. Soc. London, series A, vol. ccviii, pp. 275–332, 27 pls. London, 1908. —Dr. Anderson revisited St. Vincent and Martinique in 1907. His descriptions of the changes which have taken place between 1902 and 1907 constitute an interesting study of the secondary

phases of volcanic activity and also of the rapidity of erosion in volcanic materials, and the ease with which vegetation in tropical countries takes possession of a region which is absolutely barren. The sixteen plates from well selected photographs are excellent, and when compared with those taken in 1902 from approximately the same localities, constitute a history of stream development, erosion, and changes in volcanic materials which is very striking indeed. The present volume also contains the "Petrographical notes on the products of the eruptions of May, 1902, at the Soufrière in St. Vincent," by John S. Flett. The scientific world is fortunate in having these volcanoes studied by Anderson, La Croix, Hovey, and Heilprin, whose combined reports constitute perhaps the most elaborate treatise on any single volcanic disturbance in the world's history. The bibliography which accompanies the report is fairly complete, but fails to mention the writings of one of the most industrious students of this district, viz., Angelo Heilprin.   H. E. G.

9. *The Geology and Ore deposits of the Coeur d'Alene District, Idaho ;* by FREDERICK LESLIE RANSOME and FRANK CATHCART CALKINS. Professional paper 62. U. S. Geological Survey. Pp. 203, pls. xxix, figs. 23. Washington, D. C., 1908.—This report is of great interest to geologists since it embraces an area of 404 square miles constituting the well known Coeur d'Alene mining district of northern Idaho and gives the detailed stratigraphic and structural geology of a portion of a region concerning which but little has been previously known.

The district, as shown by the map, is one of maturely dissected mountainous topography showing a relief between river bottom and mountain top of about 4000 feet. It lies in the midst of a region which while not attaining elevations as great as certain others in the Cordillera, yet is, on the whole, of a particularly wild, rugged and forested character. The sedimentary rocks except for the surface gravels belong entirely to the great Algonkian system known as the Belt, from the earlier studies in the Belt mountains of Montana. The section here attains a thickness of 17,200 feet, the base not exposed and the top removed by erosion. They vary from sandstones to argillites and throughout the greater portion of the system the argillaceous formations show marks of shallow water deposition and subaërial exposure. No great limestone formations such as the two which occur farther east are found in this region and it is concluded that the sediments came from the west. A great fault, however, whose outcrop at the surface is known as the Purcell trench cuts off the system to the west, beyond this a highly metamorphic complex being exposed. The igneous rocks are all intrusive, the large masses varying from monzonites to syenites. The region is complexly folded and faulted but, as in other portions of this province, the rocks are remarkably free from regional metamorphism, giving unusual opportunities for studying an Algonkian system.

The mineral resources in the order of their present importance are (1) lead silver ores, (2) copper ores, (3) gold ores.   J. B.

10. *Geologie der Steinkohlenlager ;* by DANNENBERG. Erster Teil. Pp. 197, 25 figs. (Gebrüder Borntraeger.) Berlin, 1908.— This publication is evidently one of importance, and will be reviewed after the appearance of the second part, which the publishers announce will be issued sometime within the coming year. H. E. G.

11. *The Geology of Coal and Coal-mining ;* by WALCOT GIBSON. Pp. x, 328, 8 plates. London, 1908 (Edward Arnold.)— Geologists and engineers will be interested in the series of works on economic geology, dealing with mining, quarrying, water supply, etc., to be issued under the general editorship of Professor Marr. The above volume is the first of the series and discusses varieties of coal, their formation, origin, distribution, value of fossils in coal exploration, and methods for a study of exposed and concealed coal fields. Somewhat over half of the book is devoted to a critical discussion of the coal fields of the world,— those of Great Britain being treated with the greatest detail. Eighteen pages are devoted to the North American coal fields, and little use is made of the valuable investigations of the United States Geological Survey and the various state surveys. Mining engineers, prospectors, and students of economic geology will find Dr. Gibson's book helpful reading. H. E. G.

12. *Physical History of the Earth in Outline ;* by JAMES B. BABBITT. Pp. 212, 6 illustrations. Boston, 1908 (E. E. Sherman & Co.)—The object of this book is to explain the changes of climate through geological time, on the assumption that the earth has a " proper rotary motion transverse to or across the diurnal rotation." An idea of the author's views in relation to orthodox science may be gained from the fact that he accepts Agassiz's account of glaciation in Brazil and believes the irregular coast lines of Maine, Norway, and the world in general, as well as the river system of North America, to be due to glaciation. H. E. G.

13. *Triassic Ichthyosauria, with special reference to American Forms ;* by JOHN C. MERRIAM. Memoirs of the University of California, Vol. i, No. 1. Pp. 155, text-figures 154, plates 1–18. Berkeley, 1908 (University Press).—The inaugural number of this new series of memoirs contains the results of twelve or more years of thorough work upon one of the most important groups of fossil vertebrates. Ten field-expeditions, sent out by the University of California and generously aided by a patron of that institution, have brought together a magnificent collection of ichthyosaurs from the marine Triassic of California and Nevada. While this collection forms the chief subject of the memoir, the European genera are also reviewed. Admirers of the author, and they are many, will be glad to learn that the present work, with all its breadth of treatment and refinement of detail, " can be considered as no more than a report of progress, as new material and additional information regarding the structure and affinities of the Triassic forms are constantly being obtained." In this case one of the great difficulties met with in paleonto-

logical research has been tactfully overcome, viz., the question when an author should turn from the work of investigation and take the scientific public into his confidence.

From the occurrence of considerably specialized ichthyosaurs in the middle Triassic of regions as widely separated as Europe and western North America, it is argued that these forms had long been in existence as a marine type. Thus in the division of the memoir on general skeletal structure, the skull of *Cymbospondylus*, from the middle Triassic of West Humboldt Range in Nevada, is shown to be "the product of an ancestry which had expressed this special type of aquatic adaptation for a long period." In this connection it is interesting to learn that *Cymbospondylus* is still the only Triassic ichthyosaurian genus represented by a well-preserved skull. In the known Triassic forms the number of presacral vertebrae is proved to be generally larger than in the typical *Ichthyosaurus*. This is slightly disturbing to the view held by some paleontologists that the *Phytosauria* are ancestral to the *Ichthyosauria;* and there are, the author states, a number of other characters apparently indicating that these two groups have arisen independently of each other. The principal points of difference between the Triassic and the Jurassic ichthyosaurs are arranged in parallel columns so as to demonstrate that the characteristics of the earlier genera are practically all nearer to those of land or shore animals, while "the characteristics of the later genera take the direction of specialization toward an adapted fish-like form." Yet on the whole, this evolution from a semi-aquatic reptilian type to one better fitted for life in deep water has been extremely gradual, and the unity of the *Ichthyosauria* (here divided into the families Mixosauridae and Ichthyosauridae) can not be questioned. At precisely what geological period the "unknown crawling ancestor" of the ichthyosaurs asserted its independence from the parent shore-type, Prof. Merriam wisely does not state ; but he places this event not later than the early part of the Trias— possibly at an even earlier period. The text-figures and plates are excellent ; and a carefully prepared index adds greatly to the value of the work.   G. F. E.

14. *Catalogue of the Type and Figured Specimens of Fossil Vertebrates in the American Museum of Natural History, Part I—Fishes;* by L. Hussakof, Bull. Amer. Mus. Nat. Hist., Vol. xxv, pp. 1–103, with one diagram and plates i–vi, June, 1908.— In this exhaustive catalogue not only are all of the primary and secondary types of fossil fishes in the American Museum enumerated, but the condition of the specimen, together with the literary reference of the original description, or descriptions, is given. In all 49 text-figures are printed, while a number of specimens, mainly the types of Cope and Newberry, are illustrated in the excellent plates. The diagram gives in tabular form the classification and geological summary of the 562 types included in the catalogue.

R. S. L.

15. *The Conard Fissure, a Pleistocene Bone Deposit in North-ern Arkansas, with descriptions of two new genera and twenty new species of Mammals ;* by BARNUM BROWN. Memoirs Amer. Mus. Nat. Hist., Vol. ix, Part iv, pp. 155–208 ; pls. xiv-xxv.—Mr. Brown has made a most notable contribution to our knowledge of North American Pleistocene forms, not alone by this excellent work, but by the rare skill with which he explored and collected the material upon which the volume is based. The assemblage of animals contains thirty-seven genera and fifty-one species, of which four genera and twenty-one species are considered extinct. There is a notable absence of ground sloths, tapirs and proboscid-ians ; the fauna being characterized by northern forms, such as the musk ox and wapiti deer, among others. The condition of the bones, association and predominance of certain forms indicate that this fissure was the home of several contempora-neous species which preyed on others and brought their remains into it, the fauna being typically that of a forest region with open glades similar to present conditions. R. S. L.

16. *A Four-horned Pelycosaurian from the Permian of Texas;* by W. D. MATTHEW. Bull. Amer. Mus. Nat. History, Vol. xxiv, Art. xi, pp. 183–185.—This remarkable genus, *Tetraceratops,* is based upon the partially complete skull of a highly specialized, predaceous type. It is characterized mainly by the development of horn-like prominences—one in advance of each orbit and one arising from each of the premaxillaries. Among reptiles the nearest approach to them is seen in the carnivorous dinosaurs *Ceratosaurus* and *Allosaurus,* in both of which bony horns are found upon the prefrontals while the first-named genus bears a median nasal horn as well. The horns are more highly developed however, in *Tetraceratops.* Dr. Matthew's choice of name may lead to confusion, as the group of great horned Dinosauria, the Ceratopsia, includes the genera *Ceratops, Diceratops* and *Tricera-tops,* and the unrelated *Tetraceratops* should logically belong to the same group, if one were to judge from the name. R. S. L.

17. *Osteology of Blastomeryx and Phylogeny of the American Cervidæ ;* by W. D. MATTHEW. Bull. Amer. Mus. Nat. Hist., Vol. xxiv, Art. xxvii, pp. 535–562.—The lower Miocene fauna has supplied the connecting link between the Oligocene *Leptomeryx* and the later American deer in the form of *Blastomeryx,* the osteology of which is completely known. This enables Dr. Matthew to trace the evolution and relationships of the American Cervidæ in a way which places the phylum on a plane with those of the Horses and Camels. Figure 14 is a diagram showing the evolution and migration into South America of the North American deer, while fig. 15 gives us a most valuable summary of the geological distribution and phylogeny of the American ruminants as a whole. R. S. L.

18. *Rhinoceroses from the Oligocene and Miocene deposits of North Dakota and Montana;* by EARL DOUGLASS. Ann. Car-negie Museum, Vol. iv, Nos. iii and iv, 256–266, pls. lxiii, lxiv.—

In this brief paper Mr. Douglass describes a new species of the genus Aphelops, *A. montanus,* from the upper Miocene of Flint Creek Valley, Montana. *Aphelops ceratorhinus,* previously described by the writer, is made the subject of a more elaborate description, based upon the fully prepared type and upon other material referable to the same species.   R. S. L.

19. *Fossil Horses from North Dakota and Montana ;* by EARL DOUGLASS. Ibid, pp. 267-277, pls. lxv-lxviii—The middle Miocene of Montana has yielded a new genus and species of horse, *Altippus taxus,* while from the Loup Fork of Montana is described a new species of Merychippus, *M. missouriensis.* In the Oligocene Mr. Douglass found four species of Mesohippus, one of which he considers new, *Mesohippus portentus.*   R. S. L.

20. *Some Oligocene Lizards ;* by EARL DOUGLASS. Ibid, pp. 278-285.—In this paper Mr. Douglass describes a curious armored lizard from the Titanotherium beds of Montana and which he refers with a query to *Glyptosaurus* Marsh. The writer also enumerates the eight species of *Glyptosaurus* described by Professor Marsh, with brief diagnoses, tor comparison with his present form. There are also described and figured skulls from the White River formation of Sioux Co., Neb., which the writer refers to *Rhineura hatcheri* Baur and *Peltosaurus granulosus?* Cope.   R. S. L.

21. *Preliminary Notes on Some American Chalicotheres ;* by O. A. PETERSON. American Naturalist, Vol. xli, pp. 733-752.— Mr. Peterson has been fortunate in securing from the remarkable Agate Spring Quarry (Lower Harrison) of Sioux Co., Nebr., a good deal of material which decidedly increases our knowledge of the curious genus, *Moropus,* first described by Professor Marsh. The present writer figures a partially complete skull, which he refers to *Moropus elatus?* Marsh, as well as excellent photographs of the fore and hind feet. Mr. Peterson's conclusions are thus summed up : "(1) That Moropus is, excepting its unguiculate feet, essentially a perissodactyl in structure. (2) That the laterally compressed and cleft condition of the terminal phalanges is quite distinct in some of the early Perissodactyla, and that by adaptation through geological ages the unguals, as well as other parts of Moropus, were specially modified and should not, in the mind of the writer, be regarded as of ordinal importance. (3) That Moropus is generically separable from other known forms of the Chalicotherioidea."   R. S. L.

III. BOTANY AND ZOOLOGY.

1. *The Harvard Botanical Station in Cuba.*—In December 1899, the writer, in company with Mr. Oakes Ames, Assistant-Director of the Botanic Garden of Harvard University, visited the sugar estate of E. F. Atkins, Esq., with the view of ascertaining what opportunity, if any, existed for conducting experiments

on the improvement of the cane. The estate is situated a short distance from the harbor of Cienfuegos, on the coast of the south-central part of Cuba. It was found that the estate, of large size, was supplied with all modern appliances for the manufacture of sugar to the best advantage, and that facilities were there presented for conducting investigations in regard to cane-fertilization under favorable conditions. The services of the skilled chemists at the factory on the estate were placed at our disposal, for the determination of many questions arising with reference to yield and sugar-content of the cane. The results of the preliminary examination were so favorable that the work of crossing was actively begun, and continued the next year. Mr. Robert M. Grey, who had been very successful in hybridizing orchids, was invited to make a careful examination of the conditions presented by the locality, and he gave a conservative report which was decidedly encouraging. In 1902 we had also an inspection of the place by Mr. C. G. Pringle, who is well known as a hybridizer of cereals, and he likewise expressed the opinion that the estate afforded good opportunities for fruitful crossing of varieties. In the early part of the next year, Mr. Grey was made superintendent of the newly formed station, and began systematic experimenting along the lines laid down by the sugar-cane experts in Java. We were so fortunate as to have, also, the counsel of Dr. John C. Willis, Director of the Royal Botanic Gardens of Ceylon, who made a careful investigation of the capabilities of the station. His favorable report led to immediate extension of the original plan, and the development has steadily progressed with practially no interruptions except during the short period of the late insurrection. At present, ten years after the first work in crossing was done at this locality, the experiment may be regarded as successful. At great cost we have secured from the most remote localities, authentic specimens of the finest canes now known, and the varieties have been carefully perpetuated under the best conditions for each. Meanwhile we have added to the station the principal economic plants of the warm and the hot tropics, and have indicated the lines of research likely to prove most satisfactory. The results which have been reached by Mr. Grey have depended upon his skill both as a cultivator and as a plant-breeder. His monthly reports exhibit a very wide range of experimenting and wholly fruitful outcome.

Fortunately, from the very first we have been able to maintain agreeable relations with sister stations in Cuba and the West India Islands, and have received constant aid from all officials. Of course by reciprocity our results are placed at their disposal. Some of the more striking of the results have been published in the *Boletin oficial* (Cuba) and in the West India Bulletin. The monthly reports from the station are now becoming of so much interest that some of the particular features seem to require presentation in a regular publication. As to the form of this, no decision has yet been made.

Mr. Atkins, who has sustained the enterprise from the outset, expresses himself as satisfied with the substantial results reached. It is a great pleasure for the director, assistant-director, and head-gardener of the Harvard Botanic Garden to aid the rapid development of the station by every means in their power.

G. L. G.

2. *Handbuch der Blüten-biologie*, von Dr. PAUL KNUTH. Leipzig (Wilhelm Englemann). *Handbook of Flower-Pollination*, by Dr. PAUL KNUTH; translated by J. R. AINSWORTH DAVIS, M.A. Oxford (Clarendon Press).—This excellent translation brings into two volumes the subject matter contained in the three German volumes (bound in five parts). The original work is based on the interesting treatise by Hermann Müller which, it will be remembered, greatly stimulated research in the attractive field of the pollination of flowers. The innumerable contributions to this subject soon outgrew the limits which could naturally be assigned to a second edition, and necessitated entire reconstruction. Professor Knuth undertook this reconstruction, while carrying the pressure of the double burden of deep affliction and impaired health. It was hoped that a long journey, which he prosecuted in the search for fresh material, might lighten this burden, but this did not prove to be the case. His early death left an immense mass of material partly published, but to a great extent uncoördinated. Willing hands have from this material completed a lasting monument to the author. Its comprehensiveness and accuracy will enable this work long to maintain its place as a memorial. The translation presents the whole treatise in a very convenient form for the English-speaking student.   G. L. G.

3. *A Convenient Clearing and Mounting Agent.*—To a perfectly clear solution of potassium silicate add one third to one half volume of glycerine and after warming the whole, slightly shake until the two liquids are thoroughly mixed. The resultant clear liquid has proved to be an efficient agent for clearing such objects as pharmaceutical powders and the like. If the powder, for instance, capsicum, is placed on a glass slide and the glycerin-silicate placed carefully thereon, a cover-glass can be at once put in position and held for a couple of minutes or so, when it will be found to have "set" more or less firmly, constituting a fairly good mount for use within the next few days. If the edge of the cover be carefully cemented by a mixture of potassium silicate and barium sulphate, the mount becomes permanent. Two precautions must be observed; first, use enough of the glycerin-silicate to flow, at the outset, to the edge of the cover-glass, all around, and second, on no account allow any of the agent to touch the front of the objective.

A mixture of sodium silicate and glycerin (see Schürhoft, quoted in Journal of Royal Microscopical Society, 1902, p. 622) does not appear to clear the objects under inspection quite so well as the one here suggested.   G. L. G.

4. *Economic Zoology*; *An Introductory Text-book in Zoology, with special reference to its applications in Agriculture, Commerce, and Medicine;* by HERBERT OSBORN. Pp. xv, 490, with 269 figures. New York, 1908 (The Macmillan Company). —A recent tendency to emphasize those features of a science which have a practical bearing on human affairs finds expression in this little text-book, which differs from others of its class mainly in the relative amount of attention devoted to those animals which are of economic importance. The book has the usual systematic arrangement, and all the groups of the animal kingdom are included, but where a choice of examples is possible the species which concerns the human welfare is selected and its significance discussed. The numerous illustrations are largely selected from other books issued by the same publishing house, and are in many cases not so well printed as in the works from which they are taken. W. R. C.

5. *A Text-book of the Principles of Animal Histology;* by ULRIC DAHLGREN and WILLIAM A. KEPNER. Pp. xiii, 515. New York 1908 (The Macmillan Company).—In marked contrast to practically all the text-books of histology in the English language, which deal largely or exclusively with human or mammalian structures, this new book discusses the tissues of all classes of animals. It is therefore possible to treat the subject much more broadly and satisfactorily than has hitherto been done. The increased range of material makes possible the incorporation of new and vastly improved illustrations in place of the worn-out cuts of most other histologies. The animal tissues are discussed in systematic order, and the modifications of the tissues of the invertebrates find their place beside the better known vertebrate structures. The originality of the work is most praiseworthy, and although some of the illustrations are rather crude, they give at least a diagrammatic illustration of the structures they are intended to represent, and will be welcomed by all teachers of the subject. This book will doubtless supplant in many cases the older works, adapted chiefly to the needs of the student of medicine, which have hitherto alone been available for scientific college courses. W. R. C.

6. *Archiv für Zellforschung;* hrsg. von RICHARD GOLDSCHMIDT. Bd. 1, Heft 1-4 ; pp. 622, pl. i-xxi. Leipzig, 1908 (Wilhelm Englemann).—This newly established journal, devoted to the study of cellular structure and phenomena of animals and plants, takes its place at once among the highest type of biological publications. It is intended for the publication of the results of original research, and is illustrated by the finest lithographic plates. This first volume contains fifteen original contributions by some of the most prominent cytologists of Europe, the subjects of their investigations covering a wide range of cytological problems, both in plants and animals. W. R. C.

7. *Ueber die Eibildung bei der Milbe Pediculopsis graminum;* von ENZIO REUTER.—A reprint from the Festschrift fur Palmén

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(Helsingfors, 1907) containing an account of a case of ovogenesis in which certain of the egg cells, possibly those normally destined to produce the male sex, are absorbed by the more vigorous (female ?) cells, thus producing a preponderance of female individuals.   W. R. C.

IV. Miscellaneous Scientific Intelligence.

1. *Artificial Daylight for Use with the Microscope ;* by Fred. Eugene Wright. (Communicated from the Geophysical Laboratory.)—For microscopic work with rocks, and especially with artificial products, daylight on dark winter days is a factor much to be reckoned with, and the want of a good substitute for it has long been felt by the writer. Many different kinds of artificial light are available, but the results obtained by their use have not, on the whole, been satisfactory. The natural colors of mineral sections, and also interference colors, appear abnormal and unnatural in artificial light, the illumination of the field is not even, and good interference figures on small plates are not as a rule obtainable. Recently, however, the following illuminating device has been tried and has proved so satisfactory that it deserves brief mention.

The source of light is an acetylene burner fed by a J. B. Colt generator No. 102, and placed at the focus of a large condensing lens of about 20^{cm} focal length. Compared with daylight, acetylene light is slightly too strong in yellow, but by passing the parallel rays from the condenser lens through a pale blue cobalt glass plate of the proper intensity, this difficulty is eliminated and the field appears white and the colors, both natural and interference colors, are normal and correct. In certain tones, very slight differences can be detected, but these are of an order noticeable in different sections of the same substance and are not serious. With this arrangement, acetylene light, condenser lens and pale blue glass ray filter, the observer has at hand a source of illumination which is practically identical in its effect with daylight, and which is available at any moment.

2. *Ion. A Journal of Electrotonics, Atomistics, Ionology, Radio-activity and Raumchemistry.* Edited by Charles H. Walter.* Vol. I, Fasc. 1. Pp. 80. November, 1908. London (16 Heathfield Gardens, Turnham Green, W.).—An unavoidable result of the recent development of science along special lines has been the establishment of many new journals of more and more restricted field. This multiplication of periodicals is in many respects an admirable thing, having a decidedly stimulating effect upon the workers immediately interested, but, at the same time, it has its drawbacks and adds a somewhat heavy burden upon science in general. In Germany, in particular, these specialist

* The name of Frederick Soddy appears on the title page as an editor-in-chief, but in Nature for Nov. 26, Professor Soddy announces that he has " withdrawn from all connection with the journal."

periodicals are very numerous ; in England there have been but few. There is more room, therefore, for this new journal, the "Ion," which is started with the design of covering the field of physico-chemistry, or in other words the various special branches of physics in which the electron is the essential conception ; one of the most highly developed of these is the subject of radio-activity. Associated with the editor-in-chief are the following : Sv. Arrhenius, Stockholm ; W. H. Bragg, Adelaide ; A. S. Eve, Montreal ; O. Hahn, Berlin ; W. H. Julius, Utrecht ; A. Werner, Zürich ; G. Bruni, Padua ; Mde. Curie, Paris ; Guilleaume, Paris ; Van't Hoff, Berlin ; W. Marckwald, Berlin ; W. Wien, Würzburg.

The first number of Ion bears the date of November, 1908, and opens with an account of M. Henri Becquerel, the founder of radio-activity, by F. Soddy, who also contributes a paper on the charge carried by the α-particles. Other articles are on uranium and geology by John Joly ; the transmission of energy in the world of electrons by H. W. Julius ; and actinium C by Otto Hahn and Lise Meitner. Following these articles are some twenty pages devoted to reports of papers published elsewhere and notices of new books.

The new journal will be issued in monthly numbers of 64 to 80 pages, at the price of 30s. per volume ; the editorial address is given above.

3. *Life and Letters of Herbert Spencer ;* by DAVID DUNCAN. Two volumes. Pp. viii, 414 and vii, 444, with seven full-page illustrations. New York, 1908 (D. Appleton & Company). —These two attractive volumes portray the human side of the life of the great philosopher and form a fitting complement to Spencer's own voluminous autobiography. The author and compiler was commissioned by Spencer himself to prepare such a work for publication, and to incorporate certain unpublished papers and portraits. From the vast amount of correspondence which passed between Spencer and members of his family, friends, and the scientific men of the day, the author has made such judicious selection, and has woven the whole together so skillfully by explanation and anecdote, that the work can be read with perfect smoothness. And at the same time the reader gains such vivid pictures of the real man, his attitude toward the great problems of his day, and with frequent glimpses of his scientific associates, as could hardly be secured in any other manner. The letters are arranged largely with reference to subject matter, but with some regard for chronological order, and the work is illustrated by a number of portraits not only of Spencer at successive periods of his life, but also of persons with whom he corresponded. In five appendices appear several hitherto unpublished essays, together with lists of his writings (the titles covering fifteen pages) and the honors which were offered the great scholar by upwards of thirty universities and learned societies. It should be added that these honors were, however, with few exceptions declined. W. R. C.

4. *American Association for the Advancement of Science.*— The sixtieth meeting of the American Association is held at Baltimore, under the auspices of Johns Hopkins University, during the week from Dec. 28, 1908 to Jan. 2, 1909; Prof. T. C. Chamberlin of Chicago is President. This is the seventh of the " Convocation week" meetings; some twenty-four affiliated societies meet at Baltimore at this time. A Darwin commemorative meeting takes place on January 1, under the combined auspices of the Association and the Society of Naturalists. Also a meeting of the American Health League is called for Dec. 31, in connection with Section I of the Association, as a symposium on " Public Health."

5. *The Nature of Enzyme Action;* by W. M. BAYLISS. Pp. 90. London, 1908 (Longmans, Green & Co.).—This is the first of a series of monographs on bio-chemistry planned to supplement the current text-book treatment of topics in rapidly developing departments of this science. Enzyme action is shown to be a type of catalytic reaction the features of which are subjected to critical analysis by the author, and compared with the behavior of other catalysts. Special consideration is devoted to the nature of colloids as exemplified in enzymes, to the reversibility of enzyme action, and to changes in the rate of reactions as affected by them. Other appropriate details, such as the relation of the enzyme to its substrate, the influence of " co-enzymes " and " anti-enzymes," temperature and concentration, etc., are also discussed. The treatment is quite original. L. B. M.

6. *Rivista di Scienza.*—This valuable " International Review of Scientific Synthesis," commenced in 1907, has now completed its fourth volume. A recent number includes eight articles, among which may be mentioned the following : G. H. Bryan on the diffusion and dissipation of energy ; W. Ritz on the rôle of the ether in Physics ; G. Haberlandt on motion and sensation in the plant world ; G. Schiaparelli, on the astronomy of the Bablyonians.

B. G. Teubner's Verlag auf dem Gebiete der Mathematik Naturwissenschaften and Technick nebst Grenzwissenschaften. Mit einem Gedenktagebuche für Mathematiker und den Bildnissen von G. GALILEI, etc. Dem IV. Internationalen Mathematiker-Kongress in Rom. 6-11. April 1908. Pp. 392.

Obituary

Dr. OLIVER WOLCOTT GIBBS, from 1863 to 1887 Rumford Professor of Applied Science in Harvard University and for thirty years an Associate Editor of this Journal, died at his home in Newport, R. I., on December 9, in his eighty-seventh year. A notice is deferred until a later number.

Professor WILLIAM EDWARD AYRTON, the eminent English engineer, died on November 8, at the age of sixty-one years.

New Circulars.

84: **Eighth Mineral List:** A descriptive list of new arrivals, rare and showy minerals.

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RARE CINNABARS FROM CHINA.

During the past month our correspondent in China ran across fine, remarkable specimens of these Cinnabars and we immediately ordered them secured for us, and they will reach us about the time this Journal is published. Write for illustrated pamphlet and particulars.

NEW ARRIVALS.

Euclase, Capo do Lane, Brazil; Chalcocite, Bristol, Conn.; Columbite, Portland, Conn.; Iolite, Guilford, Conn.; Monazite, large loose xls. and in matrix, Portland, Conn.; Uraninite, crystal in matrix, Portland, Conn.; Eglestonite, Terlingua, Texas; Patronite, S. A.; Benitoite, San Benito Co., Cal.; Neptunite, Cal.; Crookesite, Hedenbergite, Sweden; Lievrite, Elba; Polybasite, Hungary and Durango, Mexico; Josephinite, Oregon; Herderite, Poland, Maine; Smithsonite, Kelly, N. M.; Californite, Tulare Co., Cal.; Cobaltite, loose crystals and in matrix, Cobalt, Ont., and Tunaberg, Sweden; Apatite, Auburn, Maine; Vivianite, large crystals, Colo.; Vanadinite, Kelly, N. M.; Olivenite, Utah; Sartorite, Canton Wallis; Jordanite, Binnenthal; Mohawkite, Algodonite, Domeykite, Michigan; Crocoite, Siberia and Tasmania; Cinnabar, Cal., Hungary and China; Dioptase, Siberia; Diopside, with Essonite, Ala, Piedmont; Embolite, Australia; Gypsum, twin crystals, Eisleben, Thuringia; Diamond, in matrix, New Vaal River Mine, South Africa; Argentite, Mexico; Freiberg, Saxony; Pyrargyrite, Saxony and Mexico; Wulfenite on Aragonite, Organ Mts. N. Mexico; Celestite, Sicily; Pyromorphite, Ems, Germany, Phoenixville, Pa.; Millerite, Antwerp, N. Y.; Sylvanite, Colo.; Tellurium, Colo.; Tourmalines, new find, San Diego Co., Cal.; Tourmalines, beautiful sections from Brazil; Brochantite on Chrysocolla, Utah; Pink Beryl, small and large, Mesa Grande, Cal.; Kunzite, small and large, Pala, Cal.; Sphene, Binnenthal; Titanite, Tilly Foster, N. Y.; Tetrahedrite, Utah and Hungary; Realgar, Hungary; Opal, Caribou River, Queensland; Octahedrite, var. Wiserine, Binnenthal; Heulandite, Iceland; Torbernite, Eng.; Bismuth, native, Cobalt, Ont. and Conn.; Silver, native, polished, Ont.; Emerald, loose and in matrix, Ural and Bogota; Topaz crystals with rare planes, Ural; Zircon crystals, loose, Ural; Green and Cinnamon Garnets, Minot, Maine; Vesuvianite, Poland, Maine, Italy and Tyrol; Zeolites, beautiful specimens from Erie Tunnel, Patterson and Great Notch.

CUT GEMS.

' Garnets, green and red; Aquamarines; Zircons, all shades; Sapphires, all shades; Star Sapphires and Star Rubies; Chrysoberyl, Cats-eye; Spinels, all shades; Topaz, pink, blue, brownish and golden color; Pink Beryl; Sphene; Tourmaline, all shades; Amethyst, Siberia, royal purple color; Andalusite; Star Quartz; Peridote; Opal matrix, Mexico and Australia; Precious Opal, Australia, Mexico and Hungary; Hyacinth; Turquoise, Mexico and Persia; Kunzite; Reconstructed Rubies and Sapphires; Emeralds; Opal Carvings, such as pansies, vine leaves with bunches of grapes, and other small Opal novelties; Antique and Modern Cameos; Antique, Mosaic and other semi-precious stones.

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Art. VII.—*Revision of the Protostegidæ;* by G. R. Wieland. (With Plates II–IV.)

There is no family among all American fossil turtles which, following the discovery of its initial type, has so steadily yielded new forms and additions to our knowledge of the structure and history of marine turtles as the Protostegidæ. True enough, no further members of the family were noted and few specimens were collected for twenty years after Cope's original discovery of *Protostega gigas;* but then came the addition of the related genus *Archelon* from the Pierre Cretaceous in 1895, since which time scarcely a year has passed without yielding new data to the structure, extent and significance of the Protostegidæ.

Indeed, even before the discovery of *Archelon* the attention of the brilliant and incisive Baur had been turned to *Protostega;* and since then Hay, Case, Williston and Wieland have all contributed in turn to the literature of the Protostegidæ,— while in Europe Dollo has published papers of the greatest supplemental interest dealing with the origin of marine turtles.

Furthermore the collection of the splendid cotypes of *Protostega gigas* showing the complete limb structure, now in the Carnegie Museum of Pittsburg, and more recently the mounting for exhibition of the huge type of *Archelon ischyros* in the Yale Museum, have contributed much toward the increasingly accurate picture of the Protostegidæ. With the description of new species, meanwhile, and the appearance of the great volume of Hay—easily the foremost contribution to the literature of the Testudinata yet made—it is already evident that the Protostegidæ include a series of forms of the greatest structural interest, and that further additions to the family are

certain to be made. Moreover, to all these newer facts and viewpoints we are enabled to add the description of a new species, calling for analysis of the group.

To these forewords to the present revision I wish to add praise for the painstaking labor bestowed upon the mounting of *Archelon* by the Yale Museum preparator Mr. Hugh Gibb. Likewise we are indebted to the rare skill of the well known scientific illustrator and artist Mr. R. Weber for the illustrations following.

CHELONIOIDEA Baur.

SUPERFAMILY OF THE CRYPTODIRA.

A parieto-squamosal arch; palatine foramen and free nasals sometimes present (Desmatochelyidæ); fourth cervical cyrtean, with the centra of the sixth to eighth less modified in Cretaceous than in recent forms.

The five great marine families, namely, the Cheloniidæ, Protostegidæ, Desmatochelyidæ, Toxochelyidæ, and Dermochelyidæ, all doubtless independently acquired their equipment for life in the sea.[15]

Family *Protostegidæ* Cope.

Turtles with highly specialized thalassic humeri, but with three or more claws. A leathery hide and osteodermal armature evidently present. Carapace usually greatly reduced in later forms, the disk investing less than one-half the rib lengths. Plastron not markedly reduced. Peripherals serrate to strongly digitate on their interior borders; intra-peripheral dermogene ossicles sometimes present (known in *Archelon* only). Plastron very large, dactylosternal, with prominent fontanelles; epiplastra small, out-turned, separate, and wholly supported by the very large T-shaped entoplastron; hyo- and hypoplastra moderately digitate (*Protostega advena*) to strongly digitate (*Archelon*); xiphiplastra short and bowed. Pelvis with obturator foramina enclosed by complete ischio-pubic border. Coracoid extending all the way back to the pre-pubis except possibly in *P. Copei*. Skull large; temporal region broadly roofed over; descending processes of parietals; antorbital projection marked; quadrato-squamosal vertex much depressed; narial aperture more or less upturned; choanæ far forward, opening free behind vomer.

Genus PROTOSTEGA Cope, 1872.[1]

Premaxillary beak less developed than in *Archelon;* maxilla with rather broad grinding surface, which extends backward to behind front of orbit. Lower jaw with rami early coössi-

fied. Neuralia normal so far as yet seen, and without median pits or grooves. . Radial process of humerus large and projecting.

Species of Protostega.

A. Niobrara Cretaceous :—
    1. A medium-sized to large turtle, with a thin carapace investing one-third the rib lengths, and interior borders of marginals splitting into medium-sized digitations.   *P. gigas.*
    2. A small turtle, with more than half the rib lengths expanded and with less reduced plastron than the preceding ; the hyo- but not the hypoplastra meeting on the median line ; xiphiplastrals only slightly bowed ; marginalia heavy and without digitation of interior borders.   *P. advena.*
    3. A medium-sized turtle, with a comparatively thick carapace investing the proximal half of the ribs; plastral form nearly as in *P. gigas* but with more numerous digitations and smaller fontanels ; marginal borders serrate rather than smooth ; limb bones relatively short and small. This form has the heaviest shell of any Protostegid. The carapace is little more, and the plastron less reduced than in the Cheloniidæ. *P. Copei.*
    4. A large turtle, with xiphiplastra nearly joined on the median line and epiplastral pittings on outer anterior projection of hyoplastra.   *P. potens.*
B. Pierre Cretaceous :—
    5. An immense turtle, with neuralia like *P. Copei,* but humerus without a markedly strong radial process ; marginalia strongly digitate on interior borders.   *P. (Archelon) Marshii.*

Genus ARCHELON Wieland, 1896.[6]

Premaxillary beak greatly developed and strongly decurved ; crushing surface of upper jaw set far forward and limited to vomero-maxillar region ; lower jaw with rami not coössified until old age. Neuralia greatly reduced, to partly absent anteriorly, and replaced by epineuralia with a deep median sulcus nearly continuous to the eighth true [underlying] neural ; tenth rib relatively large, free, and extending out to marginalia. Radial process of humerus weak.

Archelon ischyros from the uppermost Pierre Cretaceous of the valley of the South Fork of the Cheyenne River is the only species.

Protostega Copei sp. nov. (Figures 1-4).

A new species, which may be appropriately named for the illustrious discoverer of the Protostegidæ, is indicated by the most complete and best conserved specimen referable to its family, thus far obtained. This splendid fossil is from the Niobrara chalk of the Hackberry Creek Valley, Gove county, Kansas, and was found in the summer of 1905, by the veteran collector and explorer, Mr. Charles H. Sternberg.

Fig. 1.
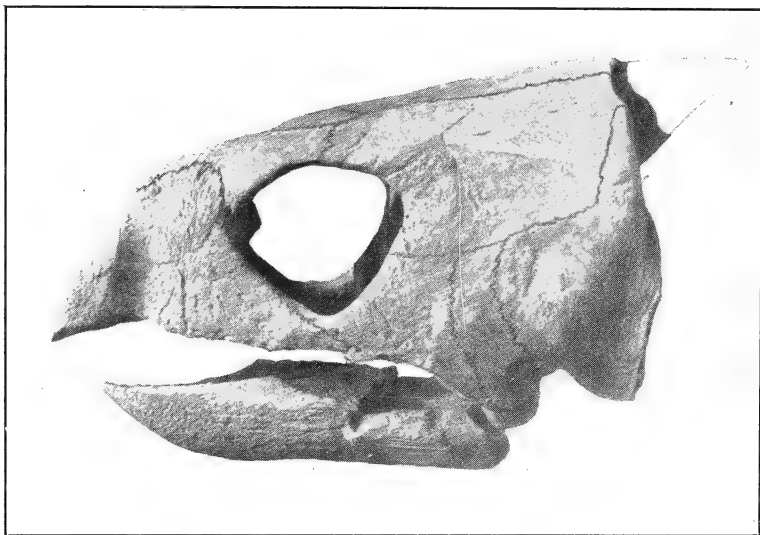
Figure 1.—*Protostega Copei.* Photograph of skull and lower jaw of type as mounted in the Yale University Museum by bringing together the dissociated and for the greater part but little crushed cranial elements. One-fourth the natural size.

Only minor portions of certain boundaries had to be restored. A little attention will at once reveal the limiting sutures of the premaxillary, maxillary, frontal, post-frontal, parietal, jugal, post-frontal and squamosal. Only the boundaries of the quadrato-jugal are generalized. The premaxillary is a little crushed to the left, and the most striking feature is the low-set position of the squamosal, which is but little if at all exaggerated. Cf. figure 6.

Not only is the present type one of the most complete of fossil turtles, but more than any other known specimen of *Protostega*, it permits exact comparison with *Archelon*, being for the most part free from the crushing which so often obscures the characters of the otherwise fine material from the

Kansas chalk. Owing to this freedom from crushing, it has been possible to restore with approximate accuracy the outline of the skull, carapace, and plastron, although all the elements of the entire skeleton were dissociated during erosion from their matrix, those recovered being as follows:

Skull, with lower jaw,—nearly complete, one squamosal and certain minor portions only missing.

Carapace : Nuchal; first to fourth neuralia; pygal; fairly complete series of ribs; first and second marginalia of both sides, with third and fourth of right side.

Plastron : Alæ of the entoplastron; hyoplastron of right side; hypoplastra and xiphiplastra complete.

Shoulder girdle : Both humeri and the procoraco-scapulars, with coracoid of right side only.

Pelvis : Only the right ischium missing.

The chief parts lacking, therefore, are the radius and ulna, the femora, and the bones of the hands and feet.

The dissociated elements of the cranium, as brought together and mounted with the lower jaw, afford the most satisfactory representation of a Protostegan skull thus far seen. In fact, the result displayed by photographic figure 1 must be of nearly the true form, since in addition to the presence of the lower jaw and nearly all the exterior elements, the main outline is further confirmed by the practically complete palatines, pterygoids, and quadrates. Only in the interior of the skull are clear characters lacking; for instance, the descending process of the parietals, noted by Dr. Hay in *Protostega advena*, cannot be observed.

In the main, the present fine cranium merely serves to corroborate the characters of the Protostegan skull, as already determined, and to bring out more clearly the major differences from *Archelon*. Thus, the strongly decurved beak and the upturned nares of the latter genus are absent, the outlines being more like those of other sea-turtles, with the orbits fairly well forward. The low-set squamosal, which certainly sent up a process along the posterior border to meet the parietal, however, is a family characteristic. The general outline reminds one not a little of the skull of *Colpochelys Kempii* Garman. Interiorly, there is no great conelike palatal projection of the vomer, as seen in *Archelon*.

While the present species is here defined as new, there is no very marked character not possessed by *Protostega gigas*, specific differences being mainly exhibited by the smaller limbs and the heavier carapace and plastron now to be described.

Carapace.—Hitherto it has not been possible to gain a satisfactory picture of the shell of any species of *Protostega*. All the specimens known have either lacked a large part of the

neuro-pleural series, or they have been so badly crushed as to render the general form and structure more or less doubtful, as in the case of the Carnegie Museum specimen that yielded such clear testimony to all the characters of limb organization; and even in the present instance the evidence is not so convinc-

FIG. 2.
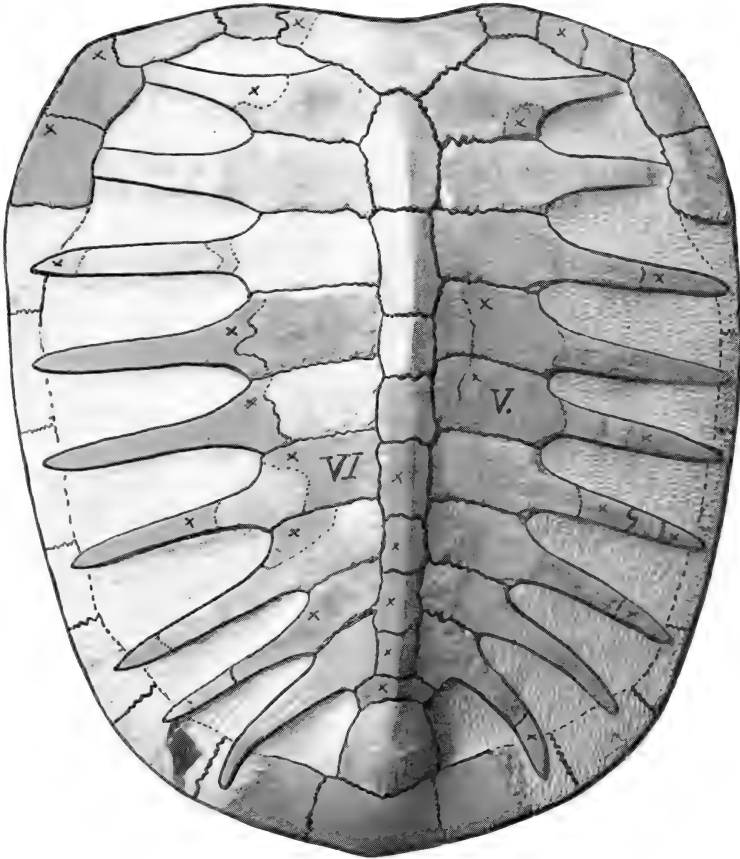
FIGURE 2.—*Protostega Copei*, 1/7 natural size. Carapace of the type as mounted in the Yale University Museum, from little crushed but dissociated elements lacking those portions marked by an (×) or else given in dotted outline. The portions actually present thus include a fine nuchal (with a nether process), the four first neurals and pygal with the three first marginals perfect, together with eight pairs of pleuralia. The disk is then correctly indicated; but concerning doubts as to the existence of a large ninth pair of ribs in contact with the marginals consult the text.

ing and complete as in *Archelon*, where the series of ribs is not only entire, but articulated. Nevertheless, owing to absence

from crushing, splendid conservation of all surface features, and the presence of a nearly complete series of ribs, with the nuchal, the anterior neurals, and important marginals completing all the frontal border, the present carapace must be regarded as a magnificent specimen. In fact, the only structural point in the restoration here given, which awaits confirmation or disproval by future discovery, is the degree of development exhibited by the tenth pair of ribs. They are represented free, as in *Archelon* in figure 2, and such ribs extending out to meet the final marginal are regarded as a probable family distinction. It may be, however, that placing the proximal portion of the right fifth pleural as assigned and then restoring a sixth and a seventh pleural on the left side are not warranted. In such a contingency two suppositions are, therefore, open, as follows: (*a*) The pair of ribs shown as the tenth may be really the ninth, and the true tenth pair of ribs may not be present, perhaps being only slightly smaller than those shown in the restoration, but passing out to meet the marginals. Such being the case, the only error made is in placing the pleuralia, from the fifth pair of ribs on, one number too far back; (*b*) An unrecovered tenth pair of ribs may be reduced, as in the Cheloniidæ, and may not have passed out to the final marginal. In this case, the post-fifth pleuralia would not only be one number too far back, but the carapace would be as here represented several centimeters too long. If either error has been made, the former seems by far the more probable.

The neuralia are heavier than in *Protostega gigas*, and form a strong unbroken mid-ridge of normal Testudinate form in sharp distinction to the epineural grooving and anomalous structure of *Archelon*. Though it is to be noted that on the first neural, the second and third, evidently on the fourth and fifth, and probably on the missing eighth and ninth, there is a strong accentuation of the mid-ridge, suggesting the appearance seen in *Toxochelys Bauri*. In the latter form, however, this feature is due to discrete epineural ossicles, while in *Protostega Copei* there is no evidence of osteodermal elements. Nor are there any hornshield groovings; on the contrary, the evidence is always to the effect that the Protostegidæ were enveloped in a leathery hide.

Fortunately, the nuchal is sufficiently complete to show the entire outline as a heavy normal element much as in *Osteopygis*, except that a prominent nether process is present. The first marginals, which are rather short and flat elements, are quite complete, as is also the rather long second marginal of the left side, with the distal half of that of the right side. On the latter may be traced with precision, one after the other,

the articular digitations and grooves corresponding to those of
the next member of the marginal series, namely, the third,
which is also complete and is followed by a fourth in equally
good preservation.   I am thus explicit, because it is important
to note that all the anterior border of the carapace is indicated
with certainty, and shows the presence of a peculiar upturning

FIG. 3.
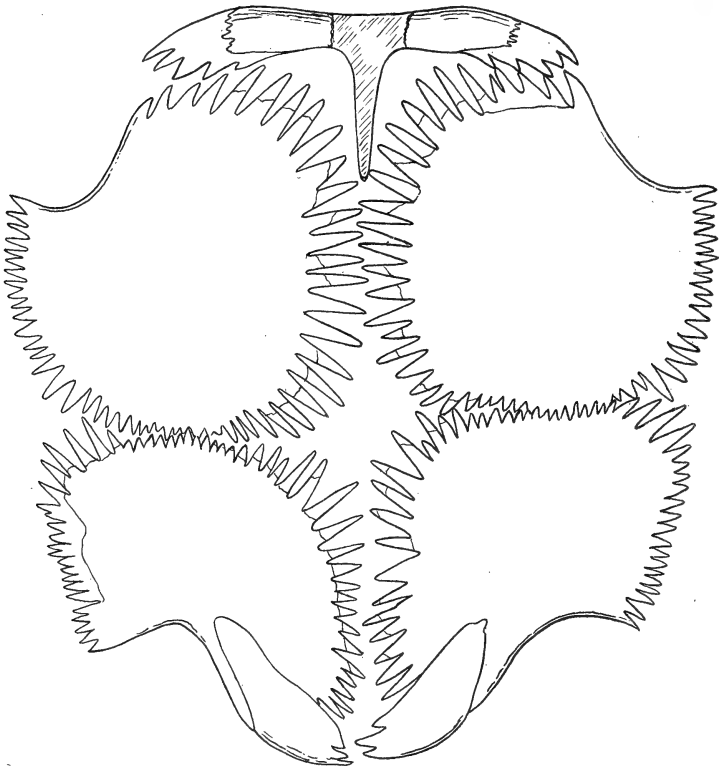
FIGURE 3.—*Protostega Copei.*   Plastron of the type × 1/7 nearly.   The
hypo-xiphilastræ are especially well conserved, and the left hyoplastron in
fair condition.   The right hyoplastron and portions of the T-shaped epiplas-
tron are not present; and as indicated in the figure, the ends of most of
the digitations of all the elements are missing.   Nevertheless the plastral
form is quite accurately indicated in its entirety by the original specimen
as here outlined.

of the portion of the carapacial edge formed by the junction of
the third and fourth marginals.   Evidence is here furnished
that the strong anterior and much upturned prolongation of
the third marginal of *Archelon* was an articulating portion

rather than a spine; and use has been made of this fact, although it might have remained in doubt but for the exact testimony of the present fine specimen. The interior borders of these marginals, however, do not have the strong digitation seen in *Archelon*, being only slightly serrated.

Fig. 4.
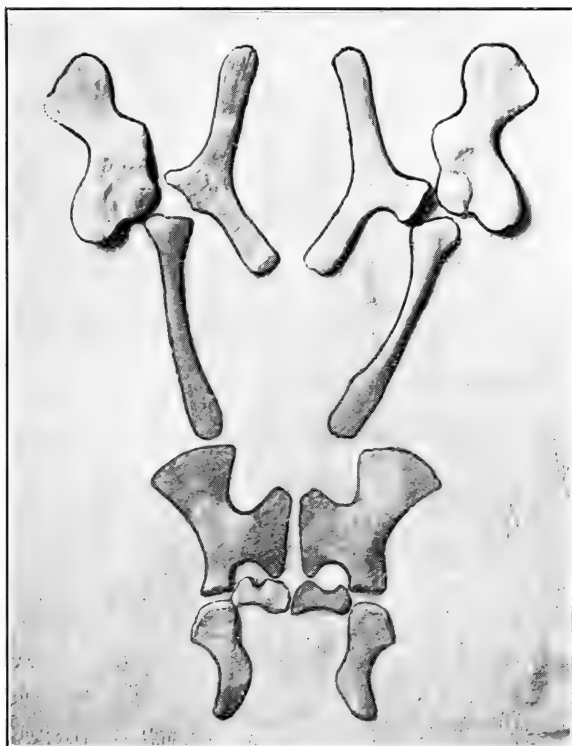
FIGURE 4.—*Protostega Copei.* Shoulder girdle with humeri and the pelvis of the type × 1/7. The only portions restored are the left coracoid and the right ischium. These elements belong to the very same individual as the skull, carapace and plastron shown in figures 1–3. [It is likely that consonant with the heavy carapace the limbs were shorter than in *P. gigas*, and that the coracoids did not actually come into contact with the ecto-pubis.]

Protostega Copei was not so orbicular a form as *Archelon ischyros*, and its plastron was relatively much shorter. As to the elements other than those now described, it appears neces-sary only to state that the accompanying illustrations suffi-

ciently exhibit not merely their characters, but their chief dimensions. Certain measurements, however, are appended, as follows:

Length of cranium from snout to condyle (accurate) __ 24·0[cm]
Greatest width of cranium across the condyles (close)__ 20·0
Length of lower jaw (on median line) _____ 15·0
Length of carapace (estimated) _____ 80·±
Greatest length of plastron _____ 63·5±
Greatest width of plastron _____ 66·0
Greatest thickness of plastral elements measured through
    their centers of ossification :
        Entoplastron _____ 15[·mm]
        Hyoplastron _____ 23·
        Hypoplastron _____ 20·
        Xiphiplastron_____ 13·

<div align="center">Fig. 5.</div>
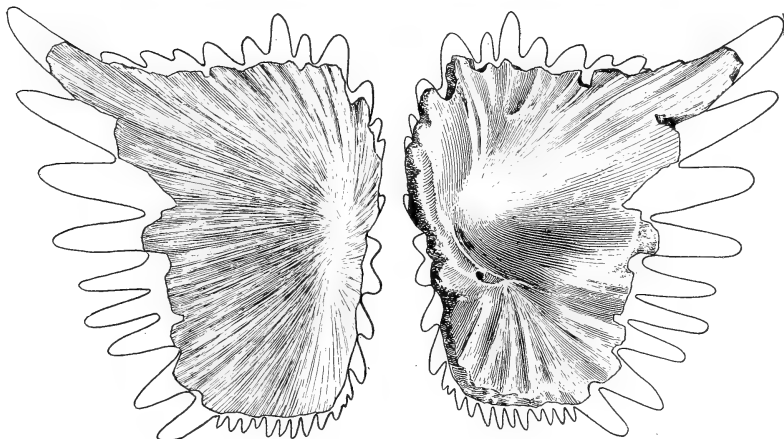
FIGURE 5.—*Protostega (Archelon) Marshii.* Right third marginal x¼. Dorsal view to the left, and ventral view showing large pit for the second rib to the right. [Dactylations should be represented as distinctly acuminate, but not much longer.] Observe, that as proven in *Protostega Copei*, articulation with the second marginal was formed by the long upward and forward projection, resulting in abrupt change in direction of the marginal line at the humeral notch, as revealed further by the figures of the entire skeleton.

Protostega (Archelon) Marshii Wieland[11] (Figure 5).

In this Journal for April, 1900, I gave a brief description of a new species of *Archelon*, which was based on the portion of a skeleton collected by me in 1898, on the left bank of the Cheyenne River. Until further material is found, as will with certainty transpire, the fragmentary condition of the present remains will scarcely justify much work upon them by a pre-

parator; nevertheless, the species represents an important fossil type.

A reëxamination of the specimen confirms the characters given, namely, a relatively short humerus and great thickness of the plastron, the latter being half as thick again as that of *Archelon.* As it is probable that the present turtle was not quite as large as *A. ischyros*, type (3·4 m.=11 feet long), however, it may be that its plastron was proportionally twice as thick as that of the latter species.

A fine third marginal of the right side shown in figure 5 is also present, and with it are articulated the keels of the more fragmentary fourth and fifth marginals. These elements are of much the same form as in *A. ischyros*, type, and although relatively heavier than in that species do not show the great disparity in weight noted in the plastron. More obvious differences of taxonomic bearing, however, are exhibited by a fragmentary, though otherwise finely conserved neural from near the middle of the neural series. This lacks the groove so highly characteristic of *Archelon*, and has a strong and continuous median ridge precisely like that in *Protostega Copei.* It therefore becomes necessary to transfer the present species from the genus *Archelon* to *Protostega*, where it holds a position of importance, as exhibiting not only the continuation of the latter genus from the Niobrara into the Fort Pierre, with marked increase in size, but, as far as we know, represents the closest structural approach of the genus *Protostega* to *Archelon*, thus far observed.

The Mounted type of Archelon ischyros (with Figures 6–12, and Plates II–IV).

All the material thus far referred to the genus *Archelon* has been discovered and collected by myself during the past fourteen years. The original type of *Archelon ischyros* was found in the brakes of the south fork of the Cheyenne River, about five miles west of the mouth of Rapid Creek, Custer county, South Dakota, in August, 1895. Though a remarkably complete fossil, it lacked the skull, which, however, was supplied by an excellent younger specimen with a fine cranium and the lower jaw in place, obtained in 1897. This is here shown by the photographic drawing, figure 6. In 1898, the related type *Protostega (Archelon) Marshii* was procured from the same horizon as the specimens of *Archelon*, but on the east bank of the Cheyenne, in the Pine Ridge Indian reservation. Later still, in 1902, a large individual of *A. ischyros*, nearly identical in size with the original type, was collected at a point several miles farther south, on the west bank of the Cheyenne. This

specimen has been of considerable value in showing the more important carpals in natural position, and in yielding additional finger bones and the epiplastron. A well-conserved lower jaw with fully coössified rami accompanies it. Like the type, it was completely imbedded in one of the lenticular masses of marl or clayey limestone common in the Pierre, but as this was much checked by cleavage planes there has been considerable shifting of parts. The specimen, while good, is not comparable to the original type, which, barring the lack of the skull (destroyed by erosion), is one of the finest of all great fossil vertebrates. It was but little crushed, and nearly all the parts present were in their normal position.

In addition to the examples mentioned, fragmentary portions of other specimens were obtained at different times, all pertaining to the uppermost one hundred feet of the Pierre, and all from within an area of about eight square miles. The best skeletal conservation was found in the bluish clays of the upper thirty feet of the Pierre, as covered by the Oligocene overlap in the Cheyenne River valley ; but most unfortunately a broad Oligocene river, the clearly marked bed of which I definitely located west of the Cheyenne, scooped out of these Pierre strata exactly the portion that must once have contained the most numerous and the best turtles, as indicated by frequency of occurrence as well as fine conservation on both banks of the old Oligocene valley.

The various specimens of *Archelon* have been made the subject of five contributions to this Journal. [6, 8, 11, 12, 14]. These partial descriptions have been repeated in a summarized abstract, with certain additional interpretations and views, in Dr. Hay's great volume on the "Fossil Turtles of North America." [17] It does not therefore seem necessary again to repeat the preliminary descriptions, except in so far as needed to call attention to inaccuracies disclosed by the final mounting of the type specimen, together with the great additions to our knowledge of *Protostega* made during the past half dozen years. It is the present purpose to give in concise form the features of this greatest of marine turtles disclosed by new discoveries and by mounting, which always sheds new light on the characters of a fossil vertebrate ; and especially to give the facts of classificatory value, together with a discussion of relationships.

The Skull (figure 6).—It is to be hoped that a second skull may be recovered. Thus far only the type skull and one additional lower jaw have been found ; hence, it is not possible to add to the earlier descriptions except in wholly minor points of interpretation. Moreover, abstracts of these descriptions with figures are given in admirable form in Hay's work previously cited, a work which every student of the Testudinata must

find indispensable. It may, however, be stated that in the restoration, Plate IV, the skull undoubtedly shows the exact proportions of the supra-occipital, this being an improvement upon the earlier figures.

The Vertebral Column.—The fact that the vertebral column of *Archelon* is so nearly complete and uncrushed, with nearly all the elements in undisturbed natural position, gives to the restoration high value. Only the four proximal cervicals and a few of the smaller caudals from near the tip of the tail are missing, while from the eighth cervical to the fifth caudal,

Fig. 6.
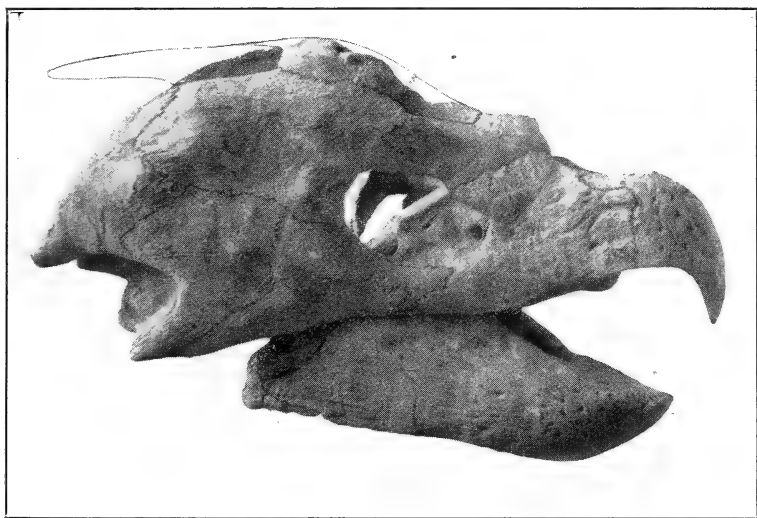
FIGURE 6.—*Archelon ischyros.* Skull of cotype shown about 1/8 natural size. The bounding sutures of all the exterior elements may readily be distinguished. [The restored supra-occipital crest, perhaps, is shown too slender.] The low set squamosal is, in comparison with *P. Copei* and *P. gigas,* seen to be a family character of the Protostegidæ.

inclusive, all the vertebræ are complete and in natural contact. Further, in the large specimen collected in 1902, the fourth cervical is present and of the normal or cyrtean form common to all marine Testudinata.

In *Archelon,* the cervicals succeeding the fourth are cœlocyrtean, with the inferior sides of the centra heavily double-keeled. The valley between the keels is broad and shallow. Neither in form nor size is there much variation in the distal cervical centra. Aside from strength and great size, the dorso-

sacral series presents no marked peculiarity, while the caudal series is rather short.   The arches of the first eight to ten caudals are free, but those of the remainder of the series are strongly fused to their centra.   It is not likely that the tail could have been so freely moved as might be implied from the over strong curve in the restoration.

Fig. 7.
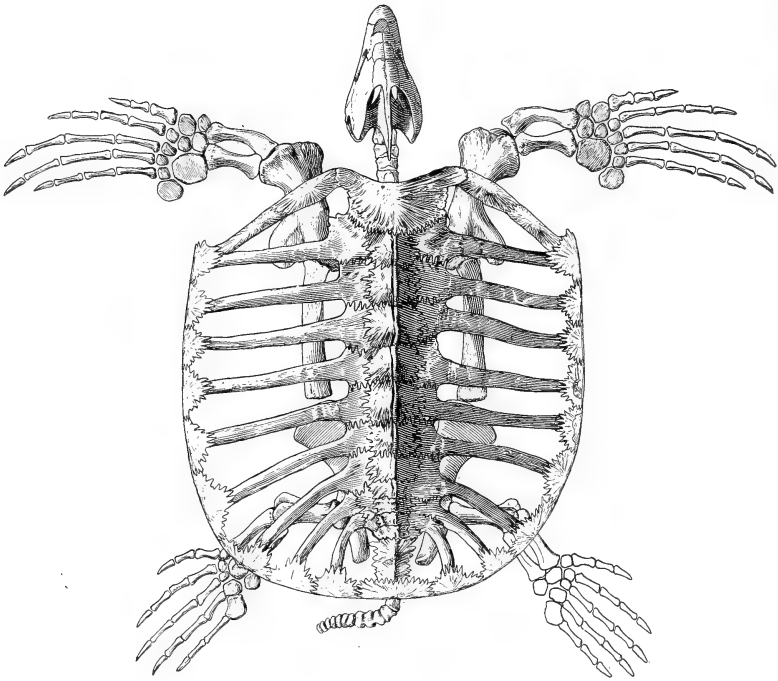
Figure 7.—*Archelon ischyros,* × 1/36.   Dorsal view of original type. It is not necessary to give in detail the exact outline of the restored portions. The skull is outlined from a cotype, and the right hind flipper shown in the normal outline was not present beyond the proximal half of the tibia and fibula, having, as explained in the text, been bitten away in the early life of the turtle.

Note on the mid-line following the nuchal seven larger plates followed by four smaller ones and then the pygal.   All these eleven plates intervening between the nuchal and the pygal are adjudged to be epineurals seated on the greatly reduced neural series which did not, as in all other turtles except *Dermochelys,* normally come into view at all.

Observe the nine pairs of fully developed ribs, of which the first large pair is the second, the small first pair not coming into view.   Infra- and supra-peripherals not indicated.

The Carapace.—The nearly orbicular form of the carapace is a striking feature.   The *nuchal* is very large and very thin,

especially in the lateral portion, indeed so thin as to suggest the necessity for strengthening by overlapping dermal ossifications. The anterior edge is strongly concave, being sharp, not rounded, in the middle region. The nether or cervico-neural articular process is prominent; it takes the form of a heavy trapezoidal ridge, longest in front, with a keel-like buttress radiating from all four corners.

The medial elements of *Archelon* are anomalous and require discussion as well as description. At first sight one would certainly say that there is a series of seven larger neurals following the broad thin nuchal, with four much smaller neurals preceding a single pygal element and making eleven neurals in all. On closer inspection, however, it is found that despite the fact that the neural region of *Protostega* is of simple and normal structure there is in *Archelon* a more complex arrangement of parts than in any turtle thus far discovered—a condition moreover that has a more distinct bearing on the meaning of the Dermochelan anatomy than any other thus far observed in fossil turtles.

In my original description I stated that " The medial plates unite very imperfectly by means of loosely doubled interlocking sutures and overlapping digitations grading into frequent free spines [spine-like projections] posteriorly. These digitations are mostly long, thin and ribbon-like, and produce a junction quite different from the usual suture. In many cases there is an appearance such as would result if the digitations of the one plate had lain upon the surface of the adjoining plate when it was in a plastic condition and thus raised rounded ridging about their edges. The order of the digitations and their size is rather regular." It was also explained that the carapace was very thin on the midline and that at a break exposing the section back of the sixth rib there were thin layerings. And it should now be added that, bearing in mind that in the mounted specimen the dorsal vertebræ remain articulated as originally, I am, perhaps, censurable for not having the carapace sawn through at the line say of the third, sixth and eighth dorsal centra. However this may be it was not done, and, awaiting further specimens, the type specimen in which all details are certainly present must yield as its only quota of new fact the superficial details. Indeed, were it not for the accidental fact that back of the ninth medial element two prepygal median elements are missing, and yet that there is continuity of the carapace, it would likely escape us that two layers of bone are present on the midline. At the point where these elements have become disarticulated one can see that the pleurals expand broadly beneath the median plates, but we cannot tell to what extent they replace or crowd the neurals,

which are evidently small posteriorly.   Immediately back of
the nuchal, however, there does not appear to be an underly-
ing neural, and one may say with certainty that all the anterior
neurals at least are very greatly reduced.   It is, too, equally
clear that these mere thin sheets of underlying bones that
can be referred to neurals, so far as they were seen in
fracture sections, have had *their function taken over by the*

FIG. 8.
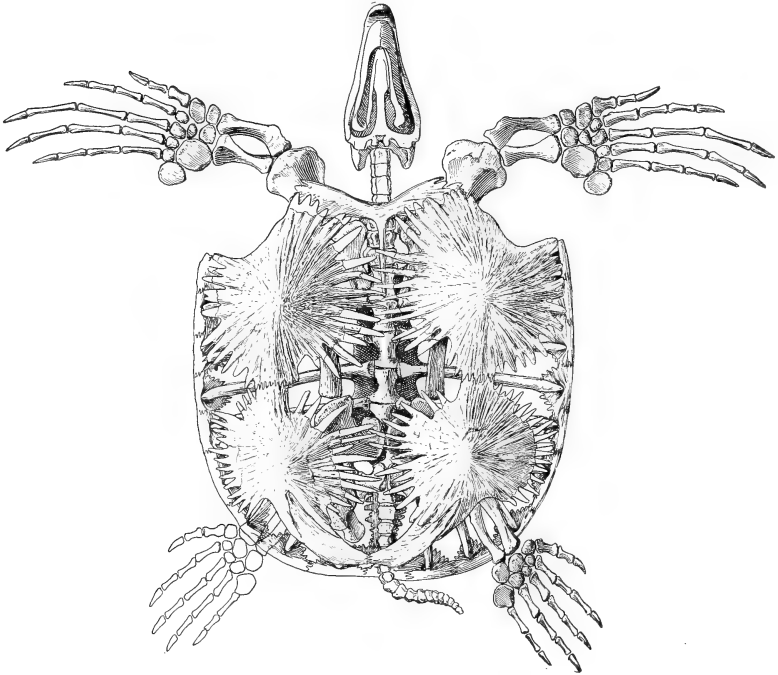
FIGURE 8.—*Archelon ischyros*, × 1/36.   Ventral view of type.   Compare
legend of the preceding figure.   Note that all the elements of the plastron
here shown occupied their normal position as originally recovered.   Only
the doubtful position of the omitted epiplastra prevents final accuracy.
Note also the great length of the plastron; it is nearly as long as the cara-
pace.   Observe the small size of the femoral notches.   The rib pair passing
beneath the hyo-hypoplastral suture is the fifth.

outer dermal series, which is continuous from nuchal to pygal
and thus corresponds to the neural keel of *Dermochelys.*
   On the nuchal itself no additional elements were observed,
but, as just stated, one may suppose from the great reduction
in thickness such may well have been present.   Indeed, it is
not impossible that the posterior end of the nuchal extended
beneath the first of the median supra-neural elements, and

that as a consequence our restoration is thus some ten centimeters too long.

Summarizing then : there are to be seen on the midline apparently overlapping all the neurals and the proximal borders of the laminæ of the nine pairs of normal ribs which pass out to meet the marginals, a series of eleven thin supra-neural elements simulating in size and outline a neural series.

These supra-neurals form a distinct median keel and are of distinctly quadrangular outline all the way back to the eighth and ninth, which are short on the median line, but nearly as broad as the others. The digitate character of the sutures between the successive members, but more particularly of the pleural overlap, has already been commented upon. All the outlines are quite exactly shown in my original figure (reference 6, Plate VI). A dominant feature of the midline is a narrow median groove which extends from the second to the seventh member inclusive and is most pronounced in the second and fifth. In the mid-region of each neural enumerated the groove is somewhat widened and deepened, sending out a radially ranged series of nutrition furrows or striations which form a dominant sculpturing of the mid-region of the carapace. Some further horny or even ossified elements may have occupied the mid-region of these shields. The aspect of the neural keel is thus seen to be different from that of any other turtle.

The supra-neurals of *Archelon,* be it noted, vary distinctly from those of *Toxochelys* in which the series is not continuous and corresponds to a normal series of vertebral horn-shields.

In *Archelon,* however, a leathery hide must have been present, with a system of keels of the usual number, as denoted by dermogene ossifications rather than hornshields ; these will be treated more fully later on. An ossicle like the supra-neurals of *Toxochelys* was found by Hay accompanying *Protostega advena,* but its derivation was left in doubt.

The pleural investment of the *ribs* occupies only the proximal fifth of their length. The free ends of the ribs are thus the dominating feature of the carapace. They are very heavy, in compensation for the light to almost paste-board thickness of the carapacial shield. The first rib is small and more or less curved and flattened. As in *Protostega,* it passed well to the front beyond the expansion of the first pleural, and may have supported either the thin posterior nuchal ala or possibly some osteodermal element.

It is here necessary to note that the type specimen remained packed, partly in the matrix, from 1898 until 1906. Owing primarily, however, to a luckless defect in my field notes,

which rendered a lapse of judgment easy, it was thought for
a time that the crushed coracoid of the specimen collected in
1902 was a heavy first rib.

As a result of this misconception, together with the uncer-
tainty regarding the carapace that had long existed in the
mind of every student of the Testudinata, I published the

FIG. 9.
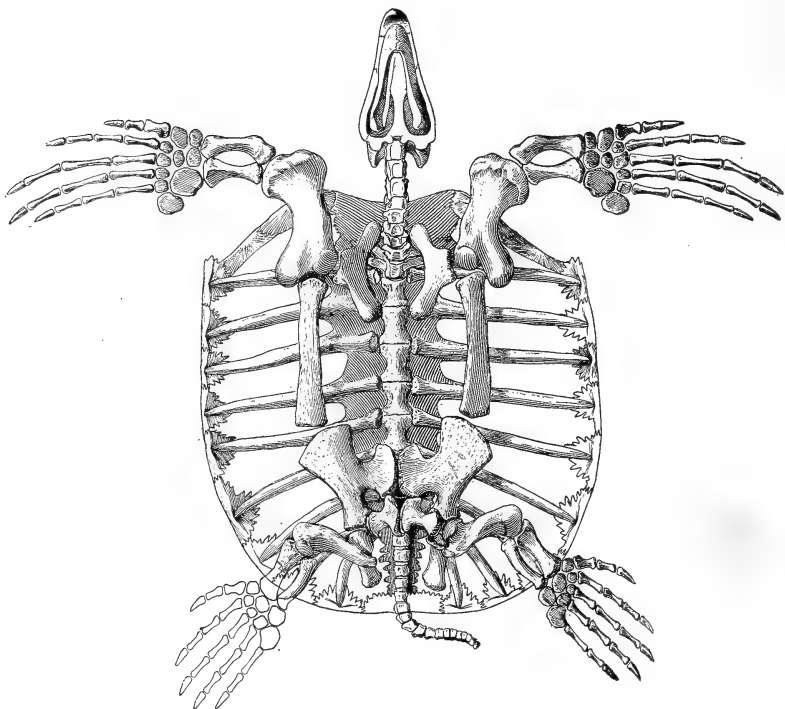
FIGURE 9.—*Archelon ischyros*, × 1/36. Ventral view of the type with plastron
removed. Compare legends of the two preceding figures. Recall that as
originally collected the vertebral column from the fourth cervical on was
found normally articulated and complete all the way to the smaller caudals,
a few of which were missing. Observe that the coracoids pass all the way
back to the ectopubes. Note in the hind paddle the large size of the tibiale
and fibulare, and the pisiformoid development or functioning of the fifth
carpal.

erroneous figure of my paper of 1903.[14]   But why Dr. Hay has
reproduced this in his volume,[17] I fail to understand, as I spe-
cifically declared the figure to be a mistaken one several years
ago. I can only regret that the original figure of *A. ischyros*[6]
was not used, and still more deplore the fact that the labor of
preparation on the type was not sufficiently advanced to permit

the offer to Dr. Hay of a photograph of the mounted skeleton
in time for use in his volume.

The tenth ribs verify the original and excellent figure of the
carapace in an important detail. In that figure, these ribs are
both shown as distally restored to a length indicating support
of the last marginal, were that element present. This restora-
tion is correct, the right tenth rib having since been found
complete, so that the length of the entire series is now abso-
lutely known; and it should here be emphasized that while
some of the ribs had disintegrated on one side or the other of
the carapace, there is not a pair in the succession, from the
first to the tenth inclusive, that lacks either a right or a left
member complete to the tip.

This functional development of the tenth rib is unique in
the Thecophora. It denotes either a more primitive condition
or a restrengthening of this element in compensation for a
carapacial shield not only in process of reduction, but probably
also of replacement by an external dermal series corresponding
to the usual Testudinate keels or lines of longitudinal develop-
ment.

The Marginals.—The marginal series of *A. ischyros*, type,
is considerably restored in the figures given (Plates II–IV), but
not hypothetically so. There are present in sufficiently good
condition for the determination of all the main features, margin-
als referred to ribs extending all the way from the second to
the eighth or ninth rib. Further, the fine third marginal is
present (cf. figure 5), which in *Protostega (Archelon) Marshii*
is suturally united with the fourth to sixth, the latter species
having marginals of quite the same form as in *A. ischyros*, type.
In the additional specimen of *A. ischyros* obtained in 1902, the
seventh (?) marginal is also present, while the first to fourth
are positively known in *Protostega Copei* (cf. figure 2).
Hence, remembering the functional tenth rib, it may be defi-
nitely stated that each rib beginning with the second bore a
marginal and that the pygal marginal, the only member of the
peripheral series not recovered in any of the larger forms
of the Protostegidæ (it is present in *P. advena*), was thin,
short, and broad, and must have had the form shown in the
restoration (Plate II).

The noteworthy and strange feature of the marginals is the
strong digitation of both the superior and inferior plates and
also of the anterior elbow formed by the outer border of the
third marginal. Were it not for the fact that in *P. Copei* the
junction with the second marginal is definitely shown, it would
scarcely be suspected that the true articulation of the third
marginal with the second in *A. ischyros*, type, takes place by
means of its long spinelike extension, which projects upward

and forward; for even in that portion of the outer border next
to the humeral notch there are blunt spines.

Did the spines of the marginals articulate with one or more
carapacial and plastral rows of dermal ossifications, and thus
afford the nearest approximation to the osteodermal mosaic of
Dermochelys yet discovered by adding dermal ossification on all
the keel lines, that is the neural keel, the pleural keel, the supra-
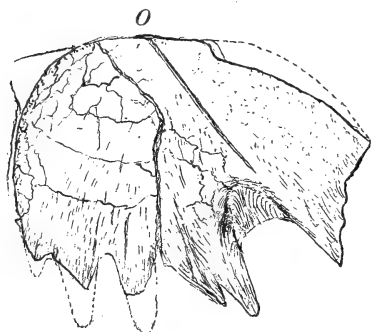marginal, and marginal
keel? I believe such to
be the case, for at least
two elements referable
to a similar additional
series corresponding to
the supra-pleural keel of
Dermochelys have been
recovered. Nor is it
strange that more have
not been obtained. A
fine shark's tooth per-
taining to a scavenger
species related to *Lam-
na* was found with the
type, and clearly indi-
cates that all dermal por-
tions loosely affixed to
other elements of the
carapace or plastron
must have been pecu-
liarly liable to disassocia-

FIG. 10.

FIGURE 10.—*Archelon ischyros* × ¼. A large
dermal ossicle found in connection with the
plastron of the original type, but possibly
dorsal. *O*, the outer view; *S*, sectional view
showing the extreme thinness of the element.
Note that the asymmetry of this element and
its dactylate border indicate not only connec-
tion with other dermal elements, but the
probability of the presence of entire series of
such elements.

tion. In what other than a supra-marginal or infra-marginal
position is it possible to place the thin and distinctly asym-
metrical element shown in figure 10? It represents an
integral part either of the carapace or of the plastron. Further,
the likewise unique element shown in connection with the
marginal in figure 11 can not be interpreted as in other
than a natural position. From the fact that it is digitate all
around and slightly asymmetrical, it may be inferred that a
series of such elements lay inside of, and articulated with, the
superior borders of the marginals, alternating quite regularly
with them in about a double number, and that beyond this
space a second much thinner supra-marginal series was present.
The space between the latter and the midline of the cara-
pace, where, as has been already seen, the presence of a median
row of supra-neural or in part osteodermal elements is demon-
strated, may or may not have been continuously occupied by
ossifications. In any event, there are the seven dorsal keels,
as in *Dermochelys*. On the plastral side, direct evidence of

dermal elements is lacking, although an agreement with the five plastral keels of the leatherback may be conjectured.

The Plastron (figure 8).—The nearly perfect plastron of the type has suffered somewhat during collection, by its removal from an exceedingly hard marl matrix into which the numerous and often interlocking spines of the mid-plastral region penetrated. Nevertheless, as finally mounted, the plastron may be said to be in splendid condition. All the central

FIG. 11.
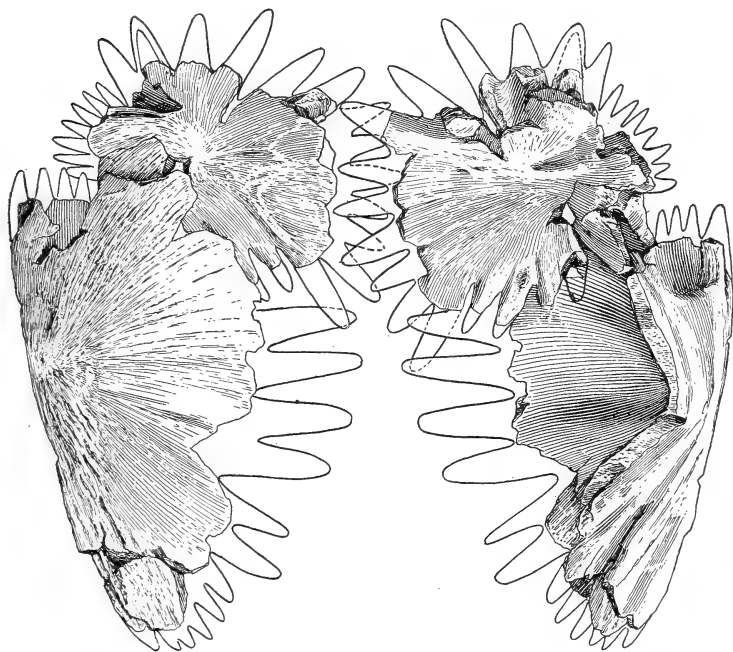
FIGURE 11.—*Archelon ischyros.* Left eighth or ninth marginal as found in conjunction with an additional element in a supra-marginal position. Shown ⅛ natural size. If the anomalous element is not a supra-marginal it must be referred to the supra-neural series just anterior to the pygal. A slight asymmetry does not prevent, although it makes such a position less probable. It is easier to consider this element as having been found in a natural position, and as perforce thus accounting for the supra-marginal keel of the carapace of *Dermochelys.*

portions of the large plates are present, with most of the spines, so that neither their size, form, length, or number, is ever in doubt. More important still, all the elements are but little crushed and, save the epiplastra, are present in their normally articulated position, just as they were figured in 1898.[9] In

commenting on this figure, Dr. Hay states that a length of 2100 millimeters is thus indicated for the plastron, making it larger than the carapace, which he considers impossible. Neglecting my measurement of the plastron, which was given as 2000+ millimeters, as well as the fact that the entoplastron is very plainly shown a little anterior to its true position, he also fails to note that the exact length of the carapace with the nuchal in position had not been determined by anyone. His first premise is therefore unfounded and his conclusion a pure assumption.

The important point, however, is that in the restoration, where the length of both carapace and plastron is definitely determined, the two are found to be nearly equal. In the dorsal view, the plastron appears a little shorter than the carapace, while in the ventral view, the enormous expanse of the plastron, greater by far than in *Protostega Copei* and greater than in any other sea-turtle, entirely cuts out the carapace. *Archelon ischyros* was certainly a very singular marine form; with its enormous size, huge plastron, and small femoral notch set far back, it had need of the great humerus, which by reason of form and musculature represents a powerful sea-type.

The unique T-shaped *entoplastron* of the Protostegidæ has had an interesting history. First called a nuchal by Hay in a Kansas specimen, it was left for Wieland[8] to determine conclusively and figure both these elements in *A. ichyros*, although there was uncertainty whether epiplastra were present at all. For reasons that now appear trivial, being merely an imperfectly indicated condition of overlap seen in the field, the excellent point of view developed in the paper just mentioned was abandoned for a time.[14]

Meanwhile the specimen of 1902 was obtained and was found to include still another puzzling bone,—the element that must be regarded as an anomalous epiplastron; and still later the fine type of *Protostega Copei*, here described, was discovered by Sternberg and acquired for the Yale collections. Thus was I enabled to determine finally that the nuchal and entoplastron noted in the paper of 1898[8] were truly such. This correction appeared in the Annals of the Carnegie Museum of Pittsburg for 1906.[15]

That scarcely one of the naturalists interested in the Protostegidæ escaped from wrong conclusions as to the nuchal and entoplastron, is after all not surprising. Both elements are of a form not before observed, this being especially true of the entoplastron, which except in *P. potens* Hay shows no indication of any ordinary type of epiplastral superposition or junction.

The epiplastra are doubtless of the form shown in figure 12. Referring to my first description, however, Dr. Hay thinks that the element figured must be the right, not the left member; superposition would therefore not be of the out-turned Trionychoid type that I have supposed. Dr. Hay saw this element soon after it was collected, and is consequently in a position to judge; nevertheless I think he errs and that the explanation of his opposite opinion is the condition he has observed in the entoplastron of *P. potens*. Moreover, I am not sure that he has correctly determined the hyo- and hypo-plastra in that turtle, for the elements he figures as xiphiplastra

Fig. 12.
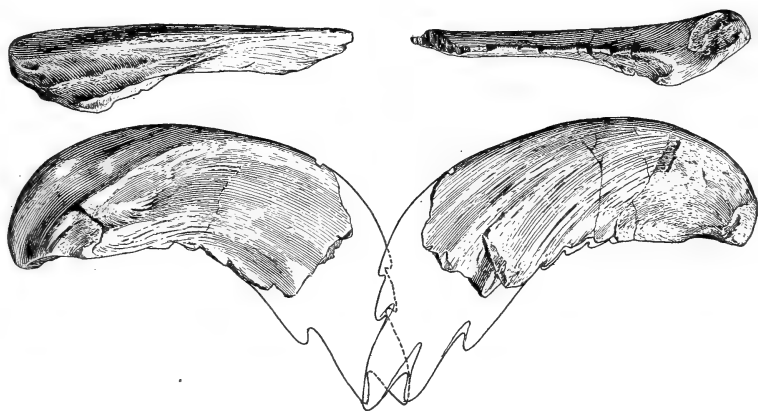
FIGURE 12.—*Archelon ischyros.* Left epiplastron, × ¼. Ectal view on the right below and ental view on the left. On the right above, the ante-rior, and on the left, the posterior edge views of the recovered portion are shown. (There is no doubt that the restoration of the thin dactylate end is fairly accurate both as to form and size.) This element was not present in the original type, having only been observed once in all the history of the Protostegidæ.

I should certainly have called hyoplastra. In either case, however, *P. potens*, the type of which Dr. Hay was kind enough to show us, is a quite different turtle from any of the foregoing, and the evidence it affords as to the form of the epiplastra is only negative and quite uncertain. It seems much better to accept the positive evidence at hand, which is to the effect that if the element figured is the true epiplastron, it projected beyond the anterior border of the entoplastron and was borne on it quite as in Trionychids. But rather than risk finality in error, it has not been given a place in the restored type of *A. ischyros*.

The *hyo-* and *hypoplastra* exhibit no very unusual features, except a great number of peripheral spines. The curved or somewhat boomerang-shaped *xiphiplastra* are of course more primitive than are the long and straight forms common to the Cheloniidæ.

That the plastral fontanelles appear to be of less area than is shown in figures of *Protostega*, is due more to the fact that the plastron under consideration is the best and most complete example known in the Protostegidæ than to any marked variance in proportions. The plastral resemblance in *Protostega* and *Archelon* is very striking, in view of other differences separating these genera.

The Shoulder Girdle and Manus.—The marked feature of the huge shoulder girdle is the projection of the coracoid all the way back to the pubis, a feature also present in *Protostega* and common to the existing *Eretmochelys*. The most characteristic element in the shoulder girdle of *Archelon* is the humerus because of its distinctly thalassic type.

The testimony as to the organization of the manus is reasonably complete and aside from minor differences exhibits general agreement with that of *Protostega*. The centrale in the latter is, for instance, more distinctly angled. While all the carpal elements of either a right or a left flipper are present, only the principal bones of the carpus have been found in position or approximately so. It is only in the left flipper that bones from another specimen have been introduced, namely, carpale I, the intermedium, and the pisiform, which fortunately were found together in this supplementary specimen. The only element in doubt was the centrale, but this seems to have been of a *rounder* form than in *Protostega*.

Of the metacarpals and phalanges, the majority are present and the proportions of the fingers are essentially those adopted in the restoration, although when a specimen is once found with these elements in place, as in the case of the Pittsburg Museum specimen, some slight modification of the present restoration may prove necessary.

The important anatomical features of the front flipper then are: (a) Agreement with *Protostega ;* (b) general agreement with the Cheloniidæ, the centrale exhibiting strong contact with metacarpal I, instead of exclusion from contact with this element by junction of the intermedium and carpale II ; (c) the comparatively slight modification and elongation of the phalanges for pelagic life, as contrasted with the much modified thalassic humerus. Although the latter is thus modified, it lacks much of the strength exhibited by the parathalassic Dermochelan humerus ; for while the radial crest has shifted toward the middle region of the shaft, it has failed to

retain a strong pedestal affording a powerful and firm type of muscular insertion. Curiously enough, the earlier Niobrara *Protostega* was better provided in this respect, since its radial crest forms a distinct ala nearly as prominent as that seen in *Dermochelys.*

This failure of *Archelon* to develop or retain, as the case may be, a prominent crest with stronger type of radial musculature may indeed indicate a certain failure to progress in swimming power and in resultant ability to follow the southward retreat of the great central Pierre sea. In fact, it was at just about this period of culmination in size of the Protostegidæ that the Dermochelan line more successfully accomplished such a change, as shown by the Eocene *Psephophorus,* a turtle nearly approaching *Archelon* in size and having a strongly pronounced and very low-set radial crest. It is on such grounds, as much as by the possible destruction of the eggs of the young by marine or even by newly evolved mammalian enemies, that sufficient cause is surmised for the extinction of these most gigantic of all marine Testudinates.

The Pelvic Girdle and Pes (figure 9).—The very perfect and uncrushed pelvis of the type was accompanied by the left femur, tibia, fibula, tarsals, and nearly all the metatarsals. On the right side, the femur is also present, with the proximal two-thirds of both tibia and fibula, which end in obliquely bitten off but healed surfaces. Both the femur and those mutilated elements are lighter and several centimeters shorter than the corresponding bones of the left side. In short, the evidence is conclusive and unmistakable that this animal had its right flipper bitten off when still young, and that as a result of this injury the remaining portion of the flipper was more or less arrested in growth by disuse. Such accidents are now and then noted in fossils. The type of *Dromocyon vorax* shows a broken lower jaw, subsequently reknitted, which was doubtless received in some raid on the young of *Palæosyops,* while a large percentage of existing marine turtles have had their flippers more or less mutilated by predaceous fishes and sharks.

I need not remind those familiar with the Testudinate osteology that the tarsal region of the sea-turtles is decidedly more variable in its organization than is the carpal region. Owing to this cause and to the failure to identify the excellently conserved tarsals with those of the crushed elements of *Protostega gigas,* it has not proved possible to orient the tarsals except in the most provisional manner. They are all free and heavy bones, and there is little doubt that all were present on the left side, however difficult and uncertain exact orientation may be.

The metatarsals are more readily recognizable, the fifth being much flattened and highly characteristic. Its distal half

is largest, not smallest as in *Protostega gigas.* In closing this brief description of the flippers of *A. ischyros,* type, it should be emphasized that while there is marked resemblance to *Protostega*, it is only the resemblance of members of the same family, and that the chief variation is in the humerus and the pes. [The other region of marked variation is on the neural line ; the crania do not differ greatly.]

The more important measurements of *Archelon ischyros,* type, are as follows :—

[Weight of humerus, exactly 75 pounds = 34 kilograms.]

Length of cranium from beak to occipital condyle 60·cm
" four distal cervicals (estimated)_____ 35·
" four proximal cervicals (present)_____ 33·
" ten dorsal centra measured on the ventral face _____ _____125·
" two sacral vertebræ_____ 9·5
" eighteen caudal centra (estimated; only a few of the more distal members are absent)_____ 67· ±

Total absolute length from beak to tip of tail, from measurements on ventral face of centra   329·5

(The corresponding total exterior measurement is not so accurately obtained, being slightly affected by pressure, but must have been $3\cdot4^m = 11$ feet.)

Length of first dorsal centrum _____ 8·cm
" second " " _____ 15
" third " " _____ 16·5
" fourth " " _____ 16·5
" fifth " " _____ 16·5
" sixth " " _____ 14·5
" seventh " " _____ 14·
" eighth " " _____ 10·
" ninth " " _____ 7·
" tenth " " _____ 6·

Total length of ten dorsal centra_____ 124·0

Length of first sacral centrum_____ 5·
" second " " _____ 4·5
" first caudal " _____ 4·5
" second " " _____ 4·5
" third " " _____ 4·5
" fourth " " _____ 4·0
" fifth " " _____ 4·0
" sixth " " _____ 3·0

Carapace :—

Greatest length on median line over slight curv-
ature, as mounted _____ 2·00ᵐ
Greatest absolute length _____ 1·93
Greatest width over partial curvature, as mounted 2·18
Width over curvature of second pair of ribs ____ 2·10

Plastron :—

Absolute length on median line _____ 1·87ᵐ
Width on line drawn across the humeral notches 1·83
Greatest width of hyo-hypoplastral fontanelle
(that at hyo-hypoplastral suture) _____ ·87
Distance between humeral and femoral notches 1·15

Comparative measurements of the right and left femora, tibiæ, and fibulæ, showing the check on growth due to the loss of the right foot.

Femora :—

	Right	Left
Extreme length _____	43·5ᶜᵐ	49·ᶜᵐ
" distal width ___ _____	20·0	22·3
Least antero-posterior thickness of shaft	7·2	·9·

*Tibiæ : *—*

Greatest proximal thickness _____	13·3	15·0

Fibulæ :—

	Right	Left
Greatest proximate thickness _____	7·2ᶜᵐ	8·3ᶜᵐ

Flippers :—

Distance between glenoid cavities _____ 58·±ᶜᵐ
Extreme length of front flipper outstretched
in a straight line (measure from glenoid
cavity), _____ 200·±
Extreme length from tip to tip of fully
outstretched front flippers _____ 458·±
Distance between acetabular foramina____ 28·
Extreme length of fully outstretched hind
flipper _____ 138·±
Extreme length from tip to tip of fully
outstretched hind flippers _____ 304·±

A few comparative measurements of *Protostega* and *Archelon*, clearly showing the differences in proportion to be expected in different genera, are the following :—

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*The distal ends of right tibia and fibula are cut away by a clean shearing bite ; hence the measurements of the left side are the normal ones.

	A. ischyros (type)	P. gigas (cotype)*
Extreme length of coracoid	75·cm	40·cm
Procoraco-scapular length	66·	30·
Median line to tip of second rib	100·	56·
Extreme length of humerus	60·	34·
Length of ten dorsal centra	127·±	68·
Extreme length of femur	49·	27·
" " " tibia	33·	20·
" " " fibula	31·	20·5
" " " radius	30·	20·
" " " ulna	35·	17·

Concluding Remarks.

Not only will future field work reveal new members of the Protostegidæ of the greatest interest, but quite all the skeletal features now in doubt must certainly be clearly observed as one specimen after another is collected. Indeed it can be freely predicted that but a very few years will be required to accumulate the material demanding a second revision.

Meantime it must be left to such further discovery to determine, among various other features, what the exact condition of the neural line of *Protostega gigas* really is, and whether this species and *P. Copei* do not really belong to separate genera; for there is a distinct suspicion that the species of Protostegidæ already known may really include a third genus. Evidently the marked difference in the structure of the carapacial midline between *Archelon* and *Protostega Copei* indicates a condition promising variations of the most striking and interesting character, to say nothing of the possibility of variety in the dermogene elements on the lines of the keels. These should very clearly be named in both *Dermochelys* and other turtles, the neural, pleural, supra-marginal, and marginal keels above, and the infra-marginal, hyo-hypoplastral, and the nether median or epi-xiphiplastral keels below.

It is not presumable that there is any doubt as to the presence of broad generic distinctions between *Protostega gigas* and *Archelon*, although the midline of these two forms may prove to be much more nearly similar than we now suppose. It is, however, a very striking fact that *Protostega Copei* and *P. (Archelon) Marshii* are both so much more nearly normal in their carapacial structure than is *Archelon*. This is to say, normal when we have in mind the great majority of turtles with normal neuralia such as the early Protostegids are shown to have. One might indeed suspect it possible from the strong

* This is the splendid specimen, No. 1421, of the Carnegie Museum, Pittsburg.

functional value of the epineurals of *Archelon* that there are turtles in which following elimination of a true neural series, an overlying dermogene series like that of *Archelon* has dropped down into the neural position once more.

The possibility of such cycles is, however, only hinted at. Taking the evidence at its face value, the important point is that *Archelon*, without having lost the power to develop an ossicular series, or perhaps in spite of having retained such a series, once had a closed carapace and plastron like that of modern turtles. Moreover, the earlier Niobrara Protostegas include the primitive forms like *P. Copei* and doubtless *P. advena* with well-developed neurals, and with far less of osteo-dermal development than in the later *Archelon*.

It is thus seen that of the two camps which have attacked the difficult and highly attractive problem of the origin of *Dermochelys*, those favoring the view of a close relationship to other turtles and a comparatively recent origin have rather the best of the argument. We have had on the one side Cope, the earlier Dollo, and Hay advocating an ancient and remote origin of *Dermochelys ;* while on the other, Baur, the later Dollo, and Wieland have believed *Dermochelys* a highly specialized descendant of true turtles, and hence of modern or relatively recent derivation. That the latter of these hypotheses more nearly expresses the final truth is now evident ; though both contain elements of truth, and are by no means so remote as they at first sight appeared to be.

Thus, just as Dollo deserted the one camp for the other, so Hay has gradually developed, not to say modified, his premises to a point where they adjoin our own. While not absolutely closed, therefore, and still lacking the testimony of many forms yet sure to be discovered, this famous controversy of the biologist as to the origin of the " leatherback " is now nearly eliminated. Nor is it too much to say that it has proved quite as fruitful throughout as the broader but scarcely more profitable question of the origin of the Testudinata.

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Art. VIII.—*The Submarine Eruptions of 1831 and 1891 near Pantelleria;* by Henry S. Washington.

Introduction.—Of the regions which are noteworthy for submarine eruptions, that part of the Mediterranean between Sicily and Tunis has become classic. In this broad, deep strait lie the two wholly volcanic islands of Pantelleria and Linosa, which undoubtedly began with submarine eruptions, but whose volcanic activity seems now to be quite extinct, or almost so. That the vulcanicity of the district is not yet at an end has been manifested several times during the nineteenth century, in the years 1831, 1845, 1846, 1863, and 1891, as well as possibly in 1801 and 1832. Of these the phenomena of the eruptions of 1831 and 1891 were noted by competent observers, and material ejected by them has been preserved and studied. Specimens of the lava from both of these came into my possession and have been examined with the miscroscope and analyzed, in connection with a study of the rocks of Pantelleria which is being carried out for the Carnegie Institution.

A map of the strait between Sicily and Tunis is given in fig. 1, based on the British Admiralty Chart No. 2158A, with a few additional data. The volcanic islands of Pantelleria, Linosa, and Graham are in solid black, and the site of Foerstner Volcano is represented by a straight line. The locations of the submarine eruptions of 1845 and 1846 are shown by small crosses. The site of the eruption of 1863, though reported to have been at that of Graham Island, is uncertain, and a note on the B. A. Chart No. 2127 indicates that it was searched for at the Hecate Patch. The hundred fathom line is marked by a dotted line, and two fifty fathom lines, inclosing the Adventure Bank and a small bank to the west, are marked by dots and dashes. Small "patches," where the depth is less than 20 fathoms and often less than 10, are shown by small dotted areas. Outside the hundred-fathom line the soundings on the chart are seldom more than 400 fathoms, though two of 717 and 890 are marked between Pantelleria and Malta.

It will be seen that the volcanic eruptions in general have originated in comparatively deep water and outside of the shelves which fringe the coasts of Sicily and Tunis, on which lie respectively the limestone islands of Malta, Gozo, Lampedusa, and Lampione, remnants of the early bridge between Italy and Africa, which were separated by faulting probably in Pliocene time. The known volcanoes, therefore, occupy the site of this fault, and the occurrence of the small, shallow "patches" in the continuation of the deep water to the northwest is interest-

ing in this connection. These areas of very shoal water are all small, and usually set in groups on a rather shallow "bank." In some cases, as the Keith reef, the bottom is so near the surface of the water that the sea breaks. Although many of these are covered with coral, the characters of their submarine topography (shown in detail for some on Chart No. 2127), which resemble those of shoals known to have been the sites of submarine eruptions, lead to the conclusion that these shal-

FIG. 1
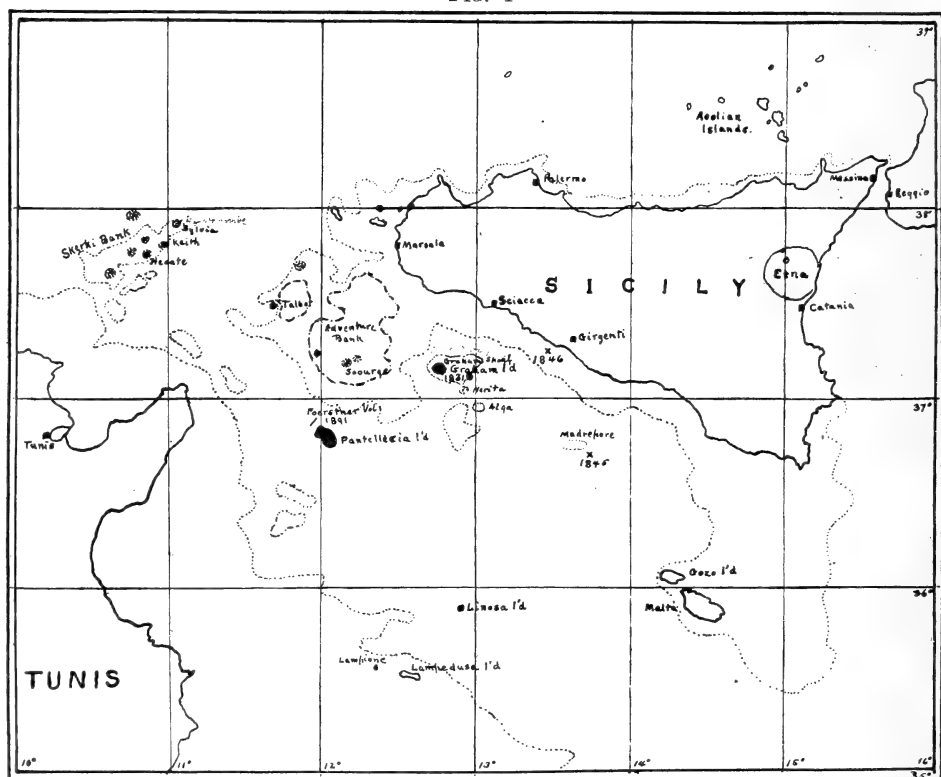
low patches have also originated in the same way, and that submarine eruptions have been of comparative frequency in this portion of the Mediterranean. That we have direct knowledge of so few of them need not cause surprise, when it is remembered that many of them probably gave rise to no solid or lasting island, as was true of Foerstner Volcano, and that their periods of activity were often short, so that, as was the case with the eruptions of 1845 and 1846, it is only by the rare chance of some passing vessel (generally the small

boat of some sponger or fisherman) that they are heard of. As Mercalli points out, also, our knowledge of the eruptions of Vesuvius and Etna prior to modern times, situated on land and in populous districts, is so fragmentary and incomplete that our ignorance of the many possible submarine eruptions is to be expected.

GRAHAM* ISLAND, 1831.

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The number of papers dealing with this eruption is fairly long. Johnston-Lavis† gives 28 titles and several others can be added to the list. The great majority date from the year of the eruption and those immediately succeeding, only one or two belonging to the latter half of the last century. The more important papers are those by H. and J. Davy,‡ H. Foerstner,§ C. Gemmellaro,‖ F. Hoffmann,¶ C. Prevost** and H.Abich;†† while general accounts are to be found in standard works dealing with vulcanology, as those of Landgrebe,‡‡ Fuchs,§§ Mercalli,‖‖ Lyell,¶¶ and Bonney.***

The Eruption.

The site of the eruption of 1831 was in lat. 37° 1′ 30″ N. and long. 12° 42′ 15″ E., about 30 miles southwest of Sciacca, on the coast of Sicily, and 33 miles northeast of Pantelleria.

The first signs of activity were shocks felt on board a vessel sailing over the spot on June 28, earthquake shocks being also felt in Sicily about the same time. During the first few days of July a fetid odor was perceived at Sciacca, and fishermen reported that the sea at the Nerita Bank appeared to be boiling and was covered with floating matter and dead fish. On

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* This small and ephemeral island has received seven names: Corrao, Ferdinandea, Giulia (Julie), Graham, Hotham, Nerita, and Sciacca. That adopted here seems to be the best founded, as it was that bestowed by the first person who landed on it, Capt Senhouse, and is that used by English and many American writers. The Italians use either Giulia or Ferdinandea, and the Germans mostly the latter.

† H. J. Johnston-Lavis, The South Italian Volcanoes, Naples, 1891, p. 105.
‡ H. and J. Davy, various papers in Phil. Trans. for 1832 and 1833.
§ H. Foerstner, Tsch. Min. Petr. Mitth., vol. v, p. 388, 1883.
‖ C. Gemmellaro, Atti Acc. Gioen., vol. viii, p. 271, 1834.
¶ F. Hoffmann, Pogg. Ann., vol. xxiv, p. 65, 1832.
** C. Prevost, Mem. Soc. Geol. France, vol. ii, p. 91, 1832.
†† H. Abich, Vulkanische Erscheinungen etc., Braunschweig, p. 72, 1841.
‡‡ G. Landgrebe, Naturgeschichte der Vulkane, Gotha, p. 50, 1855.
§§ K. Fuchs. Vulkane und Erdbeben, Liepzig, p. 22, 1875.
‖‖ G. Mercalli, Vulcani in Italia, Milano, p. 116, 1883 ; and Vulcani Attivi della Terra, Milano, p. 264, 1907.
¶¶ C. Lyell, Principles of Geology, 11th ed., vol. ii, p. 58, 1892.
*** T. G. Bonney, Volcanoes, p. 46, 1899.

July 8 the surface of the sea was seen to rise to a height of 80 feet, the column maintaining itself for ten minutes, and then again sinking down. This was repeated every quarter to half an hour, and was accompanied by a dense cloud of black smoke and loud rumblings. This column of smoke increased rapidly, and by the 12th large quantities of light-colored pumice were washed up on the beach at Sciacca. This material was analyzed by Abich.

On the 16th, Giovanni Corrao saw at the base of the column a small island about 12 feet high with a crater in its center containing boiling red water. The island increased rapidly in size, and was visited by Professors Hoffmann and Esscher. They estimated its height at about 60 feet and its diameter at 800 feet, though they do not appear to have landed. At this time the island had the form of a crescentic cone, with an opening to the sea on its southwest side, while a column of white smoke rose to an estimated height of 2000 feet.

A landing was first effected on Aug. 2, by Capt. Senhouse, who took possession of it for the British crown and gave it the name of Graham Island. After this it was visited by several geologists and others: by Gemmellaro on Aug. 12; by Hoffmann on Sept. 26, and by Prevost on Sept. 29.

The volcano seems to have attained its greatest dimensions of 65 meters high, with a circumference of about 3700 meters, in the early part of August, after which volcanic activity gradually diminished, though an eruption took place southwest of the island during this month. The general form was that of the summit of a cinder cone, the ridge being of uneven height, with a crater containing water in the center. The form changed materially from time to time, partly through the accumulation of volcanic ejections and partly through the destructive action of the sea, and the crater was sometimes breached and open to the north, and again to the south. But the sketches made of it are rather crude and unsatisfactory, for the most part. Among the best are those reproduced from drawings by Wright, given by Mercalli.*

The material of which the cone was built up is unanimously stated to be volcanic sand, lapilli, and scoriae, arranged in strata partly dipping inward toward the crater and partly dipping outward on the outer portions. The absence of lava flows is expressly noted by nearly all the observers. Although the material was undoubtedly to a large extent scoriaceous and fragmentary, yet the peculiar forms shown in some of the sketches lead to the inference that there was involved in the structure an upthrust of lava, probably in a highly viscous condition and more or less broken at the top. That is, there was probably present an upthrust plug or spine somewhat resem-

* Vulc. Ital., plates viii and ix.

bling, but on a much smaller scale than, that of Mont Pelée. In a general way, therefore, there is some reason for the belief, though it is now incapable of proof, that the structure of the island was similar to that of Bogoslof as recently described by Jagger,[*] though with by no means so perfect a spine as that shown in the photographs of Lacroix, Hovey, and Heilprin at Martinique, or in those of Jaggar. The " black rock " reported by Capt. Swinburne[†] as present in the bank remaining after the disappearance of the island is also evidence in favor of the existence of such a plug. This was 26 fathoms in diameter and projected to within 9 feet of the surface, and was sur-rounded by a bank of blocks and loose sand, sloping steeply down to great depths about 60 fathoms from the central rock.

According to Davy, carbon dioxide was the only gas evolved in considerable quantity, but other observers report hydrogen sulphide and sulphur dioxide, the odor of which was perceived at Sciacca, so that these may be assumed to have been present.

With diminishing volcanic activity the erosive action of the waves rapidly destroyed the island. By the end of October nearly all traces of the crater had disappeared, and the island was nearly level with the sea, except for a small hill of scoria which rose to a height of 190 feet on one side. During November destruction was rapid, and by the end of December only a small rock projected above the sea, and this soon disap-peared, leaving a small but dangerous shoal, with a small area only two and a half fathoms deep, as now marked on the British charts.

An eruption near the site of Graham Island is said to have taken place in 1632,[‡] and another submarine volcano is men-tioned as having been formed in 1801.[§] Subsequent to the eruption which has been described, another is said to have taken place on the site of that of 1831, beginning on August 12, 1863,[‖] which is reported to have formed an island about three-quarters of a mile in circumference, 200 or more feet high, and with a crater 30–40 yards across. The material of this is stated to have been loose ashes and sand, but none of it seems to have been preserved, and the island soon disappeared.

Mercalli[¶] also mentions two other eruptions off the Sicilian coast. That of June 18, 1845, took place in lat. 36° 40' 56'' N. and long. 13° 44' 36'' E., near the Madrepore Bank. About 9.30 P. M. the English vessel " Victory " felt a violent shock,

[*] T. A. Jaggar, Mass. Inst. Tech. Quart., vol. x, p. 31, 1908.
[†] Cf. Lyell, op. cit., p. 62.
[‡] Mercalli, Vulc. Ital., p. 117.
[§] E. Reclus, New Physical Geography, New York, 1886, vol. i, p. 408.
[‖] Cf. this Journal (2), vol. xxxvii, 1864, p. 442 ; also Mercalli, Vulc. Ital., p. 120, and Reclus, op. cit., p. 408. There seems to be some uncer-tainty as to the exact location of this eruption.
[¶] Mercalli, Vulc. Ital., p. 120.

which broke both her masts, the air was filled with a sulphur-ous odor, and three immense globes of fire were seen. The other eruption took place in the night of October 4–5, 1846, a little west of Girgenti, and nine miles from the coast. There does not appear to have been any shock, but the captain of a passing vessel, seeing a bright light, approached, and saw an immense mass of flames and smoke rising from the sea, from which were hurled incandescent globes. It is reported that the area covered by the flames was more than a mile in cir-cumference and that the sea appeared to be boiling.

Petrography.

Although it is commonly thought that the lavas of Graham Island were wholly basaltic, yet the descriptions of Gemmellaro and an analysis by Abich, as well as a brief description of one specimen by Foerstner, indicate that there was considerable diversity among them, those belonging to the earlier phases of the eruption having been distinctly trachytic in character.

The specimen examined by me is in the collection of the Peabody Museum at Yale University, having formed part of an old collection of rocks, though all record of its acquisition has been lost, according to Professor E. S. Dana, to whom I am deeply indebted for his kindness in supplying the material for analysis and microscopical study. The small specimen is accompanied by a label, on which is written in now faded ink and in an old-fashioned script: "Lava from the volcano that rose from under the sea off Sciacca, 40 miles from Sicily, Aug. 1831. Water 600 feet deep. Brought home by the Rev'd Eli Smith" (no date). There is no reason for doubting that it is what it purports to be, especially as its characters agree with Foerstner's descriptions of well-authenticated specimens.

The specimens examined by Foerstner came respectively from the museums at Palermo, Naples, and Strasburg; the first having been collected by C. Gemmellaro and the last (which differed much from the others) being labeled as "lapilli floating on the sea," and thus probably belonging to the early period when masses of such lapilli were washed ashore near Sciacca, as pointed out by Foerstner. Of these specimens Foerstner gives an analysis only of the first.

Megascopic.—My specimen is jet-black in color, and but slightly vesicular, the vesicles being very minute, and much of the small piece being quite compact. Foerstner's specimens would seem to have been much more scoriaceous and vesicular. Delicate, very small, glistening gray tables of feldspar are abundant, but no other phenocrysts are visible.

Microscopic.—The largest and most abundant phenocrysts are of labradorite, in tables from 0·5 to 2·0^{mm} long, by 0·02−0·10 thick, which are twinned according to the Carlsbad and albite laws. The extinction angles show that the composition is

about Ab_1An_2 or Ab_1An_3. These feldspars are highly euhe-
dral and the laths show well-formed terminal planes. The
tables sometimes surround portions of olivine and augite phe-
nocrysts, but carry few inclusions, mostly of black dust. Oli-
vine is rather abundant, in subhedral, and often highly euhedral,
equant individuals, up to 0.5^{mm} in diameter. It is quite fresh
and colorless, and carries few inclusions of ores and dust.
Augite is rather less abundant than the olivine, in anhedral to
subhedral, equant individuals, up to 0.5^{mm}, or rather larger.
It is almost colorless, but slightly yellowish or greenish, and
contains few inclusions. Opaque grains of magnetite, presum-
ably titaniferous, are not uncommon, though small in size.

Under low powers the groundmass is black and quite opaque,
but high powers resolve it into a colorless, isotropic glass,
thickly sprinkled with very minute black dusty grains. In
general characters my specimen resembles that of Foerstner
which he obtained from Gemmellaro, though the glass in his
was coffee-brown.

Chemical composition.—The results of my analysis are shown
in column I below. The analyses of Foerstner and Abich are
given also in II and III.

Analysis I is, in general terms, that of an ordinary feldspar-
basalt, and is remarkable in itself chiefly for the rather high
TiO_2 and the presence of considerable nickel. The high
amount of FeO as compared with the Fe_2O_3 is also a note-
worthy feature, which will be referred to again.

Foerstner's analysis (II) corresponds in general very well
with mine, showing but slightly more SiO_2 and Fe_2O_3 and a
little less Na_2O and K_2O, while the differences in the figures
for FeO, MgO, and CaO are somewhat larger, but sufficiently
close to indicate the practical chemical identity of the two
specimens. His much higher figure for Al_2O_3 is, of course, to
be ascribed to the non-determination of TiO_2 and P_2O_5, both of
which would be weighed with the alumina. In a later paper,[*]
discussing the lava of the submarine eruption of 1891 in the
analysis of which he determined TiO_2, he considers that in his
analyses of the Graham Island and Pantelleria basalts the TiO_2
was weighed with the silica, which should be corrected for
about 5 per cent of titanium dioxide. That this supposition is
incorrect is shown by the figures in analyses I and II above, as
by the facts of analysis. The residue left on correction of the
silica for impurities by evaporation with sulphuric and hydro-
fluoric acids consists largely of alumina and ferric oxide, and
does not contain all the titanium.[†] It may be noted in this
connection that this residue in my analysis amounted to only
1.73 per cent.

* H. Foerstner, Tsch. Min. Petr. Mitth., vol. xii, p. 520, 1891.
† Cf. W. F. Hillebrand, Bull. U. S. Geol. Surv., No. 305, p. 80, 1907.

	I	II	III	IV	Ia
SiO$_2$	48·97	49·24	51·87*	61·08	·816
Al$_2$O$_3$	16·37	19·06	15·30	17·37	·160
Fe$_2$O$_3$	1·33	1·77	----	7·77	·008
FeO	8·56	10·33	11·40	----	·119
MgO	6·22	5·00	8·66	4·02	·156
CaO	7·49	8·75	7·46	1·46	·134
Na$_2$O	4·09	3·89	3·90	2·85	·066
K$_2$O	1·72	1·19	0·85	1·82	·018
H$_2$O+	0·38 ⎱	0·63	----	1·63†	
H$_2$O−	0·08 ⎰				
TiO$_2$	3·95	----	----	1·45*	·049
P$_2$O$_5$	1·04	----	----	----	·007
MnO	0·06	----	0·60	0·62	.001
NiO	0·08	----	----	----	·001
	100·34	99·86	100·04	100·09	

* " Kieselerde mit Titansäure."
† " H$_2$O + Cl + H$_2$S " = loss on ignition.

I. Andose (feldspar-basalt scoria). Graham Island. Washington analyst.

II. Andose (feldspar-basalt scoria). Graham Island. H. Foerstner analyst. Tsch. Min. Petr. Mitth., vol. v, p. 391, 1883.

III. Black basaltic scoria. Graham Island. H. Abich analyst. Vulk. Ersch., p. 74, 1841.

IV. Light gray trachytic pumice. Shore near Sciacca, floated from Graham Island. H. Abich, analyst. Vulk. Ersch., Table III, No. 3, 1841.

Ia. Molecular ratios of I.

The analysis of basalt by Abich (II), made by fusion with barium carbonate, is very satisfactory, considering its date and the crude methods and reagents available at the time. It shows the broad chemical characters of the rock quite clearly, except the large amount of titanium, though the recognition of the presence of this constituent is noteworthy and is indicative of Abich's acumen and the accuracy of his analytical work. Analysis IV will be discussed later.

Classification.—Analysis I yields the following norm :

Or	10·01 ⎫			$\dfrac{\text{Sal}}{\text{Fem}} = 1 \cdot 93$	Class II
Ab	34·58 ⎬	65·72			dosalane.
An	21·13 ⎭				
Di	7·91 ⎱	22·35 ⎫		$\dfrac{\text{F}}{\text{L}} = \infty$	Order 5
Ol	14·44 ⎰				germanare.
Mt	1·86 ⎱	9·31	34·01	$\dfrac{\text{K}_2\text{O} + \text{Na}_2\text{O}}{\text{CaO}'} = 0 \cdot 90$	Rang 3,
Il	7·45 ⎰				andase.
Ap	2·35	2·35 ⎭			
Rest	0·60			$\dfrac{\text{K}_2\text{O}}{\text{Na}_2\text{O}} = 0 \cdot 27$	Subrang 4,
	100·33				andose.

The feldspar basalt scoria therefore is an andose (II.5.3.4), and it may be noted that calculation of the norm of Foerstner's analysis also leads to the same result. As the rock is highly vitreous, its mode is indeterminate.

Variation in the magma.—The second analysis by Abich (IV) was made of the light-colored pumice which was washed up on the shore near Sciacca during the first days of the eruption, while the other (III) was made of the scoria which formed the island itself and which dates from the later period of the eruption. They are of special interest, because, in spite of their crudities, they indicate that the material was not uniform in chemical character, but that the magma underwent a change in chemical composition during the progress of the eruption.

Abich, of course, does not give any description of the microscopic characters, and Foerstner's description of the light gray pumice (p. 392) which he also assumes to be that of the early phase, shows rather indefinite characters. According to him it is composed of flakes made up of minute, mostly colorless crystals, which have little action on polarized light, with redder, rust-brown particles and magnetite grains. The gray pumice contains fragments of material resembling the black basalt which he analyzed. He expresses the opinion that the light color may be due to the action of acid vapors. But his description, taken in connection with the analysis by Abich, which shows a marked variation in the alkalis, much lower lime, magnesia and iron oxides, and higher silica and alumina, as compared with the basalt, indicates that this light-gray rock is a pumiceous trachyte, presumably described from a differentiation of the magma.

The marked change in composition is commented on by Abich (p. 74), who suggests as a cause, either a gradual change in the depths from a silica-rich rock to one lower in silica with the addition of much lime (a vague forecast of the modern notion of differentiation), or the action of the volcanic, highly heated gases on pre-existing rocks, which gave rise to the gray pumice, his opinion favoring this latter interpretation.

In view of the short duration of the eruption the fact of such a decided change in magmatic character as is indicated by Abich's analyses is very striking. But its greatest interest lies in that the change is remarkably like that shown in the succession of magmas on the neighboring island of Pantelleria, where the earlier eruptions furnished highly salic and alkalic trachytes, rhyolites, and pantellerites, followed at the close by basalts very similar to that of Graham Island and the eruption of 1891. This would indicate for both localities a similar original magma and a similar course of differentiation. This matter will be discussed at greater length in a forthcoming paper on the rocks of Pantelleria.

FOERSTNER VOLCANO, 1891.

Bibliography.

The eruption of 1891, near Pantelleria, is less well-known than that of 1831.   Lasting only about a week, it was not seen by any scientific observer, and the descriptions have been derived from the testimony of fishermen.   The fullest account is that of A. Ricco.[*]   Mr. G. W. Butler visited Pantelleria about one month after the eruption and communicates some notes of his own,[†] with a brief description of the bombs (accompanied by an analysis by G. H. Perry).   He gives a translation of Ricco's report,[‡] on which the descriptions given by Geikie[§] and Mercalli[||] are also based.   H. Foerstner, in a paper describing the rocks,[¶] gives a brief account of the eruption, based partly on newspaper accounts and partly on Ricco's report, though there are some notable discrepancies.

This submarine volcano or eruptive center, which apparently gave rise to no island which projected above sea-level, has never been named, and is usually referred to as the submarine eruption of 1891, near Pantelleria.   For convenience of reference I would propose that it be called " Foerstner Volcano," in honor of the able investigator of the rocks of Pantelleria, adjacent to which the eruption took place, and the author of the best analysis and only detailed petrographic description of the rocks thrown out by the eruption yet published.

The Eruption.

The following brief account is based chiefly on Butler's translation of Ricco's report, as the original was not accessible to me.   During 1890 there were premonitory symptoms on Pantelleria, shown by increased activity of fumaroles, earthquake shocks (which cracked cisterns), and the elevation of a part of the northeast coast.   A sharp earthquake was felt during the night of October 14–15, 1891, when a further rise of the same coast line occurred, making the total elevation about 80 centimeters, as shown by a line of white incrustations marking the old sea level and by the testimony of the sea-faring population.

The eruption was immediately preceded by strong, sussultatory shocks on Pantelleria during the night of October 16–17, and the eruption began on the morning of the 17th, after which

* A. Ricco, Comptes Rendus, Nov. 25, 1891 : and Annali Uff. Centr. Meteor. e Geodinam. (2), pt. 3, vol. xi, 1892.
† G. W. Butler, Nature, vol. xlv, pp. 154, 251, 1891.
‡ G. W. Butler, Nature, vol. xlv, p. 584, 1891.
§ A. Geikie, Textbook of Geology, I, p. 334, 1903.
|| G. Mercalli, Vulcani Attivi della Terra, Milano, p. 265, 1907.
¶ H. Foerstner, Tsch. Min. Pet. Mitth., vol. xii, p. 510, 1891.

the earthquakes on Pantelleria rapidly diminished and then
ceased. Columns of "smoke," accompanied by deep rumblings,
were seen rising from the water about 4 kilometers west of the
town of Pantelleria, at the northwest end of the island. Those
who visited the spot found black, scoriaceous bombs, with much
steam, rising to the surface along a narrow line about 850–
1000 meters long, and directed northeast-southwest. Both
Ricco and Butler expressly state that no solid island was formed,
but that the erupted material was solely in the form of floating
bombs. According to Foerstner, on the other hand, by October
18, when the eruption seems to have been at its height, there
was formed an island about 1000 meters long, 200 meters wide,
and 10 meters high. The existence of a stable island may,
however, be doubted, in spite of these detailed figures, in view
of the explicit denial of Ricco and Butler.

Continuing their description of the eruption, vast numbers
of subspherical bombs rose to the surface, the largest having a
diameter of more than one meter. Some were thrown to a
height of 20 meters, and many ran hissing over the water,*
discharging steam, and being kept afloat by the gases con-
tained in their vesicles. The bombs were hot, some when
recovered sufficiently so to melt zinc (420° C.), and a few were
red-hot in daylight. After floating for a time, most of the bombs
exploded, the explosions succeeding each other so rapidly as to
resemble the noise of a battle, and the fragments sank to the
bottom. An odor "as of gunpowder" was noted, and some
H_2S and SO_2 seem to have been emitted. The eruption
ceased on October 25, and little change appears to have been
produced in the sea bottom (which, however, was not well
known previously), though the present charts show a small
area, of only about 30 fathoms, at the site of the eruption.

The most striking feature of this eruption, the ejection of
the material in the form of ellipsoidal or spheroidal masses,
called "bombs," is of interest as bearing on the origin of the
so-called "pillow" lavas, which consist of aggregates of such
forms. A very complete bibliography of these up to 1899 is
given by J. Morgan Clements,† who compares the ellipsoids
of the Crystal Falls District with the block lavas of Giorgios
Kaimeni at Santorini. Among later papers treating of the
subject may be mentioned those by I. C. Russell,‡ R. A.
Daly,§ and Reid and Dewey.‖

The origin of the structure is variously explained, a few

* One is reminded of the behavior of a globule of metallic sodium on
water.
† Mon. U. S. Geol. Surv., xxxvi, p. 112, 1899.
‡ Bull. U. S. Geol. Surv., No. 199, p. 113, 1902.
§ Amer. Geol., vol. xxxii, p. 74, 1903.
‖ Quart. Jour. Geol. Soc., vol. lxiv, p. 267, 1908.

attributing it to the accumulation of bombs or the viscosity of pahoehoe lava, ejected subaerially, while the greater number connect the structure with eruption under submarine conditions or with intrusions into mud or silt.   The authors of the last three papers cited, as well as Geikie and Teall, attribute it to truly submarine eruptions, and in the discussion of the latest paper Dr. Flett[*] cites "bombs" of the 1891 eruption in analogy with the ellipsoids of Cornwall.   It is noteworthy that, according to Butler's descriptions, the "bombs" of this agree in many respects with the Cornwall masses, especially in their highly vesicular texture, arranged in bands of somewhat varying characters.   As according to the account of Ricco, some of the "bombs" of the Foerstner Volcano were red-hot, even after floating for some time, it is evident that they must have been distinctly viscous, so that those which did not reach the surface and were piled up on one another must have been more or less flattened and distorted by the superincumbent mass, and thus have given rise to the peculiarities of shape and mutual fitting together of the curved surfaces so well shown in the illustrations to the papers cited above.

Some experiments by Johnston-Lavis, who found that globules were produced by injecting one highly viscous liquid into another, are cited by G. Platania[†] as illustrating the formation of the spheroidal basalts of Aci-Castello.   Such a division into spheroids would be favored were the injected material molten rock, when the influence of steam and the spheroidal state of water, or rather here of the injected lava surrounded by a layer of steam, would come into play, especially if the depth, and hence the supply, of water was so great as to prevent its exhaustion by evaporation.

It is notable in this connection that the examples of pillow-lavas seem to be wholly confined to the so-called "basic" rocks, those low in silica and high in femic constituents: whereas we find at eruptions in the open sea of lavas rich in silica (as at Santorini) that the mass has solidified into angular blocks. The difference is to be ascribed to the difference in the relative fusibility and viscosity of the two kinds, the highly femic magmas lending themselves readily to the assumption of a more or less spherical form as the mass separates on issuing into the water, while the very viscous siliceous magmas would, on comparatively small cooling, become so nearly solid as to crack, and their rapidly complete solidification would prevent the rounding of the sharp angles of the blocks.

[*] Quart. Jour. Geol. Soc., vol. lxiv, p. 270, 1908.
[†] In H. J. Johnston-Lavis, the South Italian Volcanoes, Naples, p. 42, 1891.

Although the eruption of Foerstner Volcano ceased in October, 1891, there appears to have been another submarine eruption in December of the same year, which took place south of Pantelleria and is said to have formed a small island about 500 meters in diameter.* Foerstner also mentions the formation of a small island "in the waters of Pantelleria" in July, 1881, observed by Captain Swinburne, but he cites no authority and there would seem to be some error in the date. This is not mentioned by Fuchs† in his list of volcanic eruptions of 1881, nor by Mercalli.

Petrography.

The petrographical characters of the bombs have been briefly described by Butler,‡ and in greater detail by Foerstner.§ The material examined by me was obtained in 1897 from Mr. Francis H. Butler, of London, a cousin of the author of the papers cited above, who collected with him on Pantelleria. Mr. Butler wrote me as follows in a letter dated 21st November, 1907, by which it appears that there can be no doubt as to the authenticity of my specimen :

"My specimens of the Pantelleria rocks were collected by myself early in November, 1891. The submarine lava was floated to the sea among the fishing boats N.E. (*sic*) of Pantelleria during an eruption in, I think, October, 1891. . . . . . The vesicular submarine lava from which my specimen came was obtained by some fishermen. Many of the masses of lava floated to the surface exploded, and all, after awhile, that were not saved by the fishermen became waterlogged and sank. I was present at the purchase of the big mass of submarine lava from which your specimen came : the greater part of the block was presented to Prof. Judd for the Royal College of Science."

According to G. W. Butler the bombs show a brownish outside layer, about one inch thick, due to the vesiculation of brown glass, which contains phenocrysts of triclinic feldspar, olivine, magnetite, and probably augite. Beneath this is a darker layer about one-half an inch thick, which is mostly glass with the same minerals. The greater part of the bomb is coarsely spongy, perfectly black with a pitchstone-like luster, and more highly crystalline in thin section, composed of about one-third triclinic feldspar, olivine, and augite, and the rest a black groundmass, opaque in thin section.

My specimen probably came from the interior, as may be inferred from this description and from the small amount of

* H. Foerstner, Tsch. Min. Petr. Mitth., vol. xii, p. 510, 1891.
† C. W. C. Fuchs, Tsch. Min. Petr. Mitth., vol. v, pp. 97-101, 1883.
‡ G. W. Butler, op. cit., p. 251.
§ H. Foerstner, op. cit., p. 513-518.

salt extracted by leaching. It is coaly black, with a slightly brownish tinge and pitchy luster; very highly vesicular, with small, rounded vesicles, the size of which varies somewhat in different parts of the specimen, as is also true of Foerstner's piece. No phenocrysts are visible.

Microscopic.—Judging from Foerstner's description and the examination of my specimen there is considerable variation in the microscopic character, though not more than is usual in such glassy scorias. The most abundant and prominent pheno-crysts are of a lime-soda feldspar, showing Carlsbad and less often albite twinning, the extinction angles of which indicate the composition Ab_1An_2, which is somewhat more sodic than appears to be true of Foerstner's rock. These feldspars are tabular and very thin in my specimen, measuring only up to $0·5^{mm}$ long by not more than $0·01 − 0·05^{mm}$ thick; while in Foerstner's they would appear to be larger and more euhedral, and more nearly like those in my specimen of the Graham Island lava. The phenocrysts of augite are few, up to about 1^{mm} in diameter, subhedral and stoutly prismatic, of a brownish or greenish gray. Colorless olivine is present, apparently in less amount than the augite and in smaller, mostly anhedral grains, though a few show euhedral rhombic sections.

The groundmass in my specimen consists of a brownish, clear glass, which is very thickly sprinkled with a rusty brown or black dust, so much so as to be almost or quite opaque in places. Foerstner notes two varieties of the glassy ground-mass; one highly vitreous, and the other less so, in which the glass is present in small amount as a cement or mesostasis. He describes these in great detail, which it is needless to quote here.

Chemical composition.—The material of the bombs ejected by Foerstner Volcano has been analyzed by Foerstner and by Perry, the results being given in II and III below. A new analysis made by me is given in I, the rock powder having been leached with water, as in the preceding case, by which process only a very small amount of salt was extracted. Foerst-ner states that his specimen contained about 25 per cent of sea salts, so that his probably came from the exterior, and mine from the interior, of a bomb.

My analysis shows low silica and alumina, very low ferric oxide but very high ferrous oxide, low magnesia and alkalis and rather high lime and phosphorus pentoxide. The most striking feature is the very large amount of titanium dioxide, which is almost unparalleled elsewhere among volcanic rocks, and is only exceeded in the melilite-basalts of the Hegau.*

* U. Grubenmann, Inaug. Diss. Zürich, 1886.

	I	II	III	Ia
SiO$_2$ -------------	44·83	44·64	46·40	·747
Al$_2$O$_3$ -----------	11·73	12·74	21·84	·115
Fe$_2$O$_3$ -----------	1·35	4·21	9·53	·009
FeO -------------	11·79	11·17	2·04	·164
MgO ------------	5·50	5·82	5·37	·138
CaO ------------	9·63	10·12	10·33	·172
Na$_2$O ------------	3·34	4·31	3·27	·054
H$_2$O + ----------	0·81 �	0·51	n.d.	
H$_2$O − ----------	0·10 ⎠			
K$_2$O ------------	1·40	1·41	1·69	·015
TiO$_2$ -----------	6·88	5·86	n.d.	·086
P$_2$O$_5$ -----------	2·14	n.d.	n.d.	·015
MnO -----------	0·20	0·20	n.d.	·003
	99·70	100·99	100·47	

Analyses of basalt scoria from Foerstner Volcano (1891) :

I. Analysis by H. S. Washington.
II. Analysis by H. Foerstner, Tsch. Min. Petr. Mitth., xii, p. 512, 1891.
III. Analysis by G. H. Perry, Nature, vol. xlv, p. 252, 1891.
Ia. Molecular ratios of I.

The amount of nickel was not determined, but it is probably about the same as that found in my analysis of the Graham Island basalt (about 0·10 per cent), as shown by the depth of the greenish tint of the filtrate from the ammonia precipitate.

Foerstner's analysis (II) agrees very closely with mine in most respects, and especially shows about the same amount of TiO$_2$ and a similar very high ratio of ferrous to ferric oxide, though his figure for the latter is decidedly higher than in I. His alumina must be corrected for one or two per cent of P$_2$O$_5$.

The alumina of Perry's analysis (III) must be corrected for about 9 per cent of TiO$_2$ and P$_2$O$_5$, the subtraction of which would bring the figure for alumina close to those of the other analyses. The figures for the iron oxides are reversed as compared with those of Foerstner and myself, and must be regarded as incorrect, especially as Perry himself expresses doubt as to their accuracy.* The somewhat higher silica may be due to its not having been corrected for impurities by evaporation with HF. The other figures are closely concordant with those of the other two analyses.

Classification. — The norm of I is calculated to be as follows :

* He remarks, " As the powder was magnetic, Fe$_2$O$_3$ was probably combined with FeO to form Fe$_3$O$_4$. This would give FeO 7·55, Fe$_2$O$_3$ 4·18." The basis of calculation for these figures is not clear, as they yield a molecular ratio of FeO : Fe$_2$O$_3$ = 4 : 1.

Or _____ 8·34 ⎫
Ab _____ 28·30 ⎬ 49·43
An _____ 12·79 ⎭

Di __ ____ 17·22 ⎫
Hy _____ 5·21 ⎬ 29·21
Ol _____ 6·78 ⎭

Mt _____ 2·09 ⎫ 15·16 ⎪ 49·41
Il_____ 13·07 ⎭

Ap _____ 5·04　5·04 ⎭

Rest ____ 0·91

——

99·75

$\dfrac{Sal}{Fem} = 1\cdot00$　Class III, salfemane.

$\dfrac{F}{L} = \infty$　Order 5, gallare.

$\dfrac{K_2O + Na_2O}{CaO'} = 1\cdot50$　Rang 3, camptonase.

$\dfrac{K_2O}{Na_2O} = 0\cdot28$　Subrang 4, camptonose

According to my analysis, therefore, the rock is a camptonose (III.5.3.4), and falls almost exactly at the center of all the divisions, except that it tends to be domalkalic. As regards the femic constituents, which may be briefly considered because the rock is salfemic, it falls in the dopyric section of the dopolic grad, and in the premiric section of the permirlic subgrad, as brought out by the following ratios:

$$\text{Grad } \frac{P + O}{M} = 1\cdot93, \qquad \text{Section of grad } \frac{Di + Hy}{Ol} = 3\cdot31.$$

$$\text{Subgrad } \frac{(Mg, Fe)O + CaO''}{Na_2O''} = \infty,$$

$$\text{Section of subgrad } \frac{(Mg, Fe)O}{CaO''} = 2\cdot35.$$

The rock is also prehemic, since $\dfrac{Mt}{Il} = 0\cdot16$, but no provision has been formally made for recognition of this relation in rocks of the salfemane class, though the relations of Fe_2O_3 and TiO_2 are expressed in the suborders of classes IV and V.[*]

According to Foerstner's analysis, as given by him, the rock falls in monchiquose (III.6.2.4), because of the higher soda and the considerable amount of lime that enters normative anorthite and diopside, and thus takes up so much silica as to give rise to the presence of much nephelite in the norm. If, however, the alumina is corrected for two per cent of P_2O_5, the subrang becomes kilauose (III.5.2.4), since much of the lime is thus used in forming apatite, leaving more silica for the soda. The relations are shown below.

These relations, while of no importance in themselves, are of interest in showing the necessity of the determination of the minor constitutents for the purposes of the quantitative classification. The norm of III need not be considered.

[*] Cf. Cross, Iddings, Pirsson, and Washington, Quant. Class., p. 134, 1903.

NORMS OF II.

	Uncorrected	Corrected
Or	8·34	8·34
Ab	16·24	27·25
An	11·40	5·84
Ne	10·79	4·83
Di	31·30	24·50
Ol	5·02	7·44
Mt	6·03	6·03
Il	11·10	11·10
Ap	none	5·00

In the prevalent classifications the rock is a vitreous feldspar-basalt scoria. The mode need not be discussed, as it is indeterminate, owing to the large amount of glass present.

Correlation of the Basalts.

In the following table are presented a number of analyses made by me of basalts from the same general region and of characters similar to those here described.

	I	II	III	IV	V	VI	VII	VIII
SiO_2	48·97	44·83	45·72	46·22	46·55	48·84	47·66	43·64
Al_2O_3	16·37	11·73	12·45	12·23	14·55	14·62	14·36	13·52
Fe_2O_3	1·33	1·35	1·57	4·91	3·17	2·08	2·33	6·40
FeO	8·56	11·79	12·01	7·71	7·88	9·00	8·44	5·52
MgO	6·22	5·50	5·29	6·74	8·61	7·15	8·19	9·36
CaO	7·49	9·63	9·58	9·86	8·75	9·33	9·36	9·52
Na_2O	4·09	3·34	3·40	3·39	3·71	2·86	3·51	3·89
K_2O	1·72	1·40	1·08	1·13	1·62	0·89	1·54	2·18
H_2O+	0·38	0·81	0·40	0·17	0·14	0·49	0·17	0·49
H_2O-	0·08	0·10	0·01	0·05	0·03	0·07	0·20	0·16
TiO_2	3·95	6·88	6·43	5·68	3·84	3·57	3·83	4·55
P_2O_5	1·04	2·14	1·54	1·46	0·55	0·36	0·45	0·74
MnO	0·06	0·20	0·16	....	0·10	0·04	....	....
NiO	0·08	....	0·15	....	0·12	0·08	....SrO	0·03
	100·34	99·70	99·82	99·55	99·62	99·89	100·54	99·60

I. Andose (II.5.3.4). Graham Island, 1831.

II. Camptonose (III.5.3.4). Foerstner Volcano, 1891.

III. Camptonose (III.5.3.4). Dike in Costa Zeneti, Pantelleria. Quart. Jour. Geol. Soc., lxiii, p. 74, 1907.

IV. Camptonose (III.5.3.4). Monte Sant' Elmo, Pantelleria. Quart. Jour. Geol. Soc., lxiii, p. 74, 1907.

V. Camptonose (III.5.3.4). Block in tuff, Il Fosso, Linosa. Jour. Geol., xvi, p. 23, 1908.

VI. Auvergnose (III.5.4.4-5). Monte Ponente, Linosa. Jour. Geol., xvi, p. 17, 1908.

VII. Camptonose (III.5.3.4). Castellfullit, Catalonia. This Jour. xxiv, p. 239, 1907.

VIII. Monchiquose (III.6.2.4). La Garrinada, Olot, Catalonia. This Jour. xxiv, p. 239, 1907.

Apart from the higher silica and alumina of the earlier one, the basaltic lavas of the two submarine eruptions are closely similar, I being slightly higher in MgO and Na$_2$O and lower in FeO, CaO, and P$_2$O$_5$. The variation in TiO$_2$ is also considerable, but in both rocks the amount of this constituent is higher than usual among basaltic rocks. The distinctly more femic character of the later eruption is in harmony with the decidedly more siliceous and salic character of the material of the early phase of the Graham Island eruption, as shown by Abich's analysis to which attention was called above, and there is thus indicated a progressive change in composition with increase in femic constituents for the general magma of the region. A change in the same general sense has already been noted as having occurred on Pantelleria, and a similar relation is observed on Sardinia, where the large volcanoes of Monti Ferru and Arci poured forth respectively phonolitic trachytes and rhyolites in the early stages of activity, followed by extensive outflows of basalt. On this island too all the small cones of the most recent date are basaltic, though varying somewhat in composition, and in general decidedly more salic than are those of Pantelleria, Linosa, and the two submarine eruptions. The basalts of Catalonia also show great analogies with those of Pantelleria and the neighboring volcanic vents, as has been elsewhere pointed out.

Aside from the very high TiO$_2$ of all these basalts, one of their most striking characters is the predominance of ferrous over ferric oxide. This ratio $\dfrac{\text{FeO}}{\text{Fe}_2\text{O}_3}$ reaches a maximum in the basalts of the two submarine eruptions and in that of the dike on Pantelleria, which are highly vesicular, and shows a minimum in the also very vesicular lava of La Garrinada, near Olot. Lavas showing ratios between these extremes are either only slightly vesicular or are solid flows.

In a former paper[*] the difference observed at the Catalan volcanoes was ascribed to the more favorable conditions for oxidation of the ferrous iron when the lava issued in a highly vesicular condition. Since, however, we find that oxidation is at a minimum in the highly vesicular basalts described in the present paper, some discussion of the matter will be pertinent.

The ready oxidizability of the ferrous iron in rocks on heating in air, even when in the solid though powdered form, is well known to all who have had to make rock analyses, and the researches of Gautier [†] have shown that steam alone also exerts a powerful oxidizing action on ferrous silicates. On the other hand, further researches of Gautier and of Hüttner showed
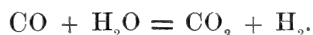
[*] H. S. Washington, this Journal, vol. xxiv, p. 240, 1907.
[†] Cf. F. W. Clarke, Bull. U. S. Geol. Surv., No. 330, 1908, p. 228.

that CO_2 can be reduced to CO by the action of hydrogen at elevated temperatures. Gautier also showed that the reaction is reversible, at a white heat being:

$$CO_2 + H_2 = CO + H_2O,$$
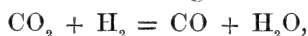
and at temperatures between $1200°$ and $1250°$

$$CO + H_2O = CO_2 + H_2.$$

As Clarke remarks: "When water emitted by heated rocks (or that of the sea, H. S. W.) mingles with carbon dioxide, within the vent of a volcano, both reactions take place, and mixed gases, which sometimes contain a trace of formic acid, are generated. This mixture is a powerful reducing agent, which acts upon the iron silicates in an opposite direction to that of the oxidizing vapor of water. Either oxidation or reduction is therefore possible, according to the preponderance of one constituent or another among the volcanic gases."

We may therefore ascribe the difference in the iron oxide ratios in the scoriaceous lavas to the fact that, in one case they were erupted subaerially and in the other subaqueously. In the former large quantities of heated air would have acted on the highly vesicular masses during their ejection, and would have materially aided the steam present in oxidizing the ferrous iron of the magma. In the other, free atmospheric oxygen was wanting and, as we know that carbon dioxide was emitted in large amount at Graham Island, and presumably also at Foerstner Volcano, we may suppose this and the steam to have reacted with the formation of carbon monoxide and hydrogen, which would have had a powerful reducing effect on any ferric iron present in the magma. In the case of the compact and scarcely vesicular lavas, such as those of Catalonia, which were ejected in the form of massive flows, there would have been comparatively little opportunity for either an oxidizing or a reducing action, and we should expect to find, as we do, ratios of ferrous to ferric oxide intermediate between those of the scorias, and presumably more nearly like that of the original magma.

The reducing conditions at the submarine eruptions must also have been very materially increased by the hydrogen sulphide and sulphur dioxide, which we know to have been present. In this connection it is of interest to recall that John Davy found that the waters of the two small craters of Graham Island, on August 5, contained hyposulphite of lime and magnesia, in addition to sulphates, but no salts of the alkalis. Although the condition of chemical analysis at the time does not give this statement much weight, yet it may be significant. Abich remarks on the absence of hydrochloric acid during the

whole progress of the Graham Island eruption, a gas which is so commonly observed at other volcanoes, as Vesuvius.

The very high $FeO : Fe_2O_3$ ratio shown by the basalt of the Zeneti dike does not seem to be explicable by the hypothesis advanced above, as it is decidedly vesicular and yet apparently not due to a submarine eruption.   Discussion of this rock must, however, be reserved for a later publication, in connection with the geology and petrography of Pantelleria.

In both his papers cited above Foerstner suggests that the basalts of the eruptions of 1831 and 1891, as well as those of Pantelleria, are connected with those of Etna.   Of the lavas of Etna, however, we have no modern or satisfactory chemical analyses, strange as it may appear.   With the exception of one of an ash by Ricciardi in 1884,[*] none of them are later than 1881.   The lavas and ashes of Etna have been analyzed[†] by O. Silvestri, Fuchs, Gümbel, Von Lasaulx, and Ricciardi. Most of the analyses show a general resemblance to each other, as well as to those by Foerstner of the basalts of Graham Island and Pantelleria, in which TiO_2 and other minor constituents have not been determined.   The studies of Von Waltershausen and Von Lasaulx also show that, while the lavas of Etna are predominantly basaltic, there are numerous flows and dikes of more salic rocks, especially belonging to the earlier phases of this volcano, a fact already noted by Abich.   There is, therefore, reason for the belief that the magmas of Etna and of Pantelleria and the submarine eruptions are chemically similar and probably genetically connected.   But, as a marked characteristic of the basalts of the latter volcanoes is the high content in titanium, it is clear that modern, complete analyses of the Etna lavas are needed before the matter can be discussed intelligently.

Locust, N. J., August, 1908.

* L. Ricciardi, Att. Acc, Gioen., vol. xviii, p. 4, 1884.
† J. Roth, Beiträge zur Petrographie, p. cxxviii, 1869, and pp. lxxvi–lxxx, 1884.

Art. IX.—*Types of Permian Insects;* by E. H. Sellards.

Part III.—Megasecoptera, Oryctoblattinidæ and Protorthoptera.

The terms *Dromeus, Scopus* and *Therates,* proposed for genera of ephemerids in Part II of this paper, have been found to be preoccupied. As substitutes I suggest for *Dromeus* Sellards (non Reiche), *Misthodotes ;* for *Scopus* Sellards (non Megerle), *Mecus ;* for *Therates* Sellards (non Latrielle), *Esca.* The term *Rekter* should read *Recter ;* while *Tupus* (Pt. I, p. 249) should read *Typus.* For these corrections I am indebted to Mr. Leonhard Stejneger of the National Museum.

Megasecoptera.

The Megasecoptera have four slender, equally developed wings, which are broadest at the middle and narrowed at the base. The anal area of the wing is notably reduced. Cross veins are not numerous. The abdomen is long, and is terminated by streamers.

The group is abundantly and typically developed in the Commentry Coal Measure deposits of France,* and is sparingly represented in some other European, and in the American Coal Measure deposits.† The Megasecoptera have been known heretofore from the Carboniferous only. Their extension into the Permian is indicated by the genus herein described.

Opter Brongniartii gen. et sp. n. Text-figure 7.

The genus *Opter* is based upon a single detached wing, the apex and a part of the inner border of which are wanting. The wing is thin, slender, and very much narrowed at the base. The costal border is straight. The subcosta is a thin vein running parallel to the radius. The media is united with the radius in the basal one-fourth of the wing. At its point of separation from the radius the media has a characteristic downward curve almost touching the cubitus. The cubitus is two-branched. Cross veins occur sparingly in the wing.

Length of wing estimated, 13 to 15^{mm} ; width, 2½ to 3^{mm}.
Type specimen No. 1286.

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* Charles Brongniart, Insectes fossiles des Temps primaires, pp. 280 et seq., 1893.
† Anton Handlirsch, Die Fossilen Insekten, p. 312 et seq., 1906.

Oryctoblattinidæ.

The family Oryctoblattinidæ has been erected recently by Handlirsch and is placed by him among the Protoblattoidea.[*] The genera referred to this family by its author are as follows: From the Carboniferous; *Oryctoblattina* Scudder, *Blattinopsis* Giebel, *Anadyomene* K. v. Fritsch, *Glaphyrophlebia* Handlirsch, *Microblattina* Scudder, *Prisca* K. v. Fritsch, and *Rhipidioptera* Brongniart; from the Permian, *Oryctomylabris* Handlirsch, and *Pseudofulgora* Handlirsch. Two additional genera obtained from the American Permian are added in the present paper.

The family contains several forms of particular interest. The genus *Rhipidioptera* was originally referred by its author, Brongniart, directly to the Homoptera, and to the recent family, Fulgoridæ.[†] The forms known in literature as *Fulgorina Goldenbergii* Brongn. and *F. ovalis* Brongn., and regarded by some as Homoptera, are included in this revised classification in the genus *Blattinopsis* Giebel. The Permian form known as *Fulgora Ebersi* Dohrn (*Fulgorina Ebersi* Gold.) stands as the type of the new genus *Pseudofulgora* Handlirsch. Some of the other genera, including the type genus, *Oryctoblattina*, had been previously regarded as cockroaches. It is thus seen that the family is made up of forms originally referred to very diverse groups. The geological range of the Oryctoblattinidæ as now known is through the Upper Carboniferous, and into the Permian.

The wing venation in this family is characteristic. The numerous veins uniting the subcosta with the costa have the appearance of cross veins rather than of oblique branches, differing in this respect from the blattid wing. Subcosta and radius are distantly separated and are united by oblique cross veins. The radical sector arises early and is repeatedly subdivided. The media is two to several times branched. The cubitus has usually numerous inferior branches. The anal area is marked off by a thin depressed line, and is traversed by a few strong veins.

That part of the wing lying between the sector and the cubitus affords the specially characteristic features of the venation. Most genera have a plainly marked line extending across this area from the cubitus to, or beyond, the sector, thus marking off the basal from the apical half of the wing. This cross line is plainly marked in *Blattinopsis*, *Anadyomene*, *Prisca*, *Pseudofulgora*, the two Permian genera described below and in two undescribed genera obtained by the writer

[*] Revision of American Paleozoic Insects, 705, 1906; Die Fossilen Insekten, p. 155 and p. 346, 1906.
[†] Insectes fossiles, p. 445, 1893.

from the Kansas Coal Measures. The line does not appear in the illustrations of *Oryctoblattina, Glaphyrophlebia, Rhipidioptera,* and *Oryctomylabris,* although the venation is otherwise closely similar. The cross line marks the location of a more or less distinct break in the continuity of the veins. The apical part of the wing beyond the line is closely filled with veins.

Among modern insects a similar interruption in the venation by a cross line is best developed and most often observed in Hemiptera, and has led, perhaps not without reason, to the comparison of some members of this family with Hemiptera. In pointing out recently the existence of a similar line in the wing of Cicadidæ, Woodworth writes*: "The most curious feature of this venation is a mark extending across the wing, which can be seen only in certain lights upon the membrane; but wherever this line crosses a vein, it is very evident, because the vein is here entirely interrupted;" and p. 123, "In this connection a similar structure in the fossil *Fulgorina* is, as already pointed out, of interest."

If this peculiarity in the wing venation occurred among Hemiptera only (Homoptera and Heteroptera) the argument for the Hemipterous affinity of the Oryctoblattinidæ would be very strong indeed. Handlirsch states, however, that a similar break occurs in some Mantidæ and in many other insects (p. 158, Die Fossilen Insekten, 1906.)

The body structure is unfortunately still very imperfectly known. Brongniart states that certain specimens representing this family from the French Coal Measures have parts of the body preserved. No illustrations of these specimens are given and the description is brief. The body is said to be short; the head rather large; the eyes large, round, and salient. The antennæ are described as in some specimens long, in others short. Regarding the mouth parts, it is stated that two little pieces are observed in front of one of the impressions which may be mandibles.† The hind wings of the family are unknown.

Until more definite information regarding the body structure and the hind wings of the Oryctoblattinidæ is obtained a satisfactory placing of the family seems hardly possible.

Pursa ovata gen. et sp. n. Text figure 4.

This is a genus of small Oryctoblattinidæ. The wings are arched, the apices bluntly rounded. The radial sector arises as a thin vein near the termination of the basal third of the wing. The media is broken up at the base. Its attachment

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* The Wing Veins of Insects ; by C. W. Woodworth, Univ. of California, Technical Bulletin No. 1, Agri. Experiment Station, p. 122, 1906.
† Insectes fossiles, p, 446, 1893.

is apparently with the sector. The cubitus has several weak, inferior branches. A complete interruption of the veins occurs at the cross line in this genus. The apical part of the wing is traversed by numerous simple, parallel veins.

Length of wing, 8^{mm}; width, 3^{mm}. Type, No. 1126.

Sindon speciosa gen. et sp. n.   Text figure 1.

The costal border of the wing of species of this genus is slightly arched. The radial sector in the type species is divided into several branches, each of which is forked at the tip. The media is two branched. The cubitus has numerous strong arched parallel branches. The interruption of the veins at the middle of the wing is much less marked than in the genus *Pursa*. Cross veins are numerous in the basal half of the wing, but are lacking in the apical half.

Length of wing, 8^{mm}; width, 2$\frac{1}{4}$^{mm}. Type, No. 85.

Protorthoptera.

The Protorthoptera although more primitive are in a general way related to modern Orthoptera. The venation of the front wing, while specialized in various ways, is still of a comparatively generalized type, the main veins of the wing being as a rule readily recognizable. The hind wing is broader than the front; the anal area expanded and folded. This group of insects is predominant in the Kansas Permian deposits, both in number of species and of individuals.

Lepiidæ, family new.

The front wings of the Lepiidæ are elongate, and of coriaceous texture. The main veins are strong and are plainly impressed in the thickened membrane. The interspaces between the veins are filled with a net-work of areoles, the lines, when seen from the top surface, showing as ridges on the membrane. The subcosta lies close to the radius and extends to or beyond the middle line of the wing. The radius gives off oblique branches beyond the termination of the subcosta. The sector is free and two or three branched. Media is also free and several times branched. Cubitus divides early in the front wing, the inner branch being simple. The main branch of the cubitus, Cu$_1$, is directed toward the inner border, but after approaching the border bends abruptly forward, and extends parallel with the border beyond the middle line of the wing, giving off several inferior branches. The anal area is marked off by a thin line and is traversed by two simple veins.

The hind wings are broad, the anal area expanded and folded. The folded part of the wing is thin, the areoles lacking. The

part of the wing not folded is coriaceous and areolated in a manner similar to the front wing. The sector of the hind wing either is detached from the radius or joins that vein close to the base. Cubitus is deeply impressed and may be reduced

FIGS. 1–8.
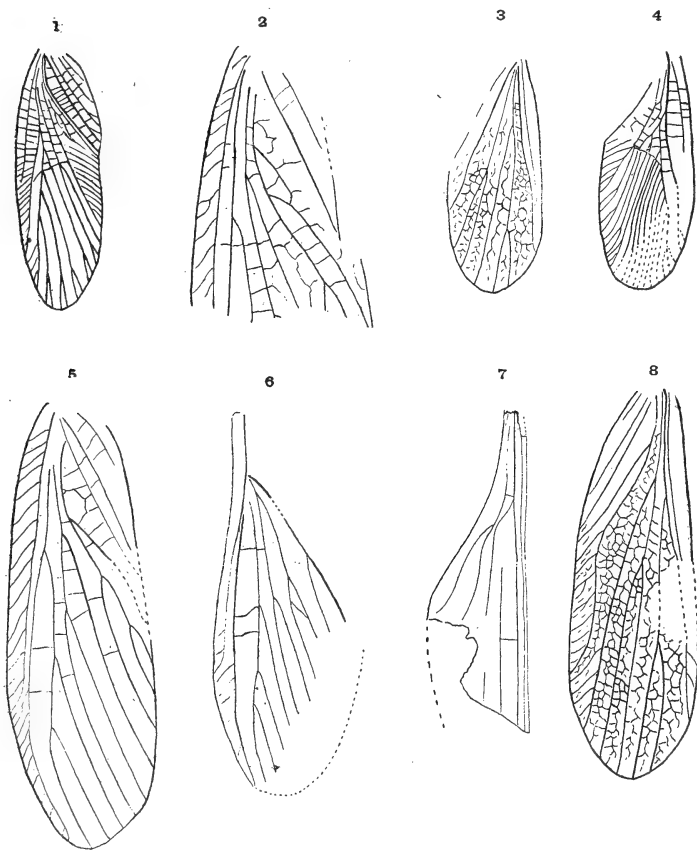
Explanation of Text Figures 1–8.

FIG. 1. *Sindon speciosa* gen. et sp. n. Front wing. No. 85.

FIG. 2. *Horates elongatus* gen. et sp. n. Front wing. No. 992.

FIG. 3. *Atava ovata* gen. et sp. n. Hind wing. No. 372.

FIG. 4. *Pursa ovata* gen. et sp. n. Front wing. The apex of the wing is restored from the counterpart of the same specimen. No. 1126.

FIG. 5–6. *Liomopterum ornatum* gen. et sp. n. Front and hind wings. No. 5. Apex of the hind wing restored from a second specimen of this genus (No. 657).

FIG. 7. *Opter Brongniartii* gen. et sp. n. Front wing. No. 1286.

FIG. 8. *Lepium elongatum* gen. et sp. n. Front wing. No. 132.

All illustrations four times natural size.

to a simple straight vein.   More commonly, however, it gives off a vaulted and forwardly directed branch.

The family is described from the wings, the body being unknown.

Lepium elongatum, gen. et sp. n.   Text figure No. 8.

The wings of the insects of this genus are elongate with rounded apex and narrowed base.   The radial sector is given off not far from the termination of the basal third of the wing, and in the type species is two branched.   Media is free.   It divides early, M_1 being deeply forked.   Near the termination of M_2 the areoles pass into accessory veins, of which there are four.   From Cu_1 several (about eight) inferior veins pass to the border.   The anal area is traversed by two simple veins.

Length of front wing, 12^{mm}; width, 4^{mm}.   Type, No. 132.

Lepium reticulatum sp. n.

This species is described from one complete front wing with which is associated parts of the hind wing.   Radius reaches farther along the costal border toward the apex than does the radius of *L. elongatum*.   The sector is three instead of two branched, one branch being lost, however, in the areoles of the wing, and not reaching the border.   Media is similar to that of the type species, as are also the cubital and anal areas.

The anal area of the hind wing is expanded, thin, and plicated. Areoles in this part of the wing are lacking.   Of the remainder of the hind wing the apical and inner parts only are preserved. This part of the hind wing is of a texture similar to that of the front wing.

Length of front wing, 13^{mm}; width, 4^{mm}.   Type, No. 152.

Lepium ? sp.

A detached hind wing, contained in the collection, probably belongs with *Lepium* or with a closely related genus.   The middle two-thirds of the wing is preserved, the extreme base as well as the apex being wanting.   The sector divides tardily, resembling in this respect *L. elongatum*.   Media is but two branched.   Cubitus is a deeply impressed vein running from the base to the inner border.   This vein gives off beyond the middle a thin, vaulted, forwardly directed, two branched division.   The anal area is seen beneath and in front of the wing.   It is thin, traversed by parallel veins, and lacks areolation.

Width at the termination of the anal area, 4^{mm}.   Width across the anal area probably not less than $4\frac{1}{2}$ to 5^{mm}.   Length estimated, 11 to 12^{mm}.   Type, No. 319.

Atava ovata gen. et sp. n.   Text figure 3.

The genus *Atava* is based upon a detached hind wing which differs so widely in venation as well as in size from other known types of this family as to represent without doubt a distinct genus. The radial sector is detached from the radius. It is three branched and fills the apex of the wing. Media is two branched. Cubitus is a straight deeply impressed vein reaching from the base to the inner border. The anal area is wanting.

Length of hind wing, 8^{mm}; width at termination of the anal area, 3^{mm}. Type, No. 372.

Liomopteridæ, family new.

The family Liomopteridæ includes a group of robust insects. The subcostal vein in this family is straight or nearly so, never arched, and gives off numerous oblique strong branches resembling in this respect many of the modern mantid species. The radius gives off oblique branches beyond the termination of the subcosta. The radial sector is several times branched. The media divides early. Cu_2 is simple. Cu_1 and the media are variable in their branching.

The hind wing is shorter and broader than the front. The anal area is imperfectly known. It is, however, marked off by a deeply impressed cubitus, and is doubtless expanded and folded.

The legs are preserved, in part, on the type specimen and are seen to be relatively long and stout. The thorax is also partly preserved and is somewhat elongated.

Liomopterum gen. n.

The front wings of the species of this genus are elongate; the costal border slightly arched. The subcosta lies in a shallow furrow and ends on the costa beyond the middle of the wing. The subcostal branches are numerous, oblique and mostly simple. The radius lies on a fold and reaches to the tip of the wing. Beyond the termination of the subcosta, numerous oblique simple veins pass from the radius to the border. The radial sector is given off at or near the termination of the basal third of the wing, and is three branched. The media divides early, one or both divisions being subdivided. The cubitus is uniformly arched at the base. Cu_1 is simple to three-branched; Cu_2 is simple.

The hind wing is thinner than the front. It is much expanded and is folded, the fold being marked off by a strong straight line. The radius of the hind wing is four branched, as is also the media.

Liomopterum ornatum **sp. n.**   Text figures 5 and 6.

M_2 of this species is simple. Cu_1 is three branched in the front wing.   The hind wing is smaller and thinner than the front.   The radial sector of the hind wing is four branched.
Length of front wing, 14^{mm} ; width, 4^{mm}.   Type, No. 5.

Liomopterum extensum **sp. n.**

The media of this species is four branched. Cu_1 is simple. Length of front wing, 14^{mm}; width, $4\frac{3}{4}^{mm}$.   Type, No. 972.

Horates elongatus **gen. et sp. n.**   Text figure 2.

A second and a somewhat larger genus is represented by the basal half of a front wing.   The media divides in this genus much in front of the origin of the sector.   Cubitus divides back of the bifurcation of media.   The strong basal arch of the cubitus together with its late bifurcation leaves a large area lying between the arch of the cubitus and the anal furrow. This area is traversed and strengthened by an accessory vein connecting the arch of cubitus with Cu_2.   The anal area is displaced and crowded partly across the wing.   It is traversed as usual by two veins.
Length of the wing (estimated), 17^{mm} ; width, 5^{mm}.   Type, No. 992.

Probnisidæ, family new.

The wings of the Probnisidæ are of coriaceous texture, the membrane indistinctly wrinkled.   Distantly placed cross veins are present.   These are strong in the basal and inner part of the wing between the media, cubitus and anal veins, but are elsewhere weak and indistinct.   The wings are long in proportion to their breadth.   They are insufficiently braced, and were evidently imperfect organs of flight.   The subcosta reaches to about the middle of the wing.   The radius reaches to the apex. The sector arises early and is simple.   Media divides near the base of the wing and is two to four branched.   Cubitus is long, not infrequently reaching well toward the apical border.   A variable number of inferior branches are given off by the cubitus.
The hind wings are broader than the front.   The sector is either detached or arises very early from the radius.   The cubitus is a deeply impressed strong vein directed obliquely toward the inner border.   A thin, forwardly directed, branched division is given off from the middle of the cubitus.   The anal area of the hind wing is imperfectly known.   The venation in this family presents many perplexing minor variations, and is probably lacking in constancy.

Probnis speciosa gen. et sp. n.   Text figures 10 and 11.

The front and hind wings of the type specimen of this genus are preserved.   The front wing is slender, being approximately three and a half times as long as broad.   The membrane is coriaceous and wrinkled ; the veins lying in the membrane are

FIGS. 9–14.
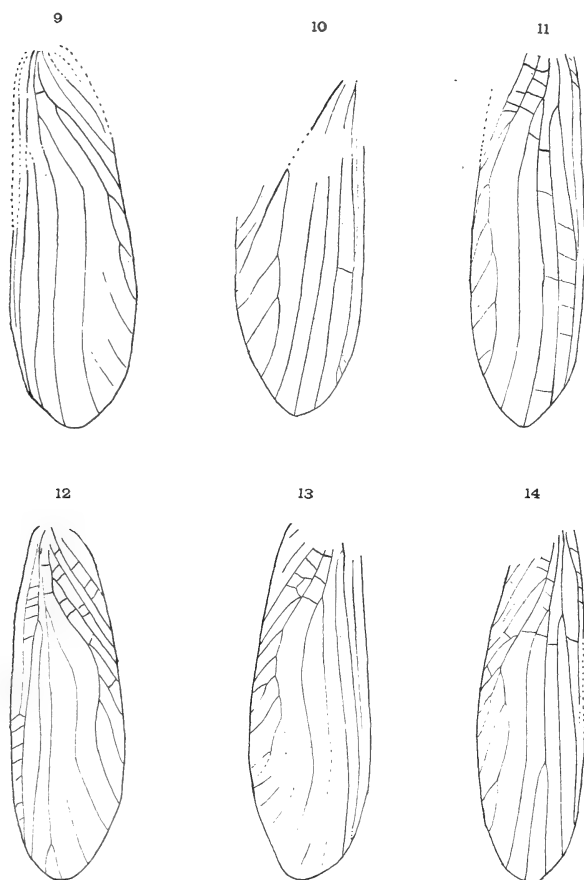
Explanations of Text Figures 9–14.

FIG. 9. *Stinus brevi-cubitalis* gen. et sp. n.   Front wing.   No. 459.
FIG. 10–11. *Probnis speciosa* gen. et sp. n.   Hind and front wings.   No. 143.
FIG. 12. *Stoichus elegans* gen. et sp. n.   Front wing.   No. 974.
FIG. 13. *Espira obscura* gen. et sp. n.   Front wing.   No. 101.
FIG. 14. *Stoichus arcuatus* sp. n.   Front wing.   No. 973.
All illustrations four times natural size.

thin and indistinct.   The subcosta is arched at the base toward
the costa and reaches to the middle of the wing.   The radius
reaches to the apex.   The sector is simple.   The media divides
just in front of the origin of the sector, both divisions remain-
ing simple.   Cubitus is a very long vein reaching well along
the apical border.   It is thin and indistinct and gives off six
slender branches.

The hind wing is broader than the front, and is not more than
three times as long as broad.   The sector arises very early.
The basal part of the cubitus is a heavy, strongly impressed
vein, directed toward the inner border.   From near the middle
of the cubitus a thin forwardly directed branched division is
given off which reaches to the apical border.   The greater
width of the hind wing results from the expansion of the inner
border, and the greater area occupied by the cubitus.   The
anal area is unknown.   The deeply impressed character of the
cubitus leads one to expect a folded anal area.   The membrane
of the hind wing is of coriaceous wrinkled appearance similar
to that of the front wings.

Length of front wing about 13^{mm}; width, 3^{mm}; length of
hind wing about 12 or $12\frac{1}{2}^{mm}$; width, 4^{mm}.   Type, No. 143.

Probnis coriacea sp. n.

The cubitus in this species is scarcely so distinctly vaulted
as in the case of the type species of the genus.   Media divides
opposite, rather than in front of, the origin of the sector.

Length of front wing, 12^{mm}; width, $3\frac{1}{4}^{mm}$.   Type, No. 655.

Espira obscura gen. et sp. n.   Text figure 13.

This genus is characterized by the very early origin of the
sector; by a three or four branched media; and by a cubitus
more vaulted and occupying a broader area, resulting in a pro-
portionately broader wing than in the type genus.   *Espira* resem-
bles *Probnis* in the late origin of the first cubital branch.   It
represents a type with broader and stronger wings, and with
thickened membrane in which the veins can scarcely be traced.

Length of wing about $11\frac{1}{2}^{mm}$; width, $3\frac{1}{2}^{mm}$.   Type, No. 101.

Stoichus elegans gen. et sp. n.   Text figure 12.

Media divides opposite the origin of the sector and is four
branched.   Cubitus is short and has beyond the first strong
division but three branches. Cu_1 is vaulted at its separation
from Cu_2 and is connected to the media by a strong cross vein.
Cu_2 is much stronger than in the genera of this family already
described.

Length of front wing, 11^{mm}; width, $3\frac{3}{4}^{mm}$.   Type, No. 974.

Stoichus arcuatus sp. n.   Text figure 14.

The first division of the media of this species is deeply forked, while the second division is simple. The cubitus is more strongly vaulted and is longer than is the cubitus of the type species. It has five slender branches, the third of which is forked.

Length of wing, $11\frac{1}{2}^{mm}$; width, $3\frac{1}{4}^{mm}$.   Type, No. 973.

Stoichus minor sp. n.

This species is very much smaller than the type species of the genus. Media$_1$ is simple ; M$_2$ is three branched. Cubitus gives off beyond the first strong branch, three inferior branches.

Length of wing, 9^{mm} ; width, 3^{mm}.   Type, No. 114.

Stoichus tenuis sp. n.

The wings of this species are thinner and the venation less distinct than in other species referred to this genus. The sector arises opposite the division of the media. Cubitus divides very early as in the type species. The offshoot from the cubitus is a thin vein reaching a little beyond the middle of the wing. Two inferior branches are given off, the first of which is forked. The first division of the media is simple, the second is apparently once forked.

Length of front wing, 10^{mm} ; width, 3^{mm}.   Type, No. 1208.

Stinus brevi-cubitalis gen. et sp. n.   Text figure 9.

The cubitus of this genus is short as compared with other genera of the family, being scarcely vaulted and reaching but slightly beyond the middle of the wing. Only two inferior branches are given off. The median area is correspondingly well developed. M$_2$ in the type species gives off three inferior branches which fill the apical border. M$_1$ is simple. The radial sector arises back of the division of the media, and is simple.

Length of wing, $12\frac{1}{2}^{mm}$; width, 4^{mm}.   Type, No. 459.

Lecopterum delicosum gen. et sp. n.

This is a genus of small Probnisidæ. The wing is slender and not so coriaceous as in other genera of the family. The veins in the apical part of the wing are thin and more or less wavy. M$_1$ is simple. M$_2$ is three branched. Cubitus divides early. Beyond this first division it has but two inferior branches and is but slightly vaulted.

Length of front wing, partly estimated, 9^{mm} ; width, 3^{mm}. Type, No. 824.

Lemmatophoridæ, family new.

The family Lemmatophoridæ includes small insects with four membranous wings as long as the abdomen. The pronotum is bordered by a membranous expansion. The mesa- and meta-thoracic segments are strong. The subcosta is simple, and terminates on the costal border near or beyond the middle line of the wing. Numerous oblique branches are given off from the radius beyond the termination of the subcosta. The radial sector is simple to four branched. The media is weak and at the base lies very close to the radius; media is two to four branched. The cubitus at the base has a strong upward curve toward the media, with which it is united by a few strong cross veins. Cu_1 is one to three branched. Cu_2 is simple. The anal area is marked off by a thin depressed line, and is traversed by one or two strong veins. Cross veins in the wing are comparatively strong although not numerous.

The hind wings are broader and shorter than the front. The anal area of the hind wing is expanded and folded.

Lemmatophora gen. n.

This genus of small Lemmatophoridæ has elongate membranous arched wings. The wing membrane is minutely scaly. Subcosta is not arched at the base and extends beyond the middle of the wing. Sector arises near the middle of the wing and is simple. M_1 is simple. M_2 is widely forked beyond the middle of the wing, and is thin at its origin from M_1. Cu_1 is vaulted near its origin, and is two to three branched; Cu_2 is simple. Two to four cross veins unite R_1 with Rs. A strong cross vein unites Rs near its origin with M_1; two to four other cross veins unite Rs and M_1. Cu_1 is united at the arch with M_2 by two or three strong cross veins. The anal area is traversed by two simple veins; inner angle squarose.

Lemmatophora typa sp. n.   Text figure 24.

Subcosta is united with the border by about nine cross veins. Two prominent cross veins occur between R_1 and Rs; three to four cross veins between Rs and M_1. M_2 is branched. Cu_1 is branched; Cu_2 simple. The position of the main and cross veins of this species are very constant. Fourteen specimens are referred to the species. The branching of the main veins is without essential variation as is also the position and curvature of the veins. The cross veins of the wing are often obscure from lack of preservation, as is also the minutely scaly surface of the wing.

Length of wing, 7^{mm}; width, $2\frac{1}{4}^{mm}$. Type, No. 1162 paratypes, Nos. 30, 32, 1266, 1376, 1377, 1379.

Lemmatophora delicosa sp. n.

This species resembles *L. typa* closely, both in size and in venation. M_2 is, however, three instead of two branched.

Length of front wing, 7^{mm}; width, $2\frac{1}{4}^{mm}$. Type, No. 1050.

Lemmatophora anomala sp. n.

One branch of the media of this species coalesces for a short distance with cubitus.

Length of wing, 7 to 8^{mm}; width, $2\frac{1}{2}^{mm}$. Type, No. 1089.

Lemmatophora hirsuta sp. n.

This species is described from a specimen having the two pairs of wings and the body preserved. The prothorax is bordered by a membranous expansion 1^{mm} wide. The venation of the wings is partly obscured as a result of the two pairs of wings lying together and partly over the abdomen. The costal border of the front wing is thickly set with short backwardly projecting spines or hairs. In other respects the venation so far as can be made out agrees with that of the type species of the genus *Lemmatophora*.

Length of body from the prothorax to the end of the abdomen, 10^{mm}; length of prothorax about 2 or $2\frac{1}{2}^{mm}$; length of abdomen, $5\frac{1}{2}^{mm}$; length of front wings, 7^{mm}; length of hind wings about $6\frac{1}{2}^{mm}$. Type, No. 1047.

Lemmatophora elongata sp. n.

This species has a more slender and a longer front wing than that of *L. typa.*

Length of front wing, 9^{mm}; width, $2\frac{3}{4}^{mm}$. Type, No. 149.

Lisca minuta gen. et sp. n.   Text figure 21.

This is a genus of small Lemmatophoridæ. The wing membrane is scaly and resembles in texture that of *Lemmatophora.* The radial sector originates not far from the middle of the wing. It is simple and is united for a short distance with M_1. M_2 is deeply forked. Cu_1 is forked. Cu_2 is simple.

Length of front wing, $5\frac{1}{2}^{mm}$; width, 2^{mm}. Type, No. 916.

Artinska gen. n.

The generic characters of this genus may be summarized as an arched subcosta, a bifurcate radius, and a minutely scaly wing membrane.

The wing is of an elongate shape. The subcosta reaches somewhat beyond the middle of the wing. Oblique branches are given off from the subcosta and beyond the termination of the subcosta from the radius. The sector originates at the ter-

Figs. 15–28.

15   16   17   18

20   21

19   22

23   24

25   26   27   28
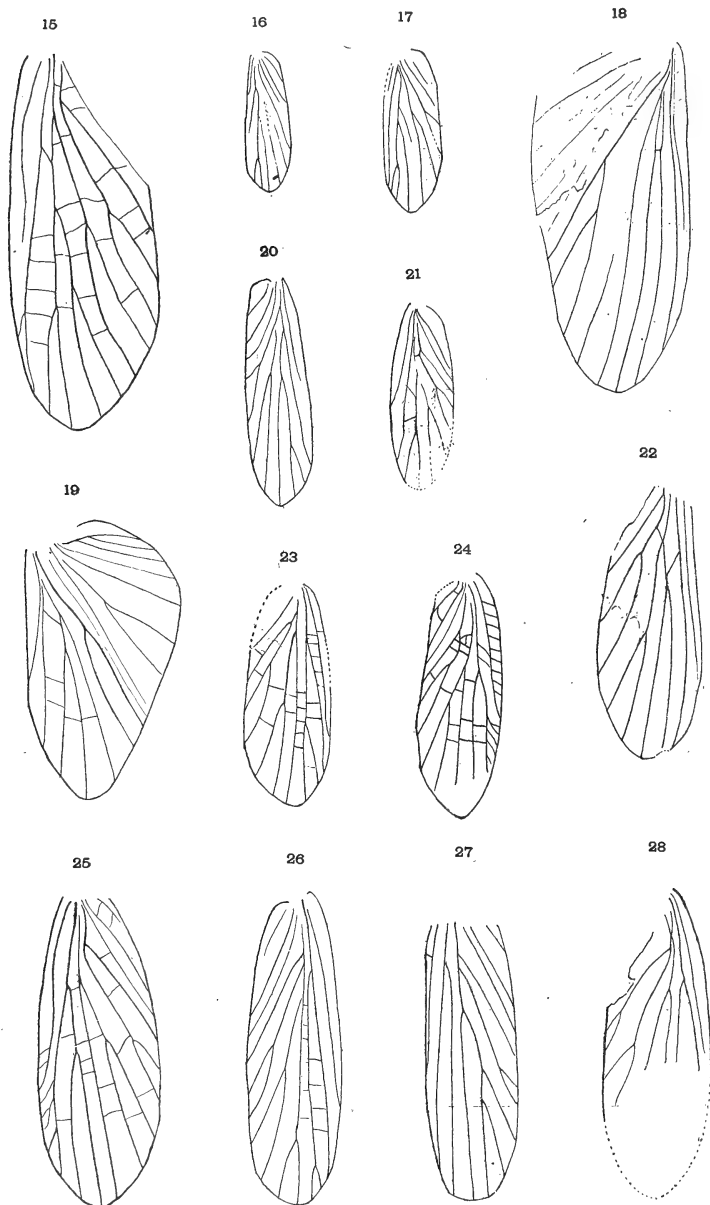
mination of the basal one-third or one-fourth of the wing. Media divides just in front of, opposite, or just back of the origin of the sector. Its subsequent divisions are variable with the different species. Cubitus divides in front of the division of the media. Its first division is variable; the second is uniformly simple. The anal area is marked off by a thin line and is traversed by two veins. The cross veins are numerous although not always well preserved. The specific characters are taken for the most part from the median and cubital areas.

Artinska clara sp. n. Text figure 25.

The radial sector is deeply bifurcate. M_1 is simple. M_2 is deeply forked. The first division of the media occurs in front of the origin of the sector. Cu_1 is branched. Cu_2 is simple.

Length of front wing, 10^{mm}; width, $3\frac{3}{4}^{mm}$. Type, No. 115.

Artinska medialis sp. n.

The media divides in front of the origin of the sector. The sector is shallow forked. M_1 and M_2 are both deeply forked. The first division of the cubitus is simple.

Length of wing, 9^{mm}; width, $3\frac{1}{2}^{mm}$. Type, No. 1381.

Artinska gracilis sp. n.

The sector is not deeply forked. M_1 is shallow forked; M_2 more deeply forked. Media divides opposite the origin of the sector. Cu_1 is three branched.

Length about 9^{mm}; width, $3\frac{1}{2}^{mm}$. Type, No. 1090.

Artinska pecta sp. n.

The sector is not deeply forked. Media divides in front of the origin of the sector. M_1 and M_2 are deeply forked. Cu_1 is three branched.

Length of front wing, 10^{mm}; width, $3\frac{1}{2}^{mm}$. Type, No. 1087; paratypes, Nos. 437 and 1068.

Explanations of Text Figures 15-28.

FIG. 15. *Estadia elongata* gen. et sp. n. Front wing. No. 1112.
FIG. 16. *Delopterum minutum* gen. et sp. n. Front wing. No. 264.
FIG. 17. *Delopterum latum* sp. n. Front wing. No. 94.
FIG. 18. Hind wing, probably of one of the Lemmatophoridæ. No. 1461.
FIG. 19. Hind wing, probably of small species of *Estadia*, or related genus. No. 758.
FIG. 20. *Delopterum elongatum* sp. n. Front wing. No. 61.
FIG. 21. *Lisca minuta* gen. et sp. n. No. 916.
FIG. 22. *Prisca fragilis* gen. et sp. n. No. 128.
FIG. 23. *Orta ovata* gen. et sp. n. Front wing. No. 295.
FIG. 24. *Lemmatophora typa* gen. et sp. n. Front wing. No. 1162.
FIG. 25. *Artinska clara* gen. et sp. n. Front wing. No 115.
FIG. 26. *Lecorium elongatum* gen. et sp. n. No. 524.
FIG. 27. *Stemma elegans* gen. et sp. n. Front wing. No. 31.
FIG. 28. *Lectrum anomalum.* Front wing. No. 173.

Figures 15, 18, 19, and 26 enlarged five times; all other illustrations four times natural size.

Artinska major sp. n.

The sector is deeply forked.   Media divides in front of the origin of the sector. M_1 is simple; M_2 is deeply forked. Cu_1 is three branched.

Length of front wing, 11^{mm}; width, 4^{mm}.   Type, No. 1375.

Artinska extensa sp. n.

The sector is shallow forked.   Media divides much in front of the origin of the sector. M_1 is three branched; M_2 is simple. Cu_1 is three branched.

Length of front wing, 10^{mm}; width, 4^{mm}.   Type, No. 28.

Estadia gen. n.

The generic characters may be summarized as an arched subcosta, and a radius which is bifurcate and is fused for a short distance with the first division of the media.

The front wings are elongate.   The subcosta reaches two-thirds of the length of the wing, and is strongly arched at the base.   The sector arises 3 or 4^{mm} from the base and is fused for a short distance with M_1.   Media is divided in front of the origin of the sector.   Its subsequent divisions are variable. $Cubitus_2$ is simple. Cu_1 is bifurcate.   The anal area is of the usual squarose form, and is traversed by two veins.   The specific characters are taken, as in the other genera, from the disposition of the veins of the median and cubital areas.

Estadia elongata sp. n.   Text figure 15.

The radial sector is fused with M_1 for a distance of one millimeter. M_1 is shallow forked; M_2 is deeply forked. Cu_1 is forked.

Length of front wing, $10\frac{1}{2}^{mm}$; width, $3\frac{1}{2}^{mm}$.   Type, No. 1112.

Estadia arcuata sp. n.

The radial sector is fused with M_1 a distance of one-half millimeter. M_1 is shallow forked while M_2 is deeply forked. Cu_1 is two branched.

Length of wing, 12^{mm}; width, $4\frac{1}{4}^{mm}$.   Type, No. 412; para-type, No. 358.

Estadia tenuis sp. n.

The sector is fused with M_1 a distance of not more than one-half millimeter. M_1 is simple; M_2 is deeply forked. Cu_1 is two branched.

Length of front wing, 9^{mm}; width, $3\frac{1}{4}^{mm}$.   Type, No. 1382; paratype No. 1274.

Lectrum anomalum gen. et sp. n.   Text figure 28.

The costal border of the front wing is gently arched.   The subcosta is but slightly arched at the base.   The radial sector arises in front of the middle line of the wing.   The veins of the wing are thin and not deeply impressed. Cu_1 is branched. Cu_2 is forked, differing in this respect from all other genera of the family.

Length of front wing, estimated, 10^{mm} ; width, 3^{mm}.   Type, No. 173.

Prosaites compactus gen. et sp. n.

The front wings of species of this genus are compact, the cross veins numerous.   The radial sector is bifurcate. M_1 is simple ; M_2 is branched. Cu_1 and Cu_2 are both simple.   The sector in the type species is united with media for a short distance only.

Length of front wing, $8\frac{1}{2}^{mm}$; width, 3^{mm}.   Type, No. 628.

Prosaites secundus sp. n.

The radial sector of this species is united with M_1 for a distance of about one millimeter. M_2 is deeply forked.

Length of front wing, $8\frac{1}{2}^{mm}$: width, 3^{mm}.   Type, No. 241.

Prisca fragilis gen. et sp. n.   Text figure 22.

The front wing is elongate.   The wing membrane is thin and the veins indistinct.   The sector is simple and is united for a short distance with M_1. M_1 is simple. M_2 is bifurcate. Cu_1 is deeply forked. Cu_2 is simple.

Length of front wing about 9^{mm} ; width, 3^{mm}.   Type, No. 128.

Lecorium elongatum gen. et sp. n.   Text figure 26.

The front wings are slender.   The sector is forked at the tip. M_1 and M_2 are forked. Cu_1 is forked.   Cross veins are present.

Length of front wing, 8^{mm} ; width, $2\frac{3}{4}^{mm}$.   Type, No. 524.

Ortadœ, family new.

This is a family of small insects.   The front wings are elongate, broadest beyond the middle.   The subcosta reaches beyond the middle line of the wing.   The radial sector is usually two branched.   The special peculiarity of this family is the union of media and cubitus at the base of the wing.   The anal area is marked off by a thin line.   Cross veins occur sparingly.

The body is small, and is shorter than the wings.

Orta ovata gen. et sp. n.   Text figure 23.

The radial sector is bifurcate.   Media and cubitus are fused at the base for a distance of one to two millimeters. M_1 is simple; M_2 is branched.   Cubitus is divided at the point of separation from media. Cu_1 is deeply forked. Cu_2 is simple.

Length of front wing, 7^{mm}; width, 3^{mm}.   Type, No. 295; paratype, No. 190.

Stemma elegans gen. et sp. n.   Text figure 27.

The front wings are long and very slender.   The sector is simple.   Cubitus and media are united for some distance at the base. Cu_2 arises as a branch vein from the united main veins. M_1 is simple; M_2 is three branched. Cu_1 is bifurcate at the tip; Cu_2 is simple.

Length of front wing, 10^{mm}; width, $2\frac{1}{2}^{mm}$.   Type, No. 31.

Stemma extensa sp. n.

The front wing is somewhat shorter than that of the type species. Cu_1 is simple.

Length of front wing, 8^{mm}; width, $2\frac{1}{2}^{mm}$.   Type, No. 1272.

Delopteridæ, family new.

This is a family of small insects.   The front wings are narrowly elongate.   The subcosta is short, rarely reaching beyond the middle of the wing.   The radial sector is one to three branched.   The cubitus, instead of dividing early into two main branches, continues simple until near the inner border, there giving off one or two thin, simple inferior veins.   The anal area is marked off by a thin depressed line.   Cross veins are not numerous in any part of the wing.

The hind wings are of approximately the same length as the front.   They are probably expanded and plicated as in other families of this group.

The body is slender.   The abdomen is much shorter than the wings.

Delopterum minutum gen. et sp. n.   Text figure 16.

These are small insects.   The subcosta is short.   Radial sector is three branched.   Media is two branched.   Cubitus is apparently simple.

Length of wing, $4\frac{1}{2}^{mm}$; width, $1\frac{1}{4}^{mm}$.   Type, No. 264.

Delopterum elongatum sp. n.   Text figure 20.

This is a much larger species, and may possibly be found to be generically separable from *Delopterum minutum*.   Cubitus in this species is branched.

Length of front wing, 7^{mm}; width, 2^{mm}.   Type, No. 61.

Delopterum latum sp. n. Text figure 17.

This species is broader and slightly larger than the type species. The sector arises very early. The sector is three branched. A fourth branch is given off but is lost in the wing membrane. Cubitus is branched.

Length of front wing, 5^{mm}; width, 1$\frac{3}{4}$^{mm}. Type, No. 94.

Urba punctata gen. et sp. n.

This genus is characterized by a slender elongate anal area traversed by three or four veins. The wing membrane has a punctate appearance, due probably to the presence of short spines bordering the veins.

Length of front wing, 9^{mm}; width, 3^{mm}. Type, No. 1117.

Correlation of the Insect-bearing Horizon.

The locality from which the insects described in this paper were obtained is three and one-half miles southeast of Banner City in Dickinson County, Kansas. The fossiliferous horizon occurs close to the top of the Paleozoic section of this part of the state and near the line of contact with the overlying Cretaceous. Fossil plants are associated with the insects. The matrix holding the fossils varies from an impure fine-grained laminated limestone to a hard concretionary limestone. Most of the insects were obtained from the laminated rock, while the plants come largely from the concretionary limestone. When the fossils were first discovered they were regarded as probably occurring in the Marion formation.

As a result of stratigraphic studies made for the Kansas State Geological Survey during the past summer, J. W. Beede states that he has shown the plant and insect horizon to occur within the Wellington shales lying next above the Marion, and immediately under the Cretaceous. *

Aside from doubtful forms, the paper contains descriptions of sixty species and thirty-five genera, all of which are new. To complete the faunal list, the cockroaches, not included in this paper, but described elsewhere, † should be added to this number. Of this family ten species, all new, have been recognized. They are referred to two genera, one of which is new. Of groups larger than genera the following have been recognized in the Wellington shales : Odonata, Plecoptera, Megasecoptera, Oryctoblattinidæ, Protorthoptera, and Paleoblattidæ.

The order Odonata is represented in the Wellington horizon by at least one form constituting a new genus and species. The Odonate phylum is known as early as the Coal Measures, being

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* Letter of Sept. 16, 1908.
† Paper prepared for the Kansas State Geological Survey.

somewhat abundant and including forms of an unusually large size in the Commentry Coal Measures of France. Handlirsch regards the Coal Measure types of Protodonates as constituting an ordinal group of equal rank with modern Odonates. With this classification I have been unable to agree, as the specimens, from the Wellington shales at least, possess the essential ordinal characters of true Odonata.

The order Plecoptera, or ephemerids, is somewhat abundant in the Wellington shales. In Part II of this paper I have described ten genera and thirteen species constituting a new family of this order. Insects which appear to be prototypes of the ephemerids exist in some abundance in the Coal Measures. Handlirsch * has recognized ephemerids as occurring sparingly in the Permian of Russia. With this exception, true ephemerids have not previously been identified from Paleozoic deposits. The relative abundance of this group of insects in the Wellington shales affords an exceptionally strong argument for the Permian age of that formation. That the members of this group, as it occurs in the Wellington, are provided with two pairs of fully developed wings and are otherwise far more primitive than modern ephemerids, by no means weakens the argument, since these are precisely the characters to be expected in early members of the order.

The order Megasecoptera is sparingly represented in the Wellington shales, a single specimen having been obtained. This order was described from Coal Measure specimens, from which deposit alone it has been known heretofore. The continuance of the order into the Permian, however, is not unexpected. Aside from cockroaches, relatively few genera of insects have been described from the Permian. This fact is sufficient to account for the previous lack of knowledge regarding the continuance of the Megasecoptera into the Permian.   .

The family Oryctoblattinidæ was established upon Coal Measure and Permian forms, seven Coal Measure and two Permian genera having been referred to the group. From the Wellington shales two genera of this family, both new, are described in this paper.

Protorthoptera is the predominant order of insects in the Wellington shales. This order is recognized as common to both Coal Measure and Permian deposits. Six families of the order are described in this paper, all of which are new. The forms making up these six families constitute twenty genera and forty-three species.

The cockroaches of the Kansas Permian have been described in a paper now being published in the reports of the Kansas

* See Pt. II, p. 345.

State Geological Survey. A detailed account of the group is therefore omitted from this paper. It has usually been observed, in collecting from Paleozoic localities, that cockroaches exceed in number of individuals all other insects combined. In the Wellington shales the cockroaches are much in the minority. A collection of something over two thousand insect specimens was found to contain only about seventy cockroaches. From these, two genera and ten species were identified. Of the two genera, one is the well known Coal Measure and Permian genus *Etoblattina*. The second genus is new. The ten species obtained are new. The rarity of cockroaches in the Wellington is in marked contrast to their relative abundance in most Coal Measure and early Permian localities.

Fossil insects have been obtained from the Birmingham shales near Steubenville and Richmond, Ohio, in the Conemaugh series just above the Ames or Crinoidal Limestone. Recently reptilian remains heretofore supposed to be Permian have been found near Pitcairn, Pennsylvania, in the red clay below the Ames limestone.* The presence of the reptilian remains has given rise to a question as to the age of the Conemaugh series. In the collection of insects from that locality, Scudder recognized twenty-two species referable to three genera. All of these are cockroaches, other families not having been found at this locality. Of these twenty-two species, seventeen were referred by Scudder to the genus *Etoblattina*, three to *Gerablattina*, and two to *Poroblattina*. Of these genera *Etoblattina* alone is recognized in the Wellington shales, and as already remarked, the cockroach family is in the minority at that locality. No one of the twenty-two species of the Richmond locality has been recognized in the Wellington. On the other hand, two of Scudder's species, *Etoblattina maladicta* and *E. benedicta* (regarded by the writer as a single species and referred to *Spiloblattina*), have been obtained from the Leroy (Coal Measure) shales of Kansas.† It should be added, however, that Handlirsch‡ does not agree with the writer either in uniting these two species, or in identifying them with the specimens from the Leroy shales. Aside from the question of discrimination of species, about which there may be differences of opinion, the essential fact remains that a closely similar type of wing development is seen in species from the two localities. This type of wing venation is referred to by Scudder as the "remarkable openness of the neuration in the middle of the tegmina.§ Handlirsch assigns to the cockroaches of this

* P. E. Raymond, Science, xxvi, p. 835, 1907.
† This Journal, vol. xviii, p. 214-216, 1904.
‡ Die Fossilen Insekten, p. 240, 1906.
§ Bulletin U. S. Geol Survey No. 124, p. 12, 1895.

type, family rank, the Spiloblattinidæ. The family as thus delimited predominates at the Steubenville and Richmond localities, and is known as high as the Cassville plant shales at the base of the Dunkard series of West Virginia. It is abundant in the Leroy shales of the Kansas Coal Measures, but has not been recognized in the Wellington shales at the top of the Kansas section. In Europe this group is reported from both Upper Carboniferous and Lower Permian. The type genus, *Spiloblattina*, was described from Fairplay, Colorado.

The Fairplay locality was placed by Scudder in the Trias. Lesquereux maintained, however, that from the plant evidence the formation could not be later than Permian. With regard to the plant material, Mr. David White states:* "The plant and insect beds at Fairplay, referred by Doctor Scudder to the Trias, and by Lesquereux to the Permian, can, on the evidence of the plants, not be regarded as later than Permian, if indeed they are above the highest Coal Measures." The insect remains as now interpreted are not in conflict with the plant evidence, and certainly do not require the reference of the formation to the Triassic.

Of the two remaining genera occurring at the Ohio locality *Etoblattina* is a Coal Measure-Permian genus. *Poroblattina* is found at Fairplay, Colorado, and in the upper Carboniferous and Lower Permian of Europe. The insect remains thus far obtained do not therefore permit a close correlation of the Birmingham shales with the Kansas section. It seems probable, however, that that formation is of somewhat later age than the Leroy shales of the Kansas Coal Measures.

A number of insects have been obtained, principally by Mr. R. D. LaCoe from the Cassville plant shales at Cassville, West Virginia. This horizon lies at the base of the Dunkard series variously regarded as Permian or as Permo-Carboniferous, and occurs, according to I. C. White, some six hundred feet in the stratigraphic column above the Birmingham shales. In the collections from the Cassville locality, Scudder recognized fifty-six species referable to five genera all of which are cockroaches. I have been unable to recognize in the Wellington shales the presence of any one of the fifty-six species occurring at the Cassville locality, and only one genus *Etoblattina* is common to the two horizons. The predominance of the cockroach fauna together with the absence of such advanced types as true ephemerids, leads to the view that the Cassville locality, although possibly Permian, is much older than the Wellington shales of the Kansas section.

Among the few insects obtained from the Permian formation of Russia, Handlirsch recognizes, as previously stated,

* U. S. Nat. Mus., vol. xxix, pp. 667, 1906.

the occurrence of true ephemerids. The Russian deposits have also yielded forms regarded as representing Paleohemiptera and Mantoidæ.* These last two groups have not been recognized in the Kansas Permian. The presence of the ephemerids, however, forms a strong tie in common between the insects of the Russian and the Kansas Permian.

The insects of the Wellington are on the average of small size as compared with Coal Measure insects. This is particularly noticeable among the cockroaches, all of which are small. This dwarfing of the fauna is of interest as probably indicating unfavorable climatic conditions.

The Geological Relations of the Associated Plants.

Plants, as previously stated, are associated with the insects at the Banner City locality. A paper describing the plants from this horizon is being published by the Kansas Geological Survey. In the writer's opinion, the plant fossils indicate unequivocally the Permian age of the formation from which they come. The evidence as to the age of the Wellington shales, derived from the flora, is thus summarized in the report referred to ; "More than two-thirds of the Wellington species are either identical with or most closely related to species or genera characteristic of the European Permian. The points which seem to have the most importance as bearing on correlation of the Wellington are the following : (1) The complete absence from the Wellington of species in any way confined to or distinctive of the Coal Measures. (2) The comparatively small number of species originating as early as Upper Coal Measure time. (3) The presence of a few species common to and characteristic of the Permian of Europe. (4) The close relation of the new forms to species characteristic of the European Permian. (5) The distinctly Permian facies of the flora as a whole and its marked advance over the flora of the Upper Coal Measures.

The advance in the flora consists in the number of species and in the abundance of individuals of callipterid and tæniopterid ferns, and of the new fern genus, *Glenopteris*, which appears to be related, on the one hand, to callipterid ferns of Permian types, and, on the other, to the Triassic genera *Cycadopteris* and *Lomatopteris*.

The evidence derived from the fossil plants as a whole seems to assure the reference of the Wellington to the true Permian in the European sense."

This conclusion drawn from the plant fossils is now fully confirmed by the evidence derived from the insects.

* Die Fossilen Insekten, 348, 1906.

Art. X.—*The Iodometric Estimation of Vanadic Acid,
Chromic Acid and Iron in the Presence of One Another;*
by Graham Edgar.

In a previous paper from this laboratory* it has been shown
that vanadic and chromic acids may be estimated in the presence
of one another by a process based upon the differential reducing
action of hydrobromic and hydriodic acids. The present paper
will show that the use of processes of differential reduction
may be extended to the estimation of three constituents; in the
present case, vanadic acid, chromic acid and iron.

A preliminary investigation was made in order to determine
whether vanadic acid and iron might be estimated iodometrically
by distillation, first with hydrobromic acid and last with hydri-
odic acid, the liberated halogen being absorbed in potassium
iodide and determined after each distillation. In the first dis-
tillation the vanadic acid should be reduced to the tetroxide,
according to the equation,

$$V_2O_5 + 2HBr = V_2O_4 + H_2O + Br_2.$$

In the second distillation, the vanadium tetroxide should be
reduced to trioxide and the ferric salt to ferrous salt, according
to the equation,

$$V_2O_4 + Fe_2O_3 + 4HI = V_2O_3 + 2FeO + 2H_2O + 2I_2.$$

It is evident that both constituents may be calculated from
the amount of halogen liberated in the two reductions.
Experiments upon solutions of sodium vanadate and ferric
chloride, carried out in the manner to be described later, gave
the results shown in Table (I).

If this process be carried out in the presence of chromic
acid the reduction by hydrobromic acid should proceed accord-
ing to the equation,

$$V_2O_5 + 2CrO_3 + 8HBr = V_2O_4 + Cr_2O_3 + 4H_2O + 4Br_2,$$

while the reduction by hydriodic acid should proceed as before,
according to the equation,

$$V_2O_4 + Fe_2O_3 + 4HI = V_2O_3 + 2FeO + 2H_2O + 2I_2.$$

If the halogen liberated in the two reductions be separately
determined, we have two equations, the first giving the sum of
the vanadic and chromic acids, and the second giving the sum
of the vanadic acid and the iron ; the halogen liberated by the
vanadium being the same in each case. If then either the
vanadium, iron or chromium be estimated separately, we obtain
a third equation, from which, with the aid of the first two, all
three constituents may be calculated.

In this investigation an attempt was made to estimate the
vanadium in a separate portion of the solution by reduction

* Edgar, this Journal, xxvi, p. 333, 1908.

with sulphur dioxide, boiling out the excess of reagent, adding barium chloride to precipitate the sulphuric acid formed, and then subjecting the solution to distillation with hydriodic acid. The chromic acid and the iron being already reduced by the sulphur dioxide, it is evident that the iodine liberated in the distillation should correspond to a reduction of vanadium-tetroxide to trioxide. This process, however, yielded faulty results, due, as was ascertained, to the formation of some dithionic acid during the treatment with sulphur dioxide.

Another attempt was made to treat the residue after distillation with hydriodic acid with an excess of standard iodine solution and make alkaline with sodium bicarbonate, the excess of iodine to be afterwards determined with standard arsenious acid. In this process the vanadium trioxide should be oxidized to pentoxide and the ferrous salt to ferric salt, thus yielding the necessary data for the third equation. This method was found to be unavailable, owing to the fact that in the presence of the bulky precipitate of chromic and ferric hydroxides the vanadium is reoxidized very slowly by iodine.

The method which finally proved successful was the estimation of the chromic acid in a separate portion by a modification of Browning's method of reduction with standard arsenious acid.*

The experiments to be described were made upon mixtures in varying proportions of solutions of sodium vanadate, potassium bichromate and ferric chloride; the entire process in detail being the following :

(I). The solution, of about fifty cubic centimeters volume, was divided into two equal parts, one of which was placed in a distillation flask. To this, one to two grams of potassium bromide were added, together with twenty-five cubic centimeters of concentrated hydrochloric acid, and the mixture was distilled until a volume of about twenty-five cubic centimeters was reached, the reduction having always been found to be complete in that time. The bromine liberated was absorbed in alkaline potassium iodide, and, after cooling and acidifying, the iodine liberated was estimated by titration with approximately tenth normal sodium thiosulphate. The results are given in (I), Table (II).

(II). The absorption apparatus was replaced, and after the addition to the solution in the distillation flask of one gram of potassium iodide, ten cubic centimeters of concentrated hydrochloric acid and three to five cubic centimeters of syrupy phosphoric acid, distillation was again carried on until a volume of ten cubic centimeters had been reached ; the iodine thus liberated being estimated as before. The results are given under (II), Table (II).

* This Journal, vol. i, p. 35, 1896.

(III). In the second half of the original solution the chromic acid was estimated by adding sulphuric acid to slight acidity, three cubic centimeters of syrupy phosphoric acid and an amount of standard arsenious acid in excess of that required to effect the reduction of the chromic acid. After standing for fifteen to twenty minutes the solution was made alkaline with sodium bicarbonate, and an excess of standard iodine solution was added. This was allowed to stand in a stoppered flask for from one half hour to an hour, the excess of iodine being then removed with arsenious acid and the solution titrated to color with iodine after the addition of starch.

The use of phosphoric acid causes the iron to be precipitated as phosphate, and thus the difficulty mentioned by Browning* in observing the end-point, due to the reddish-brown ferric hydroxide, is in large measure obviated, the blue of the starch iodide being quite clear against the pale green chromic hydroxide. The results are given in (III), Table (II).

The first step in the calculation is the reduction to terms of tenth normal solution of the figures under (I), (II) and (III). It is evident that the subtraction of (III) from (I) gives the number of cubic centimeters corresponding to reduction of the vanadium pentoxide to tetroxide, while the subtraction of this result from (II) gives the number equivalent to the reduction of the ferric salt. By multiplying these figures by the solutions' equivalents of vanadic acid, chromic acid and ferric oxide, the necessary data are obtained. An example will make this clearer :

$$
\begin{array}{llll}
& \text{cm}^3 & \text{N/10 factor} & \text{cm}^3 \\
(\text{No. 1}) \ (\text{I}) & 31 \cdot 15 \times 1 \cdot 100 & = 34 \cdot 26 \ (\text{N/10}) & \rightleftharpoons \ V_2O_5 + CrO_3 \\
(\text{II}) & 23 \cdot 4 \ \times 1 \cdot 100 & = 25 \cdot 74 \ (\text{N/10}) & \rightleftharpoons \ V_2O_5 + Fe_2O_3 \\
\text{III} & 30 \cdot 00 - 8 \cdot 74 \ (\text{N/10}) & = 21 \cdot 26 \ (\text{N/10}) & \rightleftharpoons \ CrO_3 \\
(\text{I})-(\text{III}) \ (34 \cdot 26 - 21 \cdot 26) & & = 13 \cdot 00 \ \text{cm}^3 & \rightleftharpoons \ V_2O_5 \\
(\text{II})-13 \cdot 00 \ (25 \cdot 74 - 13 \cdot 00) & & = 12 \cdot 74 \ \text{cm}^3 & \rightleftharpoons \ Fe_2O_3
\end{array}
$$

$21 \cdot 26 \times 0 \cdot 003334$ (factor for CrO_3) $= 0 \cdot 0709$ grm. CrO_3 found.
$13 \cdot 00 \times 0 \cdot 00912$ (factor for V_2O_5) $= 0 \cdot 1185$ grm. V_2O_5 found.
$12 \cdot 74 \times 0 \cdot 00799$ (factor for Fe_2O_3) $= 0 \cdot 1018$ grm. Fe_2O_3 found.

The distillation flask used in this work will be briefly described. It consisted of a 100^{cm^3} pipette modified as shown in fig. (I), the inlet tube being bent upwards and having a separatory funnel sealed to its end, while the outlet tube was bent upwards and then down to enter the absorption flask ; a small bulb being blown in it to prevent mechanical loss during distillation. In carrying out the process a slow current of hydrogen from a Kipp generator was kept up through the apparatus, and this entering near the bottom of the flask enabled distillation to be carried to very small volume without danger of

* Loc. cit.

"bumping." The flask is similar in design to that used by Professor Gooch for the determination of boric acid and has been convenient and serviceable not only for this but for other processes involving distillation; it being very simple and doing away with the necessity of ground glass connections.
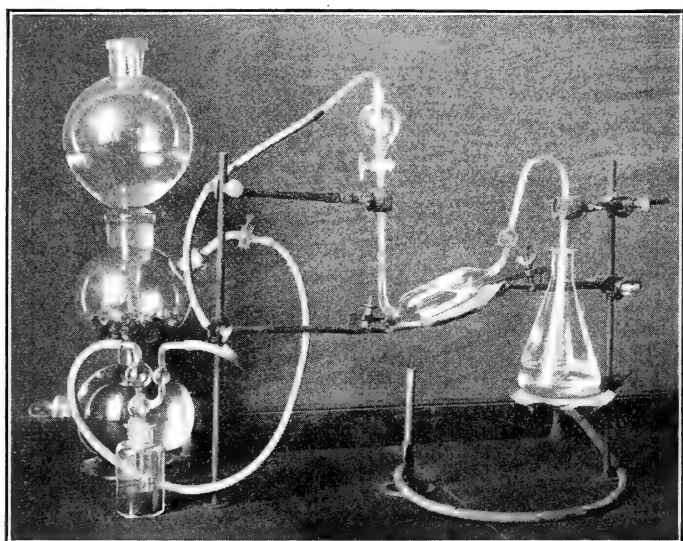
Summary.

It has been shown that vanadic acid, chromic acid and iron may be accurately estimated in the presence of one another by an iodometric process based upon the differential reducing action of hydrobromic and hydriodic acids, upon the substances in question; one constituent, the chromium, being estimated in a separate portion by reduction with arsenious acid.

TABLE (I).

Taken V_2O_5 grm.	Found V_2O_5 grm.	Error V_2O_5 grm.	Taken Fe_2O_3 grm.	Found Fe_2O_3 grm.	Error Fe_2O_3 grm.	(I) N/10 × ·9968 $Na_2S_2O_3$ cm³.	(II) N/10 × ·9968 $Na_2S_2O_3$ cm³.
0·1532	0·1532	±0·0000	0·1515	0·1515	±0·0000	16·85	35·88
0·1532	0·1532	±0·0000	0·1515	0·1518	+0·0003	16·85	35·91
0·1532	0·1531	−0·0001	0·1515	0·1518	+0·0003	16·84	35·90
0·1532	0·1531	−0·0001	0·1515	0·1516	+0·0001	16·84	35·88
0·1532	0·1535	+0·0004	0·1010	0·1001	−0·0009	16·89	29·46
0·1532	0·1533	+0·0001	0·1010	0·1007	−0·0003	16·86	29·50
0·0511	0·0509	−0·0002	0·1515	0·1516	+0·0001	5·60	24·64
0·0511	0·0511	±0·0000	0·1515	0·1515	±0·0000	5·62	24·65
0·2042	0·2045	+0·0003	0·0505	0·0502	−0·0003	22·50	28·80
0·2042	0·2042	±0·0000	0·0505	0·0505	+0·0000	22·47	28·82

TABLE (II).

No.	Taken V_2O_5 grm.	Found V_2O_5 grm	Error V_2O_5 grm.	Taken CrO_3 grm.	Found CrO_3 grm.	Error CrO_3 grm.	Taken Fe_2O_3 grm.	Found Fe_2O_3 grm.	Error Fe_2O_3 grm.	(I) N/10 × 1·100 $Na_2S_2O_3$ cm³.	(II) N/10 × 1·100 $Na_2S_2O_3$ cm³.	(III)	
												N/10 Iodine cm³.	N/10 As_2O_3 cm³.
1.	0·1183	0·1185	+0·0002	0·0709	0·0709	±0·0000	0·1021	0·1018	−0·0003	31·15	23·40	8·74	30·0
2.	0·1183	0·1179	−0·0004	0·0709	0·0710	+0·0001	0·1021	0·1023	+0·0002	31·12	23·40	8·70	30·0
3.	0·1183	0·1186	+0·0003	0·0709	0·0709	±0·0000	0·1021	0·1018	−0·0003	31·16	23·42	8·75	30 0
4.	0·1183	0·1184	+0·0001	0·1064	0·1065	+0·0001	0·1531	0·1533	+0·0002	40·80	29·25	8·10	40·0
5.	0·1183	0·1183	±0·0000	0·1064	0·1062	−0·0002	0·1531	0·1534	+0·0003	40·75	29·20	8·15	40·0
6.	0·0591	0·0590	−0·0001	0·1064	0·1065	+0·0001	0·1021	0·1019	−0·0002	34·90	17·50	8·10	40·0
7.	0·0591	0·0590	−0·0001	0·0354	0·0355	+0·0001	0·2042	0·2043	+0·0001	15·58	29·15	9·35	20·0
8.	0·1183	0·1188	+0·0005	0·0354	0·0353	−0·0001	0·1021	0·1018	−0·0003	21·50	23·45	9·40	20·0
9.	0·0591	0·0590	−0·0001	0·1417	0·1417	±0·0000	0·1021	0·1024	+0·0003	44·58	17·55	7·45	50·0
10.	0·2366	0·2365	−0·0351	0·0354	0·0352	−0·0002	0 1531	0·1530	−0·0001	33·22	41·00	9·40	20·0
11.	0·2366	0·2361	−0·0005	0·0354	0·0355	+0·0001	0·1021	0·1017	−0·0004	33·25	35·20	9·35	20·0
12.	0·1183	0·1182	−0·0001	0·0709	0·0710	+0·0001	0·0510	0·0511	+0·0001	31·15	17·60	8·70	30·0

Art. XI.—*On the Analysis and Chemical Composition of the Mineral Warwickite;* by W. M. Bradley.

Historical.—The mineral warwickite was first described by Shepard[*] in 1838 and again more fully in 1839; in the latter article he describes his method of analysis. Shepard named the new species *warwickite,* after the original locality, Warwick, Orange Co., N. Y. The mineral was found in limited quantity as small, slender crystals, imbedded in a highly crystalline white limestone. It had earlier been called hypersthene on account of the brilliant copper-red reflections afforded by its cleavage surfaces. At a second occurrence found by Young and Horton in the vicinity of the first, pieces about half an inch in diameter were obtained. These latter crystals lacked the copper-red luster characteristic of those from the first-mentioned locality, and were in a more or less decomposed condition.

From a qualitative analysis Shepard concluded that warwickite was a fluo-titanate of iron and manganese with a small percentage of yttrium. His results, however, were shown later (cf. Smith, noted below) to be erroneous and need not be discussed here.

In 1846, Hunt[†] published an article on a supposed new species from Warwick, N. Y., which he called *enceladite.* The material analyzed (I, below) was the impure altered warwickite examined by Shepard, as Hunt himself recognized later. His second analysis[‡] (II, below) was made on a purer specimen but showed a loss of nearly 20 per cent, which he attributed to an accident. Hunt's analyses are as follows:

	I		II
SiO_2	18·50		----
TiO_2	28·20		31·50
FeO	10·59	Fe_2O_3	8·10
MgO	22·20		43·50
Al_2O_3	13·84		----
CaO	1·30		----
H_2O	7·35	Ignition	2·00
	101·98		

After the completion of Hunt's analyses several years elapsed before further work was done on this mineral. About 1853, Brush and Smith, then engaged in the re-examination

* This Journal (1), xxxiv, 313, 1838, xxxvi, 85, 1839.
† This Journal (2), ii, 30, 1846.   ‡ Ibid., xi, 352, 1851.

of American minerals, pointed out that warwickite possessed a peculiar composition altogether different from what had been supposed, and that the pure mineral had not yet been analyzed. When the mineral had been subjected by the gentlemen named to a careful qualitative analysis, it was found to their great surprise to contain a large amount of boric acid, hitherto overlooked, so that it was to be considered as a boro-titanate of magnesia and iron. The quantitative analysis undertaken by Smith was made with difficulty because of the small amount of material available and from the fact that minute crystals of spinel penetrated those of warwickite. Smith, however, was finally satisfied that the results obtained expressed the true composition. The specific gravity obtained (Brush) was 3·362, and Smith's analysis is as follows :

		Oxygen	Ratio
B_2O_3	27·80	19·06	9
TiO_2	23·82	10·37	5
MgO	36·80	14·46	6
FeO	7·02	2·10	1
SiO_2	1·00		
Al_2O_3	2·21		
	98·65		

Smith regarded the silica and alumina as impurities, the latter arising from the spinel that it had been impossible to separate ; this, with a little of the magnesia, he deducted in making out the oxygen ratio from which he derived the formula :

$$6MgO . 1FeO . 2TiO_2 . 3B_2O_3.$$
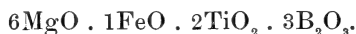
Method of Analysis.—The material used for the present analysis was obtained from the Brush collection and came from Amity, N. Y., where this mineral is found as a characteristic associate of the granite contacts of the region. The warwickite occurs in minute slender crystals showing the copper-red reflections of the cleavage surfaces which is so characteristic of the pure mineral. It is found in a coarsely crystalline white limestone, intimately associated with a greenish blue spinel, black spinel, magnetite, serpentine, chondrodite and occasional scales of graphite. The limestone rock containing the minute crystals of warwickite was crushed to small fragments and these small pieces, which contained some of the mineral, were carefully selected by means of a glass. This material was again crushed and prepared for treatment with heavy solutions. Potassium mercuric iodide solution, having when concentrated a specific gravity of 3·15, was first used to separate the greater part of the calcite and serpentine. The

final separation was made by means of barium mercuric iodide with a specific gravity of 3·55.

Considerable difficulty was caused by the presence of a greenish blue glassy spinel which in the solution closely resembled the grains of warwickite, but by repeated treatment with the heavy solution the latter was obtained in a quite pure condition. The material was further purified by the action of an electro-magnet which helped to remove some of the remaining foreign material. Finally by means of a very powerful glass the few remaining grains of the associated minerals were as far as possible removed. The final sample obtained amounted to a little over two grams and was quite uniform in character.

The specific gravity, determined by means of the barium mercuric iodide solution and a Westphal balance, was found to be 3·342 ; this is practically the same as that given by Brush, viz. : 3·351 for small fragments.

Owing to the limited amount of material available for analysis it was desirable to determine the main constituents, B_2O_3, TiO_2, MgO and total iron in one portion. After repeated fusions of the mineral with sodium carbonate the resulting cake was soaked out and the liquid decanted through a filter, the residue being thoroughly boiled with 25^{cc} of sodium carbonate solution and transferred to the filter and finally washed with dilute sodium carbonate solution. The filtrate containing the boron was transferred to a distilling bulb and the determination of boron made by distilling with methyl alcohol, the distillate being collected in ammonium hydroxide and finally evaporated over calcium oxide. The residue left in the bulb after distillation contained a trace of titanium which was recovered and added to the main solution previous to the precipitation of the titanium. The residue from the sodium carbonate fusion was brought into solution by prolonged fusion with acid potassium sulphate, and the resulting cake dissolved in cold water to which had been added strong SO_2 water. The solution was then largely diluted and rather strongly acidified with acetic acid ; the titanium precipitation being made in the presence of sodium acetate and brought about by boiling the solution from three to five minutes, strong SO_2 water being added before the boiling point was reached. The precipitate was then filtered and washed with dilute acetic acid and finally weighed as TiO_2. Some of the details of the above briefly outlined method are those recommended by Warren.[*]

The filtrate from the precipitation of titanium was concentrated and a very small precipitate was collected and added to

* This Journal (4), xxv, 23, 1908.

the main precipitate before igniting. A trace of iron was also
precipitated at this point, and this together with a mere trace
retained by the main titanium precipitate was recovered by
fusing the TiO_2 with acid potassium sulphate and a volumetric
determination for iron was made in the usual way with
$KMnO_4$. The filtrate from the titanium precipitation con-
taining the iron in the ferrous state was treated with nitric
acid to oxidize the iron, and hydrochloric acid added to form
enough ammonium chloride to keep the magnesium in solution,
when ammonium hydroxide was added to precipitate the iron,
etc. Double precipitations of the hydroxides were made and
the weight of the mixed oxides obtained. The oxides were
then fused with acid potassium sulphate, and the total iron
determined as usual by titration with $KMnO_4$. Traces of
titanium retained by the precipitate of ferric hydroxide were
determined where present by the colorimetric method and
corrections for both iron and titanium were made. The
amount of the alumina present was as usual arrived at by
difference. The filtrate from the ammonium hydroxide pre-
cipitation served for the determination of magnesium, which
was precipitated as ammonium magnesium phosphate. This
was then dissolved, reprecipitated and filtered on a Gooch
crucible and finally weighed as magnesium pyrophosphate.
The determination of ferrous iron was made by dissolving the
mineral in a mixture of hydrofluoric and sulphuric acids, and
finally titrating with $KMnO_4$, the modifications of Pratt*
being used throughout the above operation.

The results of the analysis follow:—

	I	II	Average		Ratios
B_2O_3 ____	21·21	21·36	21·29	·304	·304
TiO_2 ____	25·06	24·66	24·86	·310	·3328
SiO_2 ____	1·45	1·32	1·39	·0228	
MgO ____	35·41	36·01	35·71	·884	1·011
FeO ____	9·11	9·20	9·15	·127	
Fe_2O_3 ___	4·77	4·76	4·76	·0297	
Al_2O_3 ___	2·95	2·87	2·91	·0284	
	99·96	100·18	100·07		

The amounts of sesquioxides found are comparatively small
and the ratios obtained from them have no rational relation to
those obtained from the percentages of the other constituents.
Disregarding the Fe_2O_3 and Al_2O_3 for the present, it will be
seen that the other constituents yield,

$$B_2O_3 : TiO_2 : (Mg, Fe)O = 1 : 1·094 : 3·325.$$

* This Journal (3), xlviii, 149, 1894.

This would point to $B_2O_3 . TiO_2 . 3(Mg, Fe)O$ as the formula for the mineral. Since, however, a glassy green spinel is so intimately associated with the warwickite and its separation from it, both on account of its closely similar specific gravity, and because under the microscope it assumes an almost metallic appearance, it is thought reasonable to assign the 2·91 per cent of Al_2O_3 found to its presence in the material analyzed. This assumption would necessitate the subtraction of an equivalent amount of MgO as required by the formula $MgO . Al_2O_3$. Qualitative and quantitative tests on this spinel have proven it to correspond essentially to the variety known as chlorospinel, in which a little of the Al_2O_3 is replaced by Fe_2O_3. In this particular spinel there was found 8·92 per cent of Fe_2O_3, and corrections for this isomorphous Fe_2O_3 introduced into the warwickite analysis by means of this spinel have been accordingly made.

The presence of magnetite associated with the warwickite was proven by testing the impure material by the ordinary magnet. If, as is possible, it was intimately mingled with the warwickite it would be difficult to entirely separate it, as the warwickite itself is attracted easily by the electro-magnet. It seems reasonable therefore to assume that the greater part of the Fe_2O_3 found was contained in magnetite, and that an equivalent amount of FeO to correspond to $FeO . Fe_2O_3$ should be deducted from the analysis. Treating the analysis in this way we have the following results:

Average		Spinel	Magnetite	III	Calculated to 100	Ratio	
B_2O_3	21·29			21·29	23·87	·341	1
TiO_2	24·86			24·86	27·87	·347	⎫ 1·090
SiO_2	1·39			1·39	1·56	·025	⎬
MgO	35·71	−1·26		34·45	38·63	·957	⎫ 3·134
FeO	9·15		−1·95	7·20	8·07	·112	⎬
Fe_2O_3	4·76	− ·42	−4·34				
Al_2O_3	2·91	−2·91					
	100·07			89·19	100·00		

The ratios from the corrected analysis yield $B_2O_3 . TiO_2 . 3(Mg, Fe)O$ as before, but with sharper agreement between the theoretical and derived numbers. The formula for warwickite can then be written,

$$(Mg, Fe)_3 TiB_2O_8$$
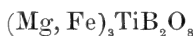
which could be developed into a symmetrical structural formula as follows:—
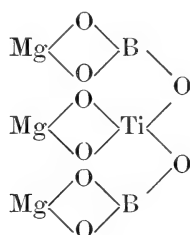
The theoretical composition corresponding to this formula would be

$$
\begin{array}{rcl}
\mathrm{B_2O_3} & = & 25{\cdot}81 \\
\mathrm{TiO_2} & = & 29{\cdot}54 \\
3\,\mathrm{MgO} & = & 44{\cdot}65 \\
\hline
& & 100{\cdot}00
\end{array}
$$

In conclusion, the author here wishes to thank Professor W. E. Ford for his kind advice and assistance.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The Question of Change in Total Weight of Chemically Reacting Substances.*—H. LANDOLT has devoted many years of the most painstaking work in investigating the weights of substances in closed glass vessels before and after they were mixed to produce chemical reactions. In 1893 he published his first paper on the subject, in which he described work with reactions between silver sulphate and ferrous sulphate, iodic acid and hydriodic acid, iodine and sodium sulphite, and chloral hydrate and alkali. As a result of these researches he was unable to establish with certainty any change in the total weight, but it appeared that the separation of silver and of iodine were accompanied by a slight loss in weight, so that the work was continued. In 1896 results were described, obtained with a balance of great precision, and with the use of much care, in which it was found that a loss was indicated, where silver or iodine were set free, in 42 out of 54 separate experiments. The changes in weight resulting from the use of 60 to 120 g. of reacting mass varied usually between ·003 and ·050 mg., and were often less than the estimated maximum error of ·03 mg. At this time it appeared to Landolt that these losses in weight, although small, were real, and he suggested the view, which was supported by the doctrine of the decomposition of radio-active atoms, that the violent shock which the atoms receive in chemical reactions might possibly cause the splitting off of minute particles of matter in the case of elements not belonging to the radio-active class, and that these might possess the property of penetrating the walls of glass vessels. Landolt has now published the results of additional, very elaborate, work on the same subject. He has explained fully the cause of former losses in weight in the fact that glass vessels which have been slightly heated by the chemical reaction within often do not return to their proper weight until after the lapse of a week or more, and he reaches the conclusion that in all of the 15 chemical reactions studied by him, no change in the total weight of the reacting substances has been established. This conclusion is of much importance in deciding the question, whether or not the atomic weights are of constant magnitude, for there appears to be no doubt that the force of gravity acts upon an atom to the same extent in any state of combination.— *Zeitschr. physikal. Chem.*, lxiv, 581. H. L. W.

2. *The Volume of Radium Emanation.*—Professor RUTHERFORD has recently made some measurements of the volume of the gaseous emanation produced by radium. For this work the Royal Academy of Science in Vienna put at his disposal a preparation containing about 250 mg. of pure radium. Much diffi-

culty was encountered in purifying the gas, and the results
varied to a considerable extent. The following table gives
examples of the amounts of emanation in equilibrium with 1 g.
of radium :

At the beginning of the experiment	At the end of the experiment
$1 \cdot 32^{c \ mm}$	$0 \cdot 80^{c \ mm}$
$0 \cdot 80$ "	----
$0 \cdot 97$ "	$0 \cdot 66$ "
$1 \cdot 05$ "	$0 \cdot 58$ "

These results, considering the difficulties encountered, agree
fairly well with the volume, $0 \cdot 57^{c \ mm}$, which Rutherford has cal-
culated theoretically, and the lowest result is only one-ninth of
the volume, $7 \cdot 07^{c \ mm}$, found by Ramsay and Cameron some time
ago. The gas underwent remarkable changes in volume after it
was collected. In some instances it contracted to less than half
its volume in the course of several hours, and then showed little
change in the course of a week. In other cases an increase in
volume was shown to double that of the original gas, and then a
slow contraction followed. ·These changes in volume, in many
cases, bear no relation to the changes in volume of the emanation
itself, for the true volume of the emanation was often only 20
per cent of the total gas volume. The author finds no satisfac-
tory explanation for these remarkable changes in volume.—
Monatshefte, xxix, 995.   H. L. W.

3. *A New Method for Separating Tungstic and Silicic Oxides*—
DEFACQZ treats the mixed acids in a boat at a red heat with a
current of hydrogen until the tungsten is completely reduced to
a lower oxide or to the metal. Then the boat is heated in a tube,
so arranged as to collect the volatile products, in a current of
perfectly dry chlorine gas. If air is absent the whole of the
tungsten is volatilized as hexachloride and oxychloride. The
volatile products are collected by means of ammoniacal water
and the tungsten is determined by one of the usual methods. The
silica in the boat is weighed after heating it in hydrogen again to
make sure, by the absence of any blackening, that the separation
is complete.—*Bulletin*, IV, iii, 892.   H. L. W.

4. *A Silicide of Uranium.*—DEFACQZ has prepared the com-
pound Si_2U by the aluminothermic method, using finely divided
aluminium, flowers of sulphur, silica, and uranium oxide in proper
proportions. The silicide forms a brilliant crystalline powder
with metallic luster. It is interesting to notice that the author
has prepared in the same way analogous silicides of molybdenum
and tungsten, Si_2Mo and Si_2W, and that these silicides all corre-
spond in type to the silicides of the iron group of metals having
the general formula Si_2M.— *Comptes Rendus*, cxlvii, 1050.

H. L. W.

5. *A New Periodic Function of the Atomic Weight.*—VIKTOR
PÖSCHL takes the percentage composition of the earth's crust as

calculated by F. W. Clarke, and by using these percentages as ordinates and the corresponding atomic weights as abscissas, shows that there is evidence of periodicity in the abundance of the elements. The curve which is carried only as far as nickel shows four maxima at oxygen, silicon, calcium and iron, and is regular enough to be very suggestive and interesting.—*Zeitschr. physikal. Chem.*, lxiv, 707. H. L. W.

6. *Velocity of Röntgen Rays; also their Influence on the Brush Discharge.*—ERICH MARX has previously measured the velocity of these rays (Ann. der Phys., xx, p. 677, 1906) by a null method, and in order to justify his use of the method he employed follows with another paper which is devoted to the theory of the method. He discusses various phenomena of the rays which come into prominence in his method, and naturally treats also of ionization.—*Ann. der Physik*, No. 1, 1909, pp. 37–56, 153–174. J. T.

7. *Radiation of Uranium X.*—Uranium X was obtained by the Moore-Schlundt and Becquerel method. HEINRICH WILLY SCHMIDT gives with many details the results of his investigation of the radiation of this substance.

(1) The hard β-rays gave

$$v = 2 \cdot 76 \cdot 10^{10} \text{ cm. sec}^{-1}$$
$$\epsilon/m = 0 \cdot 67 \cdot 10^{7} \text{ E.M.E.}$$

(2) The soft rays are absorbed by aluminium according to an exponential law, and are deviated in a magnetic field in the manner of negative particles.

(3) The curves of absorption, in different substances, varies much with the distribution of the radiation.

(4) An under limit is given for the absolute value of the reflection of the β-rays for very thick plates. The absolute value of the reflected radiation is greater for the hard β-rays than for the soft rays.—*Physikal. Zeitschrift*, Jan. 1, 1909, pp. 6–16. J. T.

8. *Influence of Self Induction on Spark Spectra.*—G. BERNDT contends that the criticisms of Néculcéa and Hemsalech on his investigation of the influence of self induction on spark spectra (Diss. Halle, 1901) do not consider the factor of time of exposure of the photographic plate, for the introduction of self induction greatly weakens the intensity of the spark.—*Physikal. Zeitschrift*, Jan. 1, 1909, pp. 28–29. J. T.

9. *Ionization of Gases, by Spark and Arc.*—It is known that gases subjected to high temperatures in the neighborhood of electric sparks or the electric arc preserve their increased conductibility much longer than gases subjected to ultra-violet light, X-rays, or α- and β-rays. HEINRICH RAUSCH, in a preliminary paper, investigates this property with a number of gases, among which were ordinary lighting gas, acetylene, hydrogen, carburetted hydrogen. He found a very long persistence of conductibility in lighting gas and acetylene.—*Physikal. Zeitschrift*, Oct. 25, 1908. J. T.

10. *Investigations in Radiation.*—The recently issued number of the Bulletin of the Bureau of Standards (vol. v, No. 2) contains two articles on radiation to which attention should be called here. The first, by W. W. Coblentz, gives the result of experiments on the selective radiation from various solids. This is practically an examination of the emission spectra of electrical insulators, or transparent media, as they are called; a line in which, thus far, almost no work has been done. The substances used were either in the form of solid rods, made in an oxy-hydrogen flame, or of thick layers of the substance spread as a paste upon the heater of a Nernst lamp. The rods were heated by an electric current from the secondary of a 2000-volt 300-watt transformer. The substances examined included a series of oxides, as those of zirconium, cerium, thorium, uranium, etc. ; also the minerals oligoclase, albite, orthoclase, beryl, rutile, apatite, calcite. All of these showed prominent emission bands at certain points; thus the oxides have a characteristic band at $2 \cdot 8$ to 3μ and a second group of bands at $4 \cdot 5$ to 5μ, which may be due to the common element oxygen. The silicates have also a sharp emission band at $2 \cdot 9\mu$ characteristic of SiO_2. In the case of oligoclase it is noted that the general emission, in distinction from the bands of selective emission, is less intense than in the other silicates studied. Further, the isochromatics of oligoclase are peculiar in that for it the emissivity is proportional to the energy consumed.

A second article, by P. G. Nutting, is an important discussion of the luminous equivalent of radiation, from the standpoint of both objective and subjective light and with especial reference to the establishment of a more precise relation between light and its radiation, by which it can be alone measured.

II. Geology.

1. *United States Geological Survey, Twenty-ninth Annual Report, 1907–1908, of the Director*, George Otis Smith. Pp. v, 99, with two plates.—This report contains a statement of the work done by the various divisions of the Survey during the fiscal year ending June 30, 1908. The freedom from political influence, the efficiency, and the high scientific esprit de corps which have marked the Geological Survey since its origin have caused it to be intrusted with various added branches of work which after a period of development have been organized as separate bureaus. This is the history of the Forest Service and the Reclamation Service. The technologic branch has had a more recent inception and the question is now under consideration by Congress as to the advisability of its development into a separate bureau of mining technology. Such a bureau would supplement, along purely technologic lines, the geologic work of the Survey, and the two bureaus could coöperate in investigations carried on

in behalf of the mining industry. A new branch of the Survey's activity which has taken form during the past year is the classification of Government coal lands, 22,700 square miles being classified and valued. This work is a result of the movement for conservation of National resources; a movement which in turn has been able to take intelligent form, as well as popularity, largely as a result of the more purely scientific labors of the Survey since its organization. The work of the Survey is thus seen to fall into two main divisions, work of a broad scope along fundamental lines, whose great value and utility may only become widely evident after the passage of decades, and work of immediate utility to meet the demands of the people and of Congress. The Survey is to be congratulated on having persistently followed work of both divisions.

During the year the geologic branch published 9 geologic folios, 1 monograph, 2 professional papers, 18 bulletins and the annual volume on Mineral Resources. Mention of the important results cannot here be made. The topographic branch mapped 25,658 square miles, making the total area surveyed to date in the United States 1,051,126 square miles, or about 35 per cent. In Alaska 6,626 square miles were mapped, mostly on the scale of 1 : 250,000. Important work by the water-resources branch was done in the lines of stream-flow and ground-water investigations, and investigations regarding the quality and pollutions of waters.

The entire appropriation for the Survey was $1,445,020, of which $300,000 was expended for topographic surveys and $200,000 for geologic surveys.　　　　　　　　　　　J. B.

2. *Geological Survey of New Jersey* : HENRY B. KUMMEL, State Geologist, Franklin Furnace Folio.—There has recently been issued by the Geological Survey of New Jersey in coöperation with the United States Geological Survey, a geologic folio of the Franklin Furnace region in Sussex County. This locality is one of the richest mineral regions in the world, alike important economically for its enormous zinc deposits at Mine Hill and Sterling Hill, and no less scientifically for the number and variety of its mineral species. In addition to the zinc minerals, over ninety well defined species are known from this locality, and eleven of these have not been found elsewhere. The region contains also extremely valuable deposits of white crystalline limestone and magnetic iron-ores.

In the descriptive text of this folio, the geography, geology and geologic history of this region are fully described. Complete information is given regarding the mineral deposits, and maps and cross sections show the location and shape of the valuable ore bodies. The folio may be obtained from the State Geologist, Trenton, N. J., price 25 cents, postage 15 cents additional.

3. *A Sketch of the Geography and Geology of the Himalaya Mountains and Tibet ;* by Colonel S. G. BURRARD, R.E., F.R.S., Superintendent, Trigonometrical Surveys, and H. H. HAYDEN,

B.A., F.G.S., Superintendent, Geological Survey of India. Pp. 230, pls. 37. Calcutta, 1907.—The three parts of this valuable monograph which have thus far been issued deal comprehensively with the geography of the Himalayas and to a less extent with the geography of all the great mountains of central Asia. Part I, on "The High Peaks of Asia" (46 pp., 8 pls.), by Col. Burrard, gives abundant statistics as to the height and distribution of the 75 known peaks which exceed 24,000 feet in height. From an interesting chapter upon errors in observations of altitude it appears that even in the case of the most accurately measured peaks the figures usually given are liable to an error of from 100 to 300 feet. In part II, on "The Principal Mountain Ranges of Asia," pp. 47–117, pls. 9–22, Col. Burrard describes in detail the various ranges, and shows how they originate in broad uplifts along axes which are generally parallel, but which often bifurcate or coalesce, and less frequently meet at right angles. A noteworthy chapter discusses observations with the plumb-line and pendulum which indicate that a concealed mass of exceptionally heavy material lies beneath the plains of India far from, but parallel to, the Himalayas and their fast-growing subsidiary range, the Siwaliks. In part III, on "The Rivers of Himalaya and Tibet" (pp. 118–230, pls. 23–37), the main streams are classified according to both location and size. They are described with the same clearness and care which are given to the description of the peaks and ranges. Attention is frequently called to the marked disagreement between divides and mountain ranges. It is the exception for a main divide to correspond with a main range. The Indus river zigzags back and forth three times across the great Ladakh range. In the Hindu Kush region part of the streams flow northward across the main range; while others cross it in the opposite direction flowing southward. Numerous other evidences indicate the young stage of the mountains and plateaus and the lack of adjustment of drainage to geologic structure. Chapters on glaciers and on recent desiccation as indicated by Tibetan lakes, complete the discussion of drainage.

The monograph as a whole is not only written in a very clear and interesting style, but is most accurate in detail, and most carefully arranged to facilitate reference. Theoretical discussions are not avoided, but they play a minor part and are clearly distinguished from accepted facts and conclusions. A valuable feature of the monograph is its clear statement, not only of our knowledge but of the limits of our knowledge of the great mountains of Asia.   E. H.

• 4. *The Gases in Rocks;* by R. T. CHAMBERLIN. Carnegie Institution, Washington, 1908, 8°, 80 pp.—This paper embodies the results arrived at by a critical study of the gases evolved by heating 112 specimens of rocks in a vacuum. The list includes all of the more important kinds of intrusive igneous rocks, lavas, stratified and metamorphic rocks and a few minerals. The

methods appear to have been well selected and carefully carried out. The results show that carbon dioxide and hydrogen are in general the gases most largely evolved, while minute amounts of carbon monoxide, hydrogen sulphide, methane and nitrogen are apt to accompany them. The author recognizes, of course, that a considerable, or even the larger, part of these gases were not contained in the rocks as such but were evolved from carbonates, sulphides and hydrates, and he discusses their possible origin from these substances and from others not known to be present in rocks, such as carbides and nitrides, but which might conceivably be present in the igneous ones. Rocks, however, are such complicated bodies and the possible reactions and interactions which may take place at high temperatures so many and so involved when a large number of factors are concerned, as brought about by the possible presence of sulphides, metallic oxides of a lower state of oxidation, carbon and even metallic particles such as copper and iron, that it appears possible that all of these gases except the nitrogen may have been produced from original solids, sulphides, carbonates and hydrates. While some of the gases such as CO_2 and water vapor are undoubtedly contained in rocks as such, it thus becomes a matter of doubt as to how much of the gases evolved are to be considered original and how much ascribed to secondary alteration of the original minerals. In this connection the reviewer regrets that the work was not accompanied by a microscopical examination in thin section of the actual specimens studied, since this would have thrown much light upon the presence or absence of such secondary products.

In conclusion the author discusses the bearing of the results obtained upon general problems of geology and with reference to the early condition and origin of the earth. While no essentially new or startling facts have been brought to light by this undertaking, it is none the less a very useful piece of work of a laborious nature which has been carefully carried out and which will prove of service in the future in aiding to solve problems of chemical geology. Many investigations of just this character are needed before speculation upon the early history and character of the earth's crust can rest upon secure foundations.   L. V. P.

III. Botany and Zoology.

1. *The Forest Flora of New South Wales;* by J. H. Maiden, Government Botanist, and Director of the Botanic Garden, Sydney.—This useful treatise has now begun its fourth volume. The training of the author for this important contribution to science has been of a peculiar character. After having familiarized himself with the most approved Museum methods in England, he took charge of the great economic Museum in Sydney, where, under many discouragements, he built up a vast

establishment, which has proved of immense use to the Colony and its sister Colonies. Early in this work of organization he prepared a useful treatise on the Useful Plants of Australia, which embodied a whole treasury of technological information. During this term of service he was in constant correspondence with all parts of Australasia, accumulating materials from all quarters. After the death of Baron von Mueller, Mr. Maiden became the Government Botanist, and he was appointed also Director of the Botanic Garden in Sydney, a post which the Baron did not occupy in his last years.

Equipped with an unusual amount of technological information, Mr. Maiden has undertaken to make his Flora, as far as possible, practical. In this he has succeeded admirably, so that the forest flora is available as a hand-book even to those who are far removed from the southern hemisphere. The illustrations and text are of a high order throughout.   G. L. G.

2. *Jaarboek van het Department van Langbouw in Nieder-landsch-Indie, 1907.*—The report on the Agriculture of the Dutch East Indies has just come to hand. It contains a full account of the efficient stations in the districts, in which the more important technical plants and their products are studied with reference to improvement. The Garden at Buitenzorg and the experiment stations are well illustrated and described. It is no wonder that the Dutch have been able to maintain their place in the fierce competition for supremacy in the export of tropical products. The authorities have spared no expense or labor in applying the most modern methods of cultivation throughout Java and the out-lying islands.   G. L. G.

3. *The Origin of Vertebrates ;* by WALTER HOLBROOK GAS-KELL. Pp. ix + 537. London and New York, 1908 (Longmans, Green & Co.).—This book forms an important contribution to the speculation as to which particular group of existing invertebrates, if any, has given rise to the vertebrate animals by a process of evolution. For twenty years the author has held the view that the nervous system of the vertebrate is in part a modification of the alimentary canal of some invertebrate ancestor. He believes that the great factor in evolution has been the growth of the central nervous system, and that with this factor it is possible to trace the evolution of the mammal from the reptile, thence back to the amphibian and the fish ; the latter arose from the arthropod, and this from the annelid. The vertebrate is therefore the natural evolution of a primitive crustacean ancestor. This view, of which the author has been one of the leading exponents for many years, is thought to be sustained by a critical comparison of each organ system of the vertebrate with that of its supposed crustacean prototype. With all the possible evidence thus ably presented, it will be of interest to learn whether further enthusiasm will be aroused for a theory which has thus far found few supporters.   W. R. C.

4. *Ticks: a Monograph of the Ixodoidea;* by GEORGE H. F.
NUTTALL, CECIL WARBURTON, W. F. COOPER, and L. E. ROBINSON.
Part I, Argasidæ. Pp. x + 104, with a bibliography of 35 addi-
tional pages. Cambridge, 1908 (University Press).—The discov-
ery that ticks play a most important part in the transmission of
certain diseases of man and domestic animals, has led to a renewed
interest in this group of parasites. The present work will contain,
when completed, a description of all known species of the group,
with a discussion of their structure, life history, and economic
importance. References are made to all the important literature
on the subject, the bibliography being printed on one side of
thin paper, so that the titles can be cut out, if desired, and
gummed on index cards. The work is well illustrated by half-
tone plates and numerous text figures.   W. R. C.

5. *Animal Romances;* by GRAHAM RENSHAW. Pp. 206.
London, 1908 (Sherratt & Hughes).—A series of vivid word
pictures of animal scenes in various portions of the world. A
Caucasian autumn scene with its background of mountain forest,
into which the characteristic birds, mammals, and other animals
are projected with kaleidoscopic effect, is followed by a glimpse
of the Malay jungle at midnight ; while the latter picture grad-
ually dissolves into the noon-day glitter, to be in turn lost in the
dusk of evening; a continuous procession of living creatures
passes before the eye, each one acting its part in the full seclu-
sion of its native haunts. Other chapters reveal the life of the
African wilderness, the Antarctic seas, the Andean mountains,
the Australian bush, the Pacific coral reef and other regions of
the globe. Most of these scenes apparently have been drawn
directly from the personal impressions of the writer, and portray
vividly and accurately the living creature in its natural activities
and customary environment. The illustrations are all taken from
photographs by the author.   W. R. C.

6. *Essays on Evolution,* 1889–1907 ; by EDWARD BAGNALL
POULTON. Pp. xlviii + 479. Oxford, 1908 (Clarendon Press).—
This volume consists mainly of ten essays on the subject of
evolution, delivered as addresses on various occasions since the
year 1889. The text of the original essay has been altered
whenever necessary to represent the views of the author at the
present time, and the last and longest essay on " The Place of
Mimicry in a Scheme of Defensive Coloration" has been entirely
rewritten and emphasis laid on the advance in the knowledge of
the subject in recent years. The new discoveries supporting the
doctrines of Mendelism and of Mutation are discussed in an
introductory chapter, and with some of the expounders of these
doctrines the author has little patience, because of their quite
unnecessary depreciation of other subjects and other workers.
On the whole, the book forms a most interesting and important
exposition of some of the most vital topics of Darwinian evolu-
tion by a well known authority on the subject.   W. R. C.

7. *Parasitology:* a supplement to the Journal of Hygiene; edited by George H. F. Nutall and A. E. Shipley.—A newly established journal devoted to the publication of original contributions on the biology of the animal parasites of man and animals.

IV. Miscellaneous Scientific Intelligence.

1. *A New Goniometer Lamp;* by Fred. Eugene Wright. (Communicated from the Geophysical Laboratory.)—The goniometric measurement of minute crystal faces requires a source of illumination of such intensity that for the past five years the writer has employed an electric arc goniometer lamp (Proc. Amer. Philosophical Soc., xlii, 237–238, 1903) for the purpose. Certain

Fig. 1.
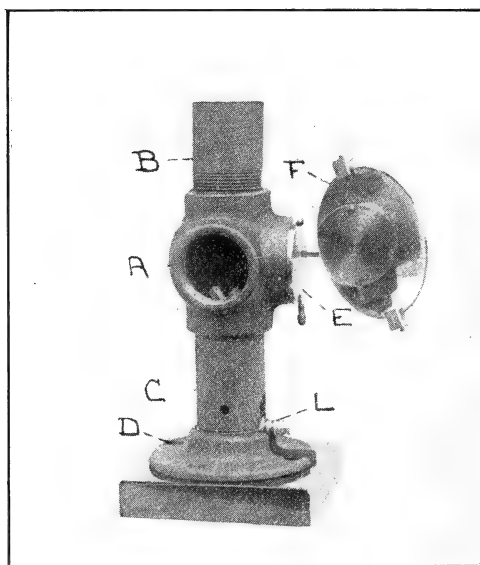
features of the arc light, however, are not favorable for its constant use, and although, on occasion, it is the best light procurable, other sources of illumination have been found better adapted for general work.—The Nernst light is an excellent source, and were it not for the present unreliability of the filaments, would serve every purpose.—The acetylene light, however, has been found by experience to be the most serviceable, and the following goniometer lamp has been constructed for its use. This lamp is

modeled in principle after the Welsbach goniometer lamp of Goldschmidt (Zeitschr. Kryst. xxiii, 149–151, 1894), and consists essentially of a tee with side outlet (fig. 1, A, 1·5-in. diameter) with iron pipe fittings, B and C, of proper length, together with a base plate, D. This device fits over the acetylene burner L, and can be removed at any time and the acetylene burner used for other purposes. The mirror, F, serves to reflect the light from the burner to the verniers of the goniometer, and, like the Gold- schmidt lamp mirror, furnishes all light requisite for goniometric work. By means of the brass shield plate at E, the side outlet of A can be opened and closed at will, and with it the light from the burner to the mirror. The materials of which this lamp is made are all on the market and can be readily procured from any pipe-fitting establishment and assembled at moderate cost by a mechanic. The acetylene burner is of the usual one-half foot type and the generator No. 102 of the firm of J. B. Colt, New York.

2. *A Containing Device for Salts Used as Sources for Mono- chromatic Light ;* by FRED. EUGENE WRIGHT. (Communicated from the Geophysical Laboratory.)—For many years sodium, lithium and thallium compounds have been employed to produce fairly monochromatic light,—yellow, red and green respectively—

FIG. 1.
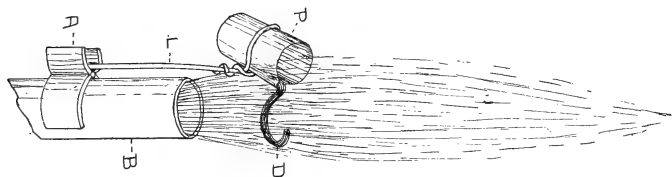
and a number of different devices for holding such salts in the Bunsen flame have been suggested which answer the purpose more or less satisfactorily. The following simple arrangement (fig. 1), which is apparently novel, has been found useful and effective by the writer in this connection and merits a brief word of description. The salt is placed in a small thin-walled platinum crucible about 1·5 to 2^{cm} long and 10^{mm} in diameter (P of fig. 1) ; a bundle of fine platinum wires (fig. 1, D, 4–5^{cm} in length serves as a wick and is held in proper place by pinching together one side of the platinum crucible, as indicated in the figure. The crucible is supported by a thick platinum wire L, which in turn is attached to the tube B of the Bunsen burner by the clamp A. The platinum crucible is purposely inclined at an angle as indi- cated in the figure, in order that its side may be reached by the flame and heated so hot that the salt it contains melts and is gradually fed into the flame by the wick of platinum wires. A single charge of sodium carbonate thus introduced has been

used for weeks at a time. By having on hand three such devices, one for sodium, the second for lithium and the third for thallium salt, the observer can at any instant change from the one to the other and proceed with his measurements for hours if necessary without further care for the flame. By this process of melting down the salts, the flow of fresh material is continuous and the flame is constant and remains practically unchanged for a long period of time.

3. *Report of the Secretary of the Smithsonian Institution for the year ending June 30, 1908.* Pp. 84. Washington, 1908.—The annual report of Dr. Charles D. Walcott, Secretary of the Smithsonian Institution, has recently been issued. It gives the usual interesting account of the workings of the Institution in its varied functions, prominent among which are the National Museum, the Bureau of American Ethnology, the International Exchanges, the National Zoological Park, and the Astrophysical Observatory. The work of the Institution is now so well organized that it goes forward in a manner most satisfactory to all the interests involved. In regard to the new building for the National Museum, it is stated that the walls are completed and the construction of the roof well under way. There remains, however, the fitting up to the interior, including some ten acres of floor space. The most interesting part of the work of the Bureau of Ethnology has been the excavation and repair of the Casa Grandé ruins in Arizona, under the charge of Dr. Fewkes. Although the work has not been completed it has progressed far enough to present a typical ruin, given the general character of the ancient Pueblo remains of that region. This most interesting subject, and others related, are described in detail in an Appendix to the present Report, prepared by the Chief of the Bureau, W. H. Holmes. Other appendixes are given by the gentlemen in charge of the different departments, among which must be mentioned that by C. G. Abbot on the work of the Astrophysical Observatory. A number of special investigations are enumerated which are now being carried on by grants from the funds of the Institution.

The Annual Report of the Board of Regents for the year ending June 30, 1907, has also been issued. This contains the Report of the Secretary, issued in advance about a year since (see vol. xxiv, p. 160). There is also the usual Appendix, pp. 95-709, containing selected articles of general scientific interest on a wide range of topics. As most of these are not easily accessible in the original, their republication here should be of great value to the intelligent reading public.

Obituary.

George W. Hough, Professor of Astronomy at Northwestern University and Director of the Dearborn Observatory, died at his home in Evanston on January 1 in his seventy-third year.

New Circulars.

84 : **Eighth Mineral List :** A descriptive list of new arrivals, rare and showy minerals.

85 : **Minerals for Sale by Weight :** Price list of minerals for blowpipe and laboratory work.

86 : **Minerals and Rocks for Working Collections :** List of common minerals and rocks for study specimens; prices from 1½ cents up.

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RARE CINNABARS FROM CHINA.

We would call attention to these remarkable Cinnabars, some of which still remain. They are beyond doubt the most beautiful and interesting crystals of Cinnabar ever discovered. They were described and illustrated in this Journal, Nov. '08. The prices range from $5, $7.50, $10, $15, $18, $25, $35, and $50.

NEW ARRIVALS.

Euclase, Capo do Lane, Brazil; Chalcocite, Conn.; Columbite, Conn.; Monazite, large loose xls. and in matrix, Conn.; Uraninite, crystal in matrix, Conn.; Benitoite, San Benito Co., Cal.; Neptunite, Cal.; Lievrite, Elba; Polybasite, Hungary and Mexico; Herderite, Poland, Maine; Californite, Tulare Co., Cal.; Cobaltite, loose crystals and in matrix, Cobalt, Ont., and Sweden; Vivianite, large crystals, Colo.; Olivinite, Utah; Sartorite, Canton Wallis; Jordanite, Binnenthal; Crocoite, Siberia and Tasmania; Cinnabar, Cal., Hung. and China; Gypsum, twin crystals, Thuringia; Diamond in matrix, New Vaal River Mine, South Africa; Argentite, Mexico; Freiberg, Saxony; Pyrargyrite, Saxony and Mexico; Pyromorphite, Ems, Germany, Phoenixville, Pa.; Tourmalines, beautiful sections from Brazil; Brochantite, on Chrysocolla, Utah; Pink Beryl, small and large, Mesa Grande, Cal.; Kunzite, small and large, Pala, Cal.; Sphene, Binnenthal; Titantite, Tilly Foster, N. Y.; Tetrahedrite, Utah and Hungary; Realgar, Hungary; Opal, Caribou River, Queensland; Torbenite, Eng.; Bismuth, native, Cobalt, Ont.; Emerald, loose and in matrix, Ural; Zircon crystals, loose, Ural; Green and Cinnamon Garnets, Minot, Maine; Vesuvianite, Poland, Maine, Italy and Tyrol; Zeolites, beautiful specimens from Erie Tunnel, Patterson, and Great Notch.

NORWAY and SWEDISH MINERALS.

Just secured a fine lot of exceedingly rare minerals; as they are now in the Custom House, and cannot be listed in time for this issue, kindly write for list of same.

CUT GEMS.

Garnets, green and red; Aquamarines; Zircons, all shades; Sapphires, all shades; Star Sapphires and Star Rubies; Chrysoberyl, Cats-eye; Spinels, all shades; Topaz, pink, blue, brownish and golden color; Pink Beryl; Sphene; Tourmaline, all shades; Amethyst, Siberia, royal purple Star Quartz; Peridote; Opal matrix, Mexico and Australia; Hyacinth; Turquoise, Mexico and Persia: Kunzite; Reconstructed Rubies and Sapphires; Opal carvings; Antique Cameos and Mosaic, and other semi-precious stones.

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Art. XII.—*Recent Observations in Atmospheric Electricity ;* * by P. H. Dike.

It is somewhat difficult to give a satisfactory résumé of recent work in Atmospheric Electricity which can claim to be complete and at the same time strictly up to date, since aside from the four or five centers from which emanate most of the contributions to the advance of the subject, work is frequently coming to light from unexpected sources.

We have been in the habit of looking to Elster and Geitel, Gerdien, Ebert, and a few others in Germany, to the Cavendish Laboratory in England, and to Rutherford and his followers at McGill University, Canada, for most of the work in Atmospheric Electricity, but of late other experimenters have begun to enter the field.

Not very much has been done as yet in this country along these lines, and what has been done has been scattering and desultory for the most part, consisting of the work of an individual here and there. There has been no such extended and persistent study of the subject, and such careful experimentation as has been going on in England and Germany for some years, and which has yielded so many important and interesting results. For this reason most of the work referred to will necessarily have been done in foreign laboratories. The field of research in Atmospheric Electricity is a broad one and presents numerous complications of a most troublesome sort, which offer to the observer abundant opportunity for the exercise of his ingenuity.

The earliest known and most thoroughly studied of all the phenomena included under the head of Atmospheric Electricity

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is the potential gradient—the existence of an electric field about the earth, resulting in a difference of potential between the earth and any point in the air above it.   The existence of such a potential is readily shown by the use of a suitable electroscope or electrometer connected to a collector, such as a flame, a water dropper or a radio-active body.   Potential gradients exceeding 100 volts/meter are ordinary, and during times of electrical disturbance, even with a clear sky, this may increase to 1000 volts or more.   The mean value at Kew, England, has for eight years exceeded 159 volts per meter, while on January 1, 1908, during a fog it exceeded 730 continuously for $8\frac{1}{2}$ hours. Its fluctuations are abrupt and of great range, sometimes passing suddenly from large positive to negative values.   At Kew, at Potsdam, and at various other observatories, continuous records have been kept of this most erratic phenomenon by means of self-recording instruments for years, in an attempt to establish some relationship between it and other meteorological elements, but so far without very definite results, except for a possible connection with the barometric pressure; and this relationship, according to Chree, seems to point to change of potential gradient as a cause, and change of pressure as a result.   It would seem to be almost impossible to correlate such a phenomenon with local weather conditions except in so far as electrical storms are concerned, when it is considered that as a charged body we have the earth, whose electrical condition is dependent on conditions prevailing over its whole surface rather than on local phenomena.

By recent observers the study of this element of the problem has been made subsidiary to other investigations in which it is involved as a factor, principally in the computation of the earth-air currents.

An interesting series of investigations with a practical end in view has been made by Creighton of the General Electric Company bearing upon the subject of electrical storms with especial reference to lightning discharges and the operation of lightning arresters on transmission lines.   Laboratory experiments were supplemented by observations at two power plants in Colorado where electric storms are of daily occurrence in summer.   By means of a rotating film or a moving sensitive tape the duration of a discharge on a transmission line was measured by means of projecting the light from a spark gap connected with the line upon the film.   A range of duration of from 0·04 sec. to 0·0001 sec. was found in 36 discharges, the greater number being of very short duration and only two exceeding 0·01 sec.   As many as seven discharges in a second were observed.   The discharge is oscillatory, showing 3000 cycles per second, corresponding to the line frequency, and

may be further analyzed into higher frequencies of the order of 1,000,000 cycles per second by coil resonators arranged to affect strips of sensitive paper by their brush discharge when excited by frequencies of the proper pitch. The potentials were approximately measured by graduated needle gaps, a number of which were arranged in parallel rows, with fuses and high resistance in series, the potential falling between the minimum sparking pressure of the longest gap crossed and that of the next higher. The measurement of the lightning current was difficult, as it depends on the capacity, inductance and resistance of the lines and the frequency of discharge. The quantity of the discharge over the line was estimated by noting the size of fuse that it would just burn out, several fuse wires of different sizes being placed in series, the arc holding in the vapor of the first fuses blown till the larger ones were melted. Using the data from one of these tests, the quantity of discharge was estimated at 0·003 of a coulomb, and if this quantity of electricity was spread out over a mile of wire having a capacity between line and ground of 0·01 micro-farad the initially impressed voltage would be about 600,000 volts.

The development of the theory of the ionization of gases opened up a new field of investigation in Atmospheric Electricity, since it afforded an explanation of the previously observed fact, that a charged body exposed to the air lost its charge at a more rapid rate than could be explained by leakage over the insulating supports. Elster and Geitel were pioneers in this field, and though the instruments devised by them for observing the "dispersion" gave erroneous results through the establishment of saturation currents, that is, currents independent of the potential difference, once a certain minimum potential is passed, they accumulated much information of a relative nature. It is to J. J. Thomson and his school that we are indebted for a better understanding of the conductivity of gases, leading to the construction of apparatus on more correct principles; results are now being obtained which may probably pretend to some degree of accuracy. The experimenter in these lines must be satisfied with somewhat approximate results, since it is obviously impossible to measure a conductivity to one or two per cent when its value is varying during the time of measurement by perhaps fifty per cent. The order of magnitude can be arrived at, but the conductivity of a gas is quite a different matter to that of a metal where the number of ions seems to be infinite, and atmospheric air is even more unstable in its properties than a confined sample of gas.

The establishment of saturation currents in the apparatus for determining the conductivity of the air may be prevented in two ways, either by the removal of all other conductors to such

a distance from the charged body, whose loss of charge is to be measured, that at the potential to be used the currents shall be unsaturated, or by setting up a current of air about the charged body of such velocity that the same result is reached.

The latter, first applied in its fullest extent by Gerdien, has proved to be of great use for field work, while the former seems more suitable for observatory use, where continuous records are desired. The Gerdien conductivity apparatus, briefly described, consists of a cylindrical condenser, the outer cylinder of which is 16^{cm} in diameter and 35^{cm} long, while the inner cylinder is 1.4^{cm} in diameter and 24^{cm} long, and is connected with an electroscope by means of which the potential of a charge put upon the cylinder can be observed. A current of air, of sufficient velocity to prevent the establishment of saturation currents, is drawn through the condenser with the aid of a fan, thus using the second of the two methods of avoiding saturation. This instrument has been used by various observers on land, in balloons and at sea, with very consistent results, and it has proved very satisfactory for field work. Gerdien has made use of it at Göttingen in conjunction with a self-recording instrument giving the course of the potential gradient for determining the value of the earth-air current.

The potential gradient and the conductivity being known, the current per square centimeter of the earth's surface is readily computed.

$$i_h = \frac{\delta v}{\delta h} (\lambda_\rho + \lambda_n)$$

A series of observations carried out during about two and a half weeks in April, 1906, gave as a mean from 49 measurements $8\,0 \times 10^{-7}$ electrostatic units per square cm. for the value of the vertical current, or 2.7×10^{-16} amperes. The conductivity was found to be $\lambda_\rho = 1.155 \times 10^{-4}$ and $\lambda_n = 1.120 \times 10^{-4}$ electrostatic units.

I have made use of the same type of instrument at sea, on board the Galilee during the cruise recently completed, beginning at Sitka and ending at San Francisco, obtaining observations, mostly in fair weather conditions, in latitudes ranging from 55° 41′ North to 45° 07′ South, crossing the tropics twice, thus securing a wide range of climatic conditions. Unfortunately on board ship I was unable to measure the normal potential gradient in an undisturbed field, and the disturbances were so great and so variable that it seemed impossible to avoid or to correct for them. Hence my observations give only the conductivity and the potential gradient can only be surmised. A few observations made in a skiff at sea in very calm weather

gave values about the same as on land, and I see no reason for supposing that the potential gradient should be less over the sea than over the land. The conductivities obtained varied considerably but not more so than at a fixed land station, apparently exhibiting some tendency to decrease as the barometric pressure increases.

The mean conductivities for the voyage were:

$$\lambda_p = 1 \cdot 603 \times 10^{-4} \text{ electrostatic units}$$
$$\lambda_n = 1 \cdot 433 \times 10^{-4} \qquad \text{``} \qquad \text{``}$$

This would make the vertical current somewhat greater than what Gerdien found, assuming the same potential gradient. The observations for a day usually extended over an hour or more and were made up of alternate readings of the conductivity for positive and for negative electricity, A charge of about 150 to 200 volts was put on the inner cylinder by means of a dry pile and the divergence of the electroscope leaves read. This reading was the most difficult part of the observation at sea since the rolling of the ship gave the leaves a pendular motion, while the rise and fall of the ship as it rode over the waves gave them a flapping motion, so that they alternately spread farther apart as the ship sank into the trough of the waves and fell together as it rose to the crest. The pendular motion was avoided to some extent by mounting the instrument on a gimbal stand and steadying it with the hands to keep it horizontal, but the flapping was unavoidable and limited the observations to moderately smooth seas. Only one leaf at a time could be watched through the eye-piece, so that the estimation of the mean position of the leaves was difficult. However, the consistency of the results shows that some degree of accuracy was obtained.

Immediately after reading the divergence of the leaves, the fan was rotated at a uniform rate for five minutes. At the end of that time a second reading of the divergence was made and the charge was removed by earthing the inner cylinder, which was then charged negatively. After a wait of about one minute to allow any of the former charge which might have been absorbed by the insulation to be neutralized, a reading of the divergence of the leaves for the negative charge was made, in time to begin the rotation of the fan two minutes after the end of the rotation for the positive charge. Closing both ends of the cylinder to exclude air currents, a leakage test to determine the normal rate of leak over the insulation was made, usually extending over fifteen to twenty minutes.

The electroscope had to be calibrated of course, and this was done at long intervals, as laboratories for testing electrical instruments are not numerous in the Pacific. An apparatus

was carried designed to give a rough calibration on board ship, but its results, after a test at Sitka, and another, an unsuccessful one, at Honolulu, were judged too rough to be relied upon. It was possible to obtain a good calibration at Christchurch, New Zealand, in the electrical laboratory of Canterbury College in January of 1908, but there was no further opportunity until the return of the instruments to this city in July, when a calibration was carried out at the Bureau of Standards, agreeing remarkably closely with the curve obtained at Christchurch, showing that at least during the last half of the voyage the values had remained practically constant, that is within three per cent, which is well within the accuracy of reading at sea. A comparison of these values with those obtained at Sitka indicates a gradual increase in sensitiveness, which goes on at a diminished rate between Christchurch and Washington. Through unexpected good fortune I was able to use the same pair of leaves throughout the voyage uninjured, though the electroscope had to be opened to clean the insulation, thus exposing the leaves to air currents and other dangers of damage, nearly every time the instrument was used.

An electroscope is far from being a satisfactory instrument for use at sea, but it is the only form of electrometer now available that would work at all, unless some form of the "string electrometer" may be found satisfactory.

C. T. R. Wilson of the Cavendish Laboratory has made some interesting observations of the earth-air current with a very different instrument, designed by himself, by means of which he is able to measure the current from a test plate which is kept at zero potential, that is, at the potential of the surface of the earth, thus approximating closely to the actual conditions.

The case of a gold-leaf electrometer is kept at a constant potential by means of a quartz Leyden jar, while the gold leaf is attached to the rod bearing the test plate, a blackened brass disk 7^{cm} in diameter surrounded by an earth-connected guard ring. A cylindrical cover rests upon the guard ring and shields the test plate except when it is to be exposed to the influence of the earth's electrical field. During exposure the test plate and gold leaf are maintained at zero potential by means of a compensator consisting of a cylindrical condenser of which the inner conductor is a metal rod connected to the gold-leaf system, the outer condenser being a brass tube maintained during any series of observations at a constant negative potential by means of a quartz Leyden jar and capable of sliding parallel to its length to give a variable capacity. A scale is attached to give the position of the outer cylinder relative to the inner and this scale is calibrated to determine the change of capacity corresponding to one scale division. Thus the

change of charge, that is the loss or dispersion of electricity from the exposed test plate, can be measured by reading the scale before and after exposure, the gold leaf being kept constantly at its zero position by means of a gradual motion of the compensator.

The test plate being covered, the gold-leaf system is earthed and the position of the compensator is read. The earth connection is then broken and the cover removed. The observer then keeps the gold leaf at its zero position, that is, keeps the test plate at zero potential by means of the compensator till a measured interval of time has elapsed, when the position of the compensator is again read. From the difference of the two readings the loss of charge can be computed and thus the current per square cm. of the test plate determined. Alternate measurements were made with the bare test plate and with a piece of turf covering the plate to represent a section taken from the surface of the earth. The dissipation factor is expressed as the percentage of the charge on an earth-connected, exposed body which is neutralized per minute. The dissipation factor for the plate alone was found to be practically the same as for the turf, though the charge on the turf was about three times as great and the distribution of charge very different. The agreement is sufficiently good to warrant assuming a definite dissipation factor depending on the condition of the atmosphere. In order to get a closer approximation to actual conditions at the surface of the ground, instead of at the elevated test plate, a large wooden test plate and guard ring with their surface very little above the surface of the ground were constructed and connected with the test plate of the apparatus. Alternate determinations were made with the small and the large test plates, precautions being taken that the field should not be disturbed by the observer. From those observations it was found that the mean density of electrification upon the exposed test plate when at zero potential was nearly $4 \cdot 2$ times that upon the surface of the ground. Using this reduction factor, observations extending over a year give a mean value for the current per square cm. of ground $2 \cdot 2 \times 10^{-16}$ amperes, agreeing with Gerdien's value $2 \cdot 7 \times 10^{-16}$ amperes deduced from measurements of conductivity and potential gradient. The dissipation factor was least for cloudless, calm days, greatest for days with cumulus and clear atmosphere, and intermediate for overcast days. The agreement between the two widely different methods is doubtless partly accidental, but is none the less gratifying as indicating that definite results are being obtained which can be duplicated by different observers using different methods.

Schering at Göttingen has worked on the problem of a self-recording apparatus for the measurement of specific conductivity, avoiding saturation currents by removing the charged body from the neighborhood of any earthed conductor. A suspended sphere of 5^{cm} radius connected by a fine wire 50^{cm} long to an electroscope was found to answer this requirement and to give results following Ohm's law and independent of air currents. This form of apparatus is not convenient for field work but may be made useful for observatory work by using a long thin wire in place of the sphere. This must be carefully screened from the earth's field by surrounding it with a cylinder of wire netting. A sort of arbor of wire netting 20^{cm} long was constructed at the Göttingen Geophysical Institute in the open and a wire $0·14^{mm}$ in diameter was stretched inside this so as to be at least $0·5^{m}$ from the netting, and supported by specially constructed insulators to make possible its continuous use out of doors. One end was connected with an electrometer indoors. Comparisons between the sphere dispersion apparatus inside the screen and Gerdien's conducting apparatus outside gave the same difference as with both instruments outside. The capacity of the wire was found to be 104^{cm} and with the normal conductivity of the air with a potential of 100 volts on the wire the current should be 1×10^{-11} amperes. This being too small to measure with a galvanometer, a uranium cell was used as a high resistance to adapt the arrangement to continuous registration by electrometer methods. The uranium cell gave a saturation current, hence a constant current, from 50 to 300 volts and was arranged so as to be adjustable to give different currents by screening some of the uranium deposit. If the inner electrode of the uranium cell is connected with the dispersion wire and the outer electrode with a potential of some hundred volts, the inner electrode and wire will be charged to the potential at which the current from the wire into the air is equal to the current in the uranium cell. If V is this potential and Z the capacity of the effective portion of the wire and the current in the uranium cell is i, the specific unipolar conductivity of the air is $\lambda = \dfrac{i}{4\pi \, V Z}$.

The value of i being constant, it is only necessary to record V to follow the course of the conductivity. This was done photographically by means of the electrometer, the wire being connected with the needle and the quadrants charged by means of a storage battery of 20 elements. In the registration various difficulties were encountered, mainly in failure of insulation of the wire through moisture or spider webs.

The apparatus charges slowly through the uranium cell after being discharged, so that it is only suitable for slow registra-

tion and not for recording rapid changes in the conductivity. For the latter purpose the same wire was used later with an electrometer with a sensitiveness of 0.82^{cm} per volt and the zero so chosen that with a charge of 88 volts the spot of light fell on the paper. A clock was arranged so that at minute intervals the wire was charged to 88 volts and then insulated. It then discharged itself for a minute to a certain point, the electrometer tracing an oblique line on the paper, the lower end of which gave the fall in potential in one minute. The trace of these points gives the conductivity curve. The curves given show large and rapid variations of the conductivity, apparently indicating that the air is not uniformly conducting but varies rapidly from place to place so that the wind brings air of different conductivities in contact with the wire. The second method of registration is recommended for eclipse work since it gives the mean values for shorter intervals than the usual apparatus.

Another subject of great interest to students of atmospheric electricity is that of the radio-active emanation in the air, first observed there by Elster and Geitel. Closely related to this is the radio-activity of soils and rocks, sea water, etc., as the probable source of the emanation. It cannot be said that it has been proved conclusively what the source of this emanation is, though it seems to be associated with land and to be almost entirely absent over the sea, making it seem probable that its source is in the soil and rocks of the land areas since sea water is only $\frac{1}{1000}$ as radio-active as the average sedimentary rock. Several observers have been at work on the problem of the determination of the quantity of the emanation per cubic meter of the air, or what amounts to the same thing, the determination of the radium equivalent per cubic meter, that is the amount of radium required to maintain in equilibrium the quantity of emanation found in the air. The electrical method by which the emanation was first collected is not adapted to these measurements, since some of the carriers of the emanation are very slow moving and are almost sure to get past the negatively charged collector. Also some of the emanation appears to be attached to negatively charged particles and would thus be repelled from the collector, while there are also neutral carriers resulting from the union of a positive and negative particle.

However, there are at least two other methods of collecting the emanation which seem to be quite efficient. One is by means of cooling a current of air in a condenser surrounded with liquid air, the emanation being condensed and remaining behind. The other is by the use of pulverized cocoanut charcoal, which, on allowing a current of air to pass through it, absorbs the emanation contained in it and gives it up on being

heated to redness. Both methods were tested by Satterly at the Cavendish Laboratory and careful series of observations were made. Using the absorption method, the pulverized charcoal was packed in porcelain tubes between asbestos plugs and the air drawn through at a constant, measured velocity by means of a filter pump, being freed from dust and dried by means of calcium chloride before reaching the charcoal. The air current was measured by a pressure gauge. After the air had passed through for a known interval of time (the volume per minute being known) the tube was placed in a furnace and heated to redness. Air freed from emanation was passed through the tube while hot, sweeping out the released emanation, and was collected in aspirators over water, where it was stored till ready for the test. The testing vessel was in the meantime tested for air and insulation leaks, the air being pumped out of the vessel and fresh air allowed to enter several times. The air was finally exhausted from the testing vessel and communication made with the aspirator containing the air loaded with emanation, which then passed into the testing vessel. The leakage current was measured for 20 minutes, not waiting for the 3-hour maximum.

In order to refer these results to radium as a standard, air was bubbled through a solution containing a known amount of radium, thus removing the emanation as it was given off. This went on simultaneously with the collection of emanation from the air, a similar charcoal tube being used for absorbing the radium emanation. This was treated in the same way as the other and a similar leakage test made. This second test gave of course the radium emanation plus the emanation from the air, but since the observations were simultaneous the air effect could be allowed for. The comparison gives the ratio of the emanation in a known volume of air to the emanation generated in the solution in a known time. The results must be corrected for decay of the emanation if not measured for some time after it was absorbed, as was sometimes the case, and for the gradual accumulation of emanation in the charcoal. The amount of emanation generated in a given time by the solution must be calculated. The resulting mean from eight measurements gives as the amount of radium required per cubic meter of air to keep up the quantity of emanation to the observed amount 88×10^{-12} grams with a range from 50×10^{-12} to 160×10^{-12}. The comparison of day with night values seem to indicate more emanation during the day than at night.

For the liquid air condenser method, a special condenser was devised with a large cooling surface and small resistance to the air current, consisting of a brass tube packed as full as possible with thin straight brass wires. This was immersed in liquid

air and required 3/4 liter of liquid air for a three-hour run at the rate of 1/2 liter of air per minute. The tests were very similar to those in the absorption method, except that on account of the large amount of liquid air required simultaneous tests with the radium solution could not be made, so they had to be alternated. A first series of seven measurements gave 140×10^{-12} grams of radium as the equivalent, and a second series of three gave 90×10^{-12} grams. A third series, using in one case sulphuric acid and in another a freezing mixture as dehydrators, gave 130×10^{-12} grams.

Parallel tests made with the two methods—condenser and charcoal—show the condenser to be rather more efficient than the charcoal. It does not seem likely that the radium emanation and its products in the air are responsible for anything like all the natural ionization of the air. Eve, in Canada, has used the charcoal absorption method of measuring the radium equivalent per cubic meter and found as the mean of observations extending over a year 60×10^{-12} grams. The ratio of the maximum to the minimum values found is seven to one. Summer and winter values are about the same. Deep cyclones with heavy rain cause increase while anti-cyclones cause a decrease in the value. Ashman, working at the University of Chicago, used the liquid air method, comparing the rate of discharge produced by the emanation from a known volume of air with that produced by the radiation from a portion of a mineral containing a known amount of uranium, assuming the amount of radium associated with one gram of uranium to be $5 \cdot 4 \times 10^{-7}$ grams.

The result of four tests gave as the radium equivalent 97×10^{-12} grams. Experiment showed that the coil condensed all the emanation and that two similar coils in parallel gave duplicate results. The highest value, 200×10^{-12} grams, was obtained after a heavy rain and general thaw following several weeks of freezing weather with the ground covered with snow. The activity curve of the emanation showed it to be identical with that of radium. The values found by all three observers are thus seen to be of the same order, and in as good agreement as could be expected considering the variability of the quantity to be measured.

Gerdien has made an elaborate study of the velocities of the carriers of the emanation in the atmosphere, using the trajectories of the particles carried by a uniform current of air and acted upon by an electrical field about a cylindrical conductor whose axis is parallel to the direction of the air current, as a basis of computation. The deposit on the cylinder was collected, and according to its distribution over the electrode and according to its rate of decay was differentiated into car-

riers of different velocities and different sources.   The presence
of both radium and thorium emanations was shown, and the
specific velocities of the positive carriers of radium emanation
were found to be in region between 25 and $\dfrac{1}{40,000}\ \dfrac{\text{cm.}}{\text{sec.}}\ \Big/\ \dfrac{\text{volt}}{\text{cm.}}$,'
while that of thorium emanation lay in the region between 15
and $0\cdot2\ \dfrac{\text{cm.}}{\text{sec.}}\ \Big/\ \dfrac{\text{volt}}{\text{cm.}}$.   The negatively charged carriers could not
be collected in sufficient quantity to give a quantitative measure-
ment.   From the specific number of the carriers found in the
atmosphere the ionization caused by them was computed and
found to be only a small portion of the total ionization of the
atmosphere.   Most of the authorities agree in concluding that
the radio-activity of the atmosphere can play only a minor role
in its ionization, and that the ionization must be referred to
other causes.   My own experience at sea led me to the same
conclusion, for there no measurable amount of induced radio-
activity could be collected, while the ionization was as great
as on land if not greater.   Eve, on the other hand, reports that
he has found the amount of emanation in the air over the
Atlantic Ocean to be as great as over the land.   Freshly fallen
rain and snow on land ordinarily are very noticeably radio-active,
but I could find no trace of radio-activity in rain water collected
at sea.   Observations on a mountain peak in South Germany
at a height of 2954 meters at intervals throughout a year
showed no trace of radio-activity in the rain water collected there,
while it was present in that collected on the plains below, show-
ing that the rain must pick up its radio-activity in the lower
layers of the atmosphere.   Observations in balloons have shown
that the ionization increases with the altitude, proving that the
ionization is not proportional to the emanation.   It is a well-
known fact that the ultra violet rays, the Röntgen, cathode and
Becquerel rays are all capable of causing ionization, and it seems
very plausible that coming from the sun they may produce a
high degree of ionization in the upper regions of the atmos-
phere, and, to a less degree, in the lower regions, while in the
lower regions the radio-active substances may add a certain
portion to the ionization.   In this connection the investigation
of the problem of the spontaneous ionization of air in closed
vessels may be cited.   Campbell and Wood, at the Cavendish
Laboratory, have made a long study of the subject and found
that air enclosed in a vessel and left undisturbed is constantly
being ionized and that the rate of ionization undergoes a peri-
odic diurnal variation with pretty well-defined maxima and
minima.   Screening the vessel with masses of lead reduces the

rate of ionization though it does not entirely stop it, the inference being that the ionization is caused by a penetrating radiation from without, which can be partially screened off by the lead. W. W. Strong, working at the John Hopkins Physical Laboratory, has investigated the same problem, and by screening the vessel on all sides except the top and noting the rate of ionization, arrived at the conclusion that part of the radiation comes from above. Observations in a cave gave a lower rate of ionization than in the open, a fact pointing in the same direction.

There is a great field for investigation along all these lines and, as I have said, one that is almost entirely neglected in this country. A well-equipped observatory with opportunity for research work and the development of improved apparatus could add largely to our knowledge of the electrical condition of the atmosphere and aid in solving some of the puzzling problems, while a single observer here and there can accomplish comparatively little. The need at present is for investigation, and persistent sustained attacks on single problems rather than extended field work, though this is of value when the atmospheric conditions encountered are such as can not be attained at the existing observatories, as on mountain peaks, at sea or in caves.

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Art. XIII.—*Iodyrite from Tonopah, Nevada, and Broken Hill, New South Wales;* by E. H. Kraus and C. W. Cook.

In November last the Mineralogical Laboratory of the University of Michigan received a consignment of minerals from the Foote Mineral Company of Philadelphia, Pa., which contained ten selected crystals of iodyrite from Tonopah, Nevada, a new locality for this mineral. Our attention was called to this fact by Mr. W. M. Foote, manager of the company. On examination, several of these crystals showed that they possess a pronounced hemimorphic development, and also several forms which had not as yet been observed on iodyrite. We immediately informed Mr. Foote of these facts and he most cordially placed a very liberal quantity of selected material at our command. He subsequently sent us a specimen from Broken Hill, New South Wales, which contained crystals of a most interesting character.

Through the courtesy of Director H. C. Bumpus and Curator L. P. Gratacap of the American Museum of Natural History of New York City, we were able to examine specimens 2609 and 2610 of their mineral collection. The first of these is from Broken Hill, the second from Chile.

The various contributions on iodyrite are rather fragmentary and also widely separated in time. It was, therefore, deemed advisable to preface the results of our study with a brief survey of the work already done on this mineral.

Historical.

In 1825 Vauquelin[*] pointed out that certain silver ores from Mexico contained the element iodine, probably in the form of the iodide. This was the first record of the occurrence of the element iodine in the mineral kingdom, it having been previously observed only in plants and animal remains. Cantu[†] had, however, showed the presence of iodine in traces in certain mineral waters from Asti, Italy. That silver iodide occurs in nature was first definitely pointed out by Domeyko,[‡] who in 1844 analyzed material from Chanarcillo, Chile. As to the crystallographic development of this material the only statement made by Domeyko is that rhombohedral-like forms were occasionally observed and also that the structure was more or less lamellar. Domeyko did not make a complete analysis but showed conclusively that the amount of silver in the natural

[*] Annales de Chimie et de Physique, xxix, 99, 1825.
[†] Annales des Mines (4), vi, 158, 1844.
[‡] Cited by Vauquelin, loc. cit.

compound agreed very closely with that of the artificial product. Crystals from this same locality, which were in the mineral collections of the École de Mines, Paris, were measured by Des Cloizeaux[*] in 1854. Des Cloizeaux assigned the mineral to the hexagonal system and calculated the axial ratio to be $a : c = 1 : 0.81438$. The nine forms observed by him are given in the tabulation on page 217. Although it is not clear that Des Cloizeaux observed hemimorphism, it is, nevertheless, of interest to note that he pointed out the very close similarity of the angles of the natural iodide of silver and the hemimorphic mineral greenockite.

In 1854 Dana[†] suggested the name *iodyrite* for this mineral, although Haidinger[‡] had previously (1845) called it *iodite*. The name iodyrite has become international in spite of the fact that Leymerie[§] introduced *iodargyrite* in 1859.

The next contribution to our knowledge of this compound was made in 1879 by Zepharovich,[||] who carried out a rather extensive examination of artificial crystals, which had been prepared by Belohoubek. In all Zepharovich observed twelve forms, seven of which had, however, been previously noted by Des Cloizeaux on natural crystals ; see the tabulation on page 217. It is of some interest to indicate in this connection that although the hexagonal prism of the first order is, according to Des Cloizeaux, a common form on iodyrite, it was, nevertheless, not observed by Zepharovich on artificial crystals. Zepharovich established a new axial ratio which differed considerably from the one obtained by Des Cloizeaux. According to Zepharovich the ratio is as follows: $a : c = 1 : 0.8196$. These values have been generally adopted.[¶] The crystals examined by Zepharovich possessed a pronounced hemimorphic development.

In 1881 Seligmann[**] examined crystals of iodyrite from Dernbach, Nassau, and observed seven forms ; see page 217. The development of these crystals was such as to point to hemimorphism in that $i\{20\bar{2}1\}$, $o\{10\bar{1}1\}$, and $u\{40\bar{4}1\}$ were observed above the prism of the first order while $i'\{20\bar{2}1\}$ was noted below. Seligmann also examined crystals from Chile and on these noted four forms which had not been observed on either natural or artificial crystals of silver iodide ; see page

[*] Annales de Chimie et de Physique, xl, 85, 1854.
[†] System of Mineralogy, 4th edition, 95, 1854.
[‡] Chester, A Dictionary of the Names of Minerals, 1896, 134.
[§] Chester, loc. cit.
[||] Zeitschr. Kryst., iv, 119, 1879.
[¶] Dana, System of Mineralogy, 6th edition, 1892, 160 ; Groth, Tabellarische Uebersicht der Mineralien, 4th Auflage, 1898, 50 ; Naumann-Zirkel, Elemente der Mineralogie, 14te Auflage, 1901, 505.
[**] Zeitschr. Kryst. vi, 229, 1881.

217. These crystals were apparently holohedral in their development.

The work of Seligmann was followed in 1885 by a description of crystals of iodyrite from Lake Valley, New Mexico, by Genth and vom Rath.* Only three forms were noted by them, but they describe an interesting type of twin crystal, the individuals of which possess a rhombohedral development. A plane parallel to a face of $e\{30\bar{3}4\}$ acts as the twinning plane. A twin of this character is reproduced by Dana.†

The only other work on iodyrite up to the present time, which has come to our knowledge, is that by Spencer‡ in 1901. Spencer describes crystals from Broken Hill, New South Wales. The simple crystals were tabular or short prismatic and showed practically the same forms as observed by Seligmann on crystals from Chile; see page 217. Spencer, however, noted extremely interesting twins possessing a pseudo-cubical development. These twins are interpreted by him as being composed of four individuals of a trigonal character. The twinning law is the same as that observed by Genth and vom Rath, namely, $e\{30\bar{3}4\}$. Repeated attempts were made by Spencer to obtain etch figures but without success.

Iodyrite from Broken Hill, New South Wales.

The crystals examined from this locality occur on a specimen of limonite and psilomelane, which was placed at our disposal by the Foote Mineral Company of Philadelphia, Pa. The crystals are very small, being from 1 to 2^{mm} in length and in all cases show an apparently holohedral development. The color is a rather bright lemon yellow. The faces are not nearly as brilliant as those possessed by the crystals from Tonopah, Nevada, which will be described later. Although it was necessary in making our readings to rely almost entirely upon the maximum shimmer or luster, we, nevertheless, feel that considerable confidence may be placed in the results thus obtained. The following forms, $c\{0001\}$, $c'\{000\bar{1}\}$, $m\{10\bar{1}0\}$, $a\{11\bar{2}0\}$, $u\{40\bar{4}1\}$, and $u'\{40\bar{4}\bar{1}\}$, were definitely determined. Another form of a pyramidal character was also noted, but our readings in this case were somewhat unreliable so that we do not feel warranted in making a statement as to its probable indices. The crystals possess

1
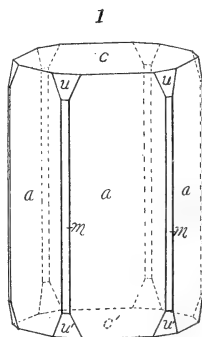
* Zeitschr. Kryst., x, 473, 1885.
† System of Mineralogy, 6th edition, 1892, 160.
‡ Zeitschr. Kryst., xxxv, 460, 1901.

a prismatic habit, $a\{11\bar{2}0\}$, being by far the predominating form. The prism $m\{10\bar{1}0\}$ occurs as very narrow faces truncating the edges of $a\{11\bar{2}0\}$. This is the first time that the simultaneous occurrence of the prisms of the two orders on a single individual of either the artificial or natural compound has been recorded. Furthermore, the prism, $a\{11\bar{2}0\}$, had not previously been observed on natural crystals. The general type of development, possessed by these crystals, is clearly shown by figure 1.

The averages of several of the more important readings used for the identification of the forms given above are as follows:

				Observed	Calculated
c	: u =	(0001)	: $(40\bar{4}1)$	75° 21′	75° 13′
c	: m =	(0001)	: $(10\bar{1}0)$	90° 4′	90° 00′
m	: a =	$(10\bar{1}0)$	: $(11\bar{2}0)$	30° 2′	30° 00′

Through the courtesy of the American Museum of Natural History of New York, we have been able to examine specimen 2609, which shows some excellently developed crystals. Our examination of this interesting specimen was, however, confined to the use of the hand lense, but it is evident that the crystals are undoubtedly twinned according to the law noted above. Not being able to carry out goniometric measurements on any of the individuals on this specimen, we are unable to state definitely what forms occur upon them.

Iodyrite from Tonopah, Nevada.

The material examined from Tonopah, Nevada, consisted of several thousand isolated crystals and two matrix specimens furnished by the Foote Mineral Company. From a study of the matrix specimens, composed almost entirely of quartz, on which the iodyrite occurs as isolated crystals or in crystalline crusts, it is clearly evident that the mineral is of secondary origin.

The crystals vary considerably in color and size. Those studied more closely varied from a bright lemon-yellow through the darker shades of yellow to a yellow-green. They measured from 1 to 5^{mm} in length. The crystals possess a greasy adamantine luster and occur as simple crystals, parallel groupings, twins, and rosette clusters. In all nine types of development were observed, four of which appear to be characteristic of simple crystals.

Type 1. Crystals of this type possess a pronounced hemimorphic development. They show the following forms: $c\{0001\}$, $m\{10\bar{1}0\}$, $i\{20\bar{2}1\}$, $i'\{20\bar{2}\bar{1}\}$, $t\{70\bar{7}3\}$, $w\{90\bar{9}2\}$,

$w'\{90\bar{9}\bar{2}\}$, $y\{90\bar{9}1\}$, and $y'\{90\bar{9}\bar{1}\}$. Of these forms $m\{10\bar{1}0\}$ predominates. The lower pyramid, $i'\{20\bar{2}\bar{1}\}$, is also rather large. The upper basal pinacoid, $c\{0001\}$, is usually next in size. The other forms generally occur as rather narrow faces. The relative sizes of the faces of the various forms are clearly shown in figure 2. Of the forms observed on crystals of this type, it is well to point out that $t\{70\bar{7}3\}$, $w\{90\bar{9}2\}$, $w'\{90\bar{9}\bar{2}\}$, $y\{90\bar{9}1\}$, and $y'\{90\bar{9}\bar{1}\}$, are all new. The close agreement between the calculated and observed values for these new forms makes us feel confident that they are to be considered as established.

Type 2. A pyramidal habit is a striking characteristic of crystals of this type. The following forms were noted on

Figs. 2–5.
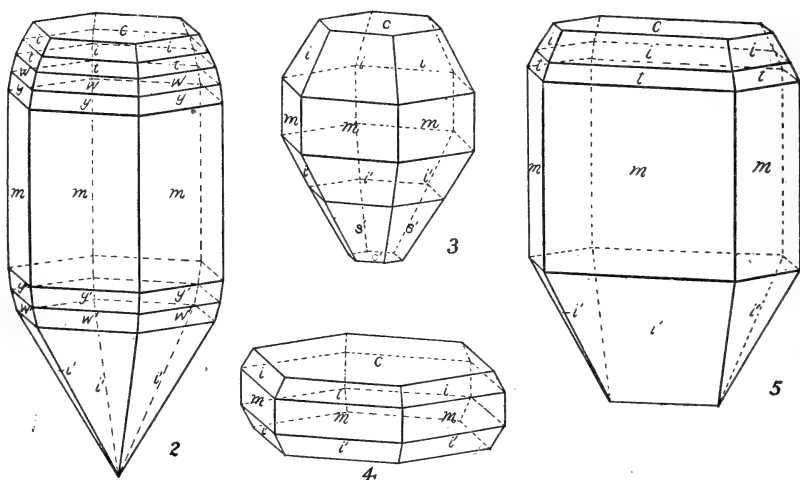
them : $c\{0001\}$, $c'\{000\bar{1}\}$, $m\{10\bar{1}0\}$, $i\{20\bar{2}1\}$, $i'\{20\bar{2}\bar{1}\}$, and $s'\{15.0.\bar{1}\bar{5}.\bar{8}\}$. Of these forms $s'\{15.0.\bar{1}\bar{5}.\bar{8}\}$ was observed for the first time. The general character of crystals of this type is shown in figure 3, which consists of a combination of the forms just enumerated. Hemimorphism is very pronounced on these crystals.

In several instances on crystals of types 1 and 2 the additional new forms were noted : $r\{70\bar{7}4\}$, $x\{70\bar{7}1\}$, and $z\{33.0.\bar{3}\bar{3}.2\}$. These forms are usually to be observed as very narrow faces, and as they do not occur often, we did not deem it necessary to figure them.

Type 3. Crystals of this type of development are not very common. They possess a tabular habit and are appar-

ently holohedral. The forms observed are $c\{0001\}$, $c'\{000\bar{1}\}$, $m\{10\bar{1}0\}$, $i\{20\bar{2}1\}$, and $i'\{20\bar{2}\bar{1}\}$. Figure 4 shows these forms in combination.

Type 4. Due to the predominance of two parallel faces of the prism, $m\{10\bar{1}0\}$, crystals of this type are also tabular. They are, however, hemimorphic, as is clearly shown in figure 5. The figure shows a combination of the following forms : $c\{0001\}$, $m\{10\bar{1}0\}$, $t\{70\bar{7}3\}$, $i\{20\bar{2}1\}$, and $i'\{20\bar{2}\bar{1}\}$. These crystals are by no means as common as those of types 1 and 2.

Type 5. Parallel grouping plays an important part in the formation of crystals of this group. This is shown in figure 6. These crystals are made up of several simple individuals which possess, in general, a habit similar to that which is so characteristic of crystals of type 2. Although they show hemimorphism, they are, nevertheless, more or less barrel-shaped, resembling to a large extent the development so often observed on crystals of corundum. The observed forms are $c\{0001\}$, $m\{10\bar{1}0\}$, $i\{20\bar{2}1\}$, and $i'\{20\bar{2}\bar{1}\}$. These crystals are rather common and are sometimes as much as 5^{mm} in length.

Type 6. Crystals belonging to this group are more or less carrot- or top-shaped. This is illustrated by figure 7. As is shown by the illustration, these crystals are made up of a number of individuals possessing a tabular development similar to that of type 3 (figure 4). The crystals show the upper base $c\{0001\}$ rather large and are terminated below by the pyramid $i'\{20\bar{2}\bar{1}\}$, thus giving the groups a decided hemimorphic development. In many cases these crystals show a skeletal development in that they are more or less hollow. In figure 7 we show the general character of these crystals and also indicate the skeletal development by figuring a depression in the upper base. In some cases this depression does not extend far into the crystal, while in other instances it extends almost the entire length of the same. The bottom of this depression, which is usually irregular in outline, but sometimes may be hexagonal, is a plane surface, which from the reflections obtained on the goniometer we know to be parallel with base $c\{0001\}$. The sides of the depression are usually characterized by parallel and horizontal corrugations. These can be seen best in the crystal fragments. The forms observed on crystals of this type are $c\{0001\}$, $m\{10\bar{1}0\}$, $i\{20\bar{2}1\}$, and $i'\{20\bar{2}\bar{1}\}$.

Type 7. Here belong contact twins with the pyramid $e\{30\bar{3}4\}$ acting as the twinning plane. The two individuals are about equally developed and possess a tabular habit, as shown in figure 8. This tabular habit is due to the predominance of two parallel faces of the prism $m\{10\bar{1}0\}$. These twins are rather common.

Type 8.   Figure 9 illustrates clearly the characteristic devel-
opment of twins belonging to this group.   Here one of the
individuals is fully developed and generally somewhat tabular
in habit.   Hemimorphism is pronounced.   Attached to the
side of the fully developed crystal is the second smaller indi-
vidual and in the position demanded by the common twinning
law e $\{30\bar{3}4\}$.   The second individual is also more or less tab-

ular.   Twins of this character were not as frequently encoun-
tered as those of type 7.
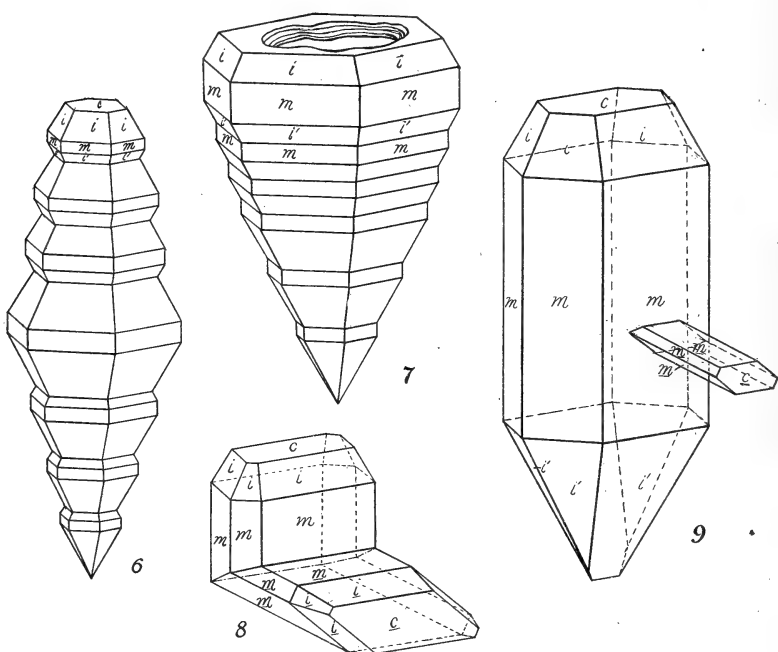
Type 9.   Quite a number of contact twins, the individuals of
which possess a rhombohedral development, were observed.
They resemble very closely the twins from Lake Valley, New
Mexico, which were described in 1885 by Genth and vom Rath.
The figure given by them is reproduced in Dana's System of
Mineralogy.*

In the writings of the earlier contributors to our knowledge
of the crystallography of iodyrite much confusion exists as to
the occurrence of the pyramidal forms about the upper and

* 6th. edition, 1892, 160.

lower poles. Especially Zepharovich, in reporting upon the forms observed on artificial crystals with a decided hemimorphic development, is not at all clear in his statements as to the occurrence of certain pyramidal forms. In the text these forms are indicated as occurring only below, while in the table of angles they are given as upper forms. It is also rather common for crystallographers, when describing the forms on hemimorphic crystals, to designate the upper and lower forms possessing the same indices by different letters. This is somewhat clearer but still confusing.

Letter	Artificial	Natural						
		Chile		Dernbach	Lake Valley	Broken Hill		Tonopah
	Zepharovich	Des Cloizeaux	Seligmann		Genth & Rath	Spencer	Kraus and Cook	
c	$\{0001\}$	$\{0001\}$	$\{0001\}$	$\{0001\}$	$\{0001\}$	$\{0001\}$	$\{0001\}$	$\{0001\}$
c'	----	$\{000\bar{1}\}$*	$\{000\bar{1}\}$	$\{000\bar{1}\}$	----	$\{000\bar{1}\}$	$\{000\bar{1}\}$	$\{000\bar{1}\}$
m	----	$\{10\bar{1}0\}$	$10\bar{1}0$	$\{10\bar{1}0\}$	----	$\{10\bar{1}0\}$	$\{10\bar{1}0\}$	$\{10\bar{1}0\}$
a	$\{11\bar{2}0\}$	----	----	----	----	$\{11\bar{2}0\}$	----	----
μ	----	$\{10\bar{1}2\}$	----	----	----	----	----	----
μ'	$\{10\bar{1}2\}$	$\{10\bar{1}2\}$*	----	----	----	----	----	----
o	$\{10\bar{1}1\}$	----	----	$\{10\bar{1}1\}$	$\{10\bar{1}1\}$	----	----	----
o'	$\{10\bar{1}\bar{1}\}$	----	----	----	----	----	----	----
i	$\{20\bar{2}1\}$	$\{20\bar{2}1\}$	$\{20\bar{2}1\}$	$\{20\bar{2}1\}$	$\{20\bar{2}1\}$	$\{20\bar{2}1$	----	$\{20\bar{2}1\}$
i'	$\{20\bar{2}\bar{1}\}$	$\{20\bar{2}\bar{1}\}$*	$\{20\bar{2}\bar{1}\}$	$\{20\bar{2}\bar{1}\}$	----	$\{20\bar{2}\bar{1}$	----	$\{20\bar{2}\bar{1}\}$
v'	$\{20\bar{2}\bar{3}\}$	----.	----	----	----	----	----	----
f	----	----	$\{30\bar{3}1\}$	----	----	$\{30\bar{3}1\}$	----	----
f'	----	----	$\{30\bar{3}\bar{1}\}$	----	----	----	----	----
g	----	----	$\{30\bar{3}2\}$	----	----	$\{30\bar{3}2\}$	----	----
g'	----	----	$\{30\bar{3}\bar{2}\}$	----	----	----	----	----
e	$\{30\bar{3}4\}$	----	----	----	----	----	----	----
u	$\{40\bar{4}1\}$	$\{40\bar{4}1\}$	----	$\{40\bar{4}1\}$	----	----	$\{40\bar{4}1$	----
u'	----	$\{40\bar{4}\bar{1}\}$*	----	----	----	----	$\{40\bar{4}\bar{1}$	----
π'	$\{40\bar{4}5\}$	----	----	----	----	----	----	----
β'	$\{9.9.\overline{18}.\overline{20}\}$	----	----	----	----	----	----	----
r	----	----	----	----	----	----	----	$\{70\bar{7}4\}$
t	----	----	----	----	----	----	----	$\{70\bar{7}3\}$
x	----	----	----	----	----	----	----	$\{70\bar{7}1\}$
y	----	----	----	----	----	----	----	$\{90\bar{9}1\}$
y'	----	----	----	----	----	----	----	$\{90\bar{9}\bar{1}\}$
w	----	----	----	----	----	----	----	$\{90\bar{9}2\}$
w'	----	----	----	----	----	----	----	$\{90\bar{9}\bar{2}\}$
s'	----	----	----	----	----	----	----	$\{15.0.\overline{15}.8\}$
z	----	----	----	----	----	----	----	$\{33.0.\overline{33}.2\}$

* Inasmuch as Des Cloizeaux makes no definite statement as to the development of these crystals, we have considered them as being apparently holohedral.

In order to avoid all confusion we have divided the basal pinacoid and the various bipyramids into upper and lower forms, following the practice of the more recent texts on crystallography. Certain letters are then assigned to the various bipyramids and the basal pinacoid, which, when unprimed, indicate upper forms, when primed, lower forms; thus, $o\{10\bar{1}1\}$, upper; $o'\{10\bar{1}1\}$, lower. We believe that this system of nomenclature offers decided advantages over what has been heretofore in use for hemimorphic crystals, in that it does away with all confusion.

In accordance with the plan outlined in the preceding paragraph we have prepared a general summary of all forms thus far reported as occurring on either natural or artificial silver iodide.

As previously stated, p. 211, the axial ratio generally adopted for iodyrite is the one which was established by Zepharovich* for artificial crystals. Inasmuch as it is always highly desirable to have ratios based upon reliable observations on the natural compound, we have taken a very large number of readings with the view of establishing a new axial ratio. The values thus obtained differ but slightly from those given by Zepharovich. In order to show the close agreement of the two determinations we place them below and at the same time also add the values obtained by Des Cloizeaux† on natural crystals in 1854.

	a :	c
Des Cloizeaux	1 :	0·81438
Zepharovich	1 :	0·81960
Kraus and Cook	1 :	0·82040.

In all fifteen crystals were measured. The observed and calculated angles based upon the axial ratio, given by us, show in nearly all cases very close agreement.

						Observed			Calculated	
c	:	i	=	(0001)	: $(20\bar{2}1)$	62°	10′	30″*	- - - - - -	
m	:	m	=	$(10\bar{1}0)$	: $(01\bar{1}0)$	59°	59.′		60°	00′
c	:	r	=	(0001)	: $(70\bar{7}4)$	58°	47′		58°	50′
c'	:	s'	=	$(000\bar{1})$	: $(15.0.\bar{1}\bar{5}.8)$	60°	32′		60°	47′
c	:	t	=	(0001)	: $(70\bar{7}3)$	65°	33′		65°	39′
c	:	w	=	(0001)	: $(90\bar{9}2)$	76°	46′		76°	48′
c	:	x	=	(0001)	: $(70\bar{7}1)$	81°	22′		81°	25′
c	:	y	=	(0001)	: $(90\bar{9}1)$	83°	13′		83°	19′
c	:	z	=	(0001)	: $(33.0.\bar{3}\bar{3}.2)$	86°	20′		86°	21′
i	:	i	=	$(20\bar{2}1)$	: $(02\bar{2}1)$	52°	30′		52°	29′
m	:	i	=	$(10\bar{1}0)$	: $(02\bar{2}1)$	63°	43′		63°	45′

* Loc. cit.   † Loc. cit.

Etch Figures and Class of Symmetry

Iodyrite is generally* placed in the class of symmetry which is designated by Groth† as the dihexagonal pyramidal class. This is based entirely upon the geometrical development of the crystals, which, however, might allow of such interpretations as to permit assigning the compound to at least three other classes, since no faces of the most general form have as yet been observed, Hence, it is necessary to rely upon etch figures in order to determine with definiteness the symmetry of iodyrite.

Spencer ‡ indicates that repeated attempts were made to obtain etch figures upon the crystals which he studied from

Fig. 10.
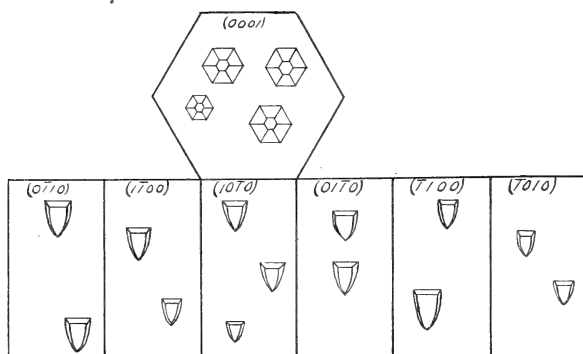
Broken Hill, New South Wales. These attempts were unsuccessful. Spencer, unfortunately, does not mention the solvents which he employed.

A solution of potassium iodide is considered by Roscoe and Schorlemmer§ as a good solvent for silver iodide. A solution of N/2 potassium iodide was used by us for the production of etch figures on carefully selected crystals of iodyrite from Tonopah. Although the solution etches the crystals, we were unable after repeated attempts to obtain figures possessing a definite outline.

According to Gmelin‖ silver iodide is soluble in a solution of mercuric nitrate and in a concentrated solution of either

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* See Dana and Naumann-Zirkel, loc. cit. ; also Bauer, Lehrbuch der Mineralogie, 2te Auflage, 1904, 439 ; Klockmann, Lehrbuch der Mineralogie, 4te Auflage, 1907, 403 ; Groth, Tabellarische Uebersicht der Mineralien, 4te Auflage, 1898, 50.

† Physikalische Krystallographie, 4te Auflage, 1904, 496.

‡ Loc. cit.

§ Treatise on Chemistry, 1907, ii, 468.

‖ Handbook of Chemistry, 1852, vi, 157.

potassium or sodium chloride. It was, therefore, decided to use a cold concentrated solution of sodium chloride. Immersion in such a solution for fifteen seconds produced excellent microscopic etch figures of an hexagonal outline on the base and located as shown in figure 10. Figures of the general form and position, as illustrated in the diagram, were produced on the prism faces after a treatment of about forty seconds. The position and outline of these figures show conclusively that crystals of iodyrite possess six vertical planes of symmetry and one polar axis of hexagonal symmetry. These elements show that the classification which has been followed, as indicated above, is to be considered as the correct one.

Chemical Analysis.

For the chemical analyses somewhat over a gram of clear, semi-transparent crystal fragments of a pale yellow color was used. This material was from Tonopah, Nevada, and was placed at our disposal by the Foote Mineral Company, to whom we desire at this time to express our thanks for the cordial manner in which assistance was rendered us during this investigation.

As to the analysis only the method of decomposition need be given in detail. This consists of placing a small sample of the finely powdered homogeneous material in an evaporating dish and covering the same with water acidified with one or two drops of concentrated sulphuric acid. A small piece of chemically pure zinc is then suspended in the solution so as to just come into contact with the powdered mineral. Decomposition is generally complete after about twenty-four hours. The hydriodic acid which is liberated passes into solution, while the silver collects in the dish in the finely divided metallic state. In this way any loss of hydriodic acid by volatilization was avoided. For the sake of convenience the zinc was attached to a piece of platinum wire, so that after the decomposition was complete, it could be readily removed and any adhering silver washed off. In order to remove any traces of silver which could not be washed off, the zinc was immersed for an instant in nitric acid. After filtration the metallic silver was dissolved in nitric acid and then precipitated and weighed as the chloride. Silver nitrate was added to the filtrate and the iodine precipitated and weighed as the iodide.

Two analyses were made which show very close agreement and indicate that the composition of iodyrite may be expressed by the formula AgI.

In 1854 J. Lawrence Smith[*] made two analyses of iodyrite.

[*] Dana, System of Mineralogy, 4th edition, 1855, 506.

The localities from which the material was obtained are not indicated by Smith. We give below the average results of Smith's analyses. Smith reports that aside from silver and iodine, he found traces of copper and chlorine. Repeated tests were made by us for bromine and chlorine, as also for the metals lead and mercury, which would most likely replace the silver. But in no case did we find the slightest trace of any of them.

The results of the analyses are as follows:

	Kraus and Cook			Smith	Theoretical
	I	II	Average		
Ag	45·87%	46·04%	45·95%	46·45%	45·97%
I	53·92	54·09	54·01	53·02	54·03
Total	99·79	100·13	99·96	99·47	100·00

We are indebted to Professor E. D. Campbell, Director of the Chemical Laboratory of this University, for suggestions relative to methods of decomposition and analysis.

Specific Gravity.

Considerable variation exists in the values given for the specific gravity of iodyrite or the artificial compound. This variation is clearly shown by the following tabulation:

Iodyrite.

Bauer*	5·5 — 5·7
Damour†	5·677
Dana*	5·6 — 5·7
Domeyko*	5·504
Klockmann*	5·707
Naumann–Zirkel*	5·6 — 5·7
Vom Rath*	5·609

Artificial Silver Iodide.

Damour†	5·669
Deville	5·540

Since the material which we used for the chemical analysis proved to be exceptionally pure, we feel that the values we obtained for the specific gravity are very reliable. Two determinations were made on material which differed slightly in color. There is also a slight difference to be noted in the

* Loc. cit.
† Rammelsberg, Handbuch der Krystallographisch-Physikalische Chemie, I, 303, 1881.

results.   The determinations were made with the common specific gravity flask at room temperature.

The results are :

Dark variety	5·519
Light variety	5·504
Average	5·5115

These values are much lower than those given by Damour, Dana, vom Rath, Klockmann, and Naumann-Zirkel, but agree fairly well with the determinations of Domeyko on natural crystals and with the value given by Deville for the artificial compound.   Our results also fall within the limits set by Bauer.

Mineralogical Laboratory,
University of Michigan,
December 22, 1908.

Art. XIV.—*On the Deviation of Rays by Prisms;* by
H. S. Uhler.

While making certain deductions from the formulæ for the directions of rays passing obliquely through prisms, as given in standard text-books,* the writer found that conclusions which are at variance with physical facts were unavoidable. An investigation of the source of this difficulty showed that the primary error consisted in tacitly changing the definition of deviation in passing from considerations which refer to principal sections of prisms to cases where the rays traverse the prisms outside of these sections. If it were never necessary to combine the formulæ for rays in principal sections with formulæ for rays not in such planes, the error would only amount to inconsistency of notation and hence it would hardly deserve formal notice. As a matter of fact, however, it is sometimes necessary to combine formulæ for the two cases and, when this is done, false results follow. Therefore, it may not be superfluous to give a brief discussion of the fundamental formula for rays not in principal sections in such a manner as to retain the definition of deviation in the form which is usually, if not universally, given to it when principal sections alone are concerned.

This definition may be concisely stated as follows: *The deviation of a ray is the angle through which the unlocalized vector representing the initial direction of the ray must be turned in order to make it coincide in sense and direction with the like vector which symbolizes the final direction of the ray.* This sentence expresses precisely what is meant by the deviation of light when making observations with an ordinary spectrometer or even when considering the passage of plane waves through a plane-parallel layer of some transparent medium. On the other hand, the above definition makes the angle of deviation supplementary to the deviation involved in the current formula for obliquely transmitted rays.

If D and D' denote respectively the deviations, produced by a single prism of greater index of refraction than the surrounding medium, of a ray not in a principal section and of the projection of the same ray on a principal section, and if i_1 symbolizes the angle which the incident (or emergent) ray makes with the plane of such a section, then the mutual dependence of these quantities upon one another is given by

$$\sin \tfrac{1}{2} D = \sin \tfrac{1}{2} D' \cos i_1 \qquad (1)$$

* Czapski, Heath, Kayser, Winkelmann, etc.

This formula may be obtained in two different ways. Either the classic relation " $\cos \frac{1}{2} D = \cos \frac{1}{2} D' \cos i_1$ " may be first demonstrated in the customary manner and then D and D' may be replaced respectively by $\pi - D$ and $\pi - D'$, or else an independent proof may be given. The latter plan seems to be preferable because it is more direct, and also since it does not involve a knowledge of a formula of spherical trigonometry, whereas the usual proof does. In other words, the direct method is even more elementary than the indirect. Consequently an independent proof of equation (1) will now be presented.

Fig. 1.
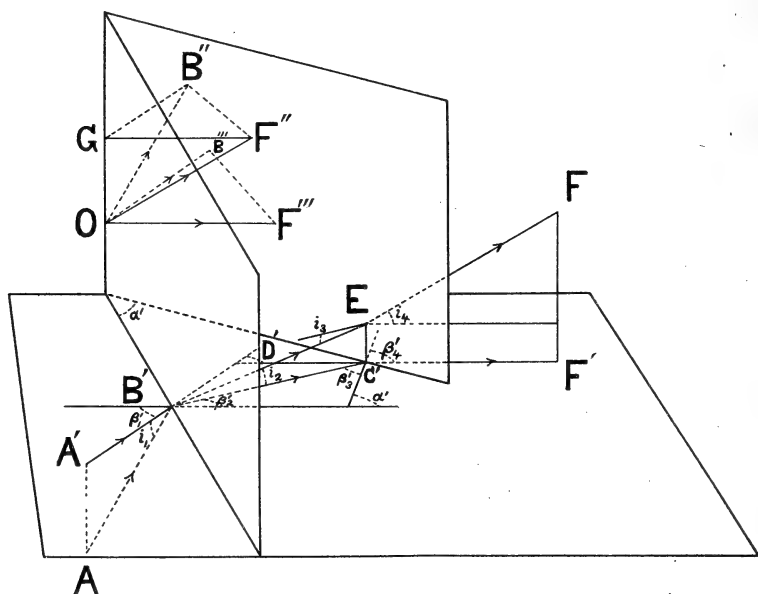
Figure 1 may serve to define the positive directions of the various angles as well as the symbols for the angles themselves. The use or omission of accents on small letters shall serve to differentiate respectively symbols which refer to angles in the principal section from those which denote angles lying outside of this plane. The path of the ray is $AB'EF$. The projection of the ray on the principal section is $A'B'C'F'$. Further, let D symbolize the deviation of the ray from its initial direction AB' to its final direction EF.

Move the directed lines AB', $A'B'$, EF and $C'F'$, of figure 1, parallel to themselves until they assume respectively the posi-

tions OB'', OB''', OF'' and OF''', that is, all starting from any common point O. Lay off $OB''=OB'''=OF''=OF'''=L$. $\angle B'''OB''=i_1$, $\angle F'''OF''=i_4$, $\angle B''OF'''=D'$ and $\angle B''OF''=D$. Since, from the general theory of prisms, $i_1=i_4$, a triangle $B''GF''$ may be constructed in a plane containing B'' and F'' and perpendicular to OG. Join B''' to F'''.

Now in the triangle $B''GF''$, $\overline{B''F''}=2\overline{GF''}\sin\frac{1}{2}D'$ and, in the triangle $B''OF''$, $\overline{B''F''}=2L\sin\frac{1}{2}D$. Also $\overline{GF''}=L\cos i_1$, hence

$$\sin\tfrac{1}{2}D=\sin\tfrac{1}{2}D'\cos i_1.$$

Furthermore, when $\cos i_1<1$, equation (1) shows that the deviation of a ray not in a principal section is *less* than the deviation of its projection on such a plane, whereas the text-books agree in writing " $D>D'$. "

We shall next consider what bearing formula (1) has on the question of minimum deviation. The well-known, general equations for refraction by prisms are

$$\begin{aligned} \sin i_1 &= n\sin i_2 \\ \sin i_4 &= n\sin i_3 \end{aligned} \Big\} \text{ and } \Big\{ \begin{aligned} i_2 &= i_3 \\ i_1 &= i_4 \end{aligned}$$
$$\cos i_1 \sin \beta'_1 = n\cos i_2 \sin \beta'_2$$
$$\cos i_4 \sin \beta'_4 = n\cos i_3 \sin \beta'_3$$
$$a' = \beta'_2 + \beta'_3$$
$$D' = \beta'_1 + \beta'_4 - a',$$

where n denotes the ratio of the absolute index of refraction of the material of the prism to the absolute index of the surrounding medium. In general, we shall assume $n>1$. By using the equations of the above list together with the relation

$$\cos\beta'_1\cos\beta'_3=\cos\beta'_2\cos\beta'_4,$$

which is a necessary condition that D' shall be either a maximum or minimum, when i_1 is kept constant, we find $\beta'_2=\beta'_3=\frac{1}{2}a'$ and hence

$$\cos i_1 \sin \tfrac{1}{2}(D'_0+a')=(+\sqrt{n^2-\sin^2 i_1})\sin\tfrac{1}{2}a'. \qquad (2)$$

D'_0 denotes the possible stationary value of D'.

Equation (2) is equivalent to the usual formula

$$\text{`` }\cos i_1 \sin \tfrac{1}{2}(D'_0+a')=n\cos i_2 \sin \tfrac{1}{2}a',\text{ ''}$$

since $n\sin i_2=\sin i_1$ and $i_2\ngtr\frac{1}{2}\pi$. It should be observed that, in obtaining equation (2), use has to be made of the relation $D'=\beta'_1+\beta'_4-a'$ and this shows that the various writers intend to employ the same definition of deviation as the one given above.

If we actually test $\dfrac{d^2D'}{d\beta'^2_1}$, under the specified conditions, we

find that D'_0 is a true minimum, as would be expected from our knowledge of the existence of a minimum when $i_1 = 0$, that is, when the projection of the ray coincides with the ray itself and the latter lies in a principal section. Hence, we can conclude from equation (1), since sines affect both D and D', not only that D has a stationary value simultaneously with D' but further that D attains a minimum value D_0 at the same time that D' acquires its minimum D'_0.

Again, since by hypothesis n exceeds unity, $\dfrac{+\sqrt{n^2 - \sin^2 i}}{\cos i_1}$ $> n$. Hence equation (2) shows that when the deviation of the projection of a ray not in a principal section assumes a minimum value, this value is *greater* than the minimum of deviation for rays in a principal section. Now equation (1) gives $D_0 < D'_0$, $(i_1 \gtrless 0)$, and equation (2) implies $D'_0 > \triangle_0$, where $\triangle_0$ represents the minimum deviation for principal sections. Consequently, on the face of it, nothing can be concluded about the relative sizes of D_0 and $\triangle_0$. For example, how do we know that the deficit of D_0 with respect to D'_0 may not be numerically greater than the excess of D'_0 over $\triangle_0$ so as to make the minima of deviation for rays not in principal sections less than the minimum of deviation for rays in principal planes? In other words, how can we logically deduce the usual and correct theorem that: "The deviation of a ray by a prism is least when the ray passes through the prism in a principal plane and when the angles of incidence and emergence are equal"?[*]

The usual argument is to say that D'_0 exceeds $\triangle_0$ in value, that the equation "$\cos \frac{1}{2}D = \cos \frac{1}{2}D' \cos i_1$," shows D to be *greater* than D', that D passes through a *minimum* value simultaneously with D' and that therefore *a fortiori* $D_0 > \triangle_0$. This assumes that D has a minimum, whereas both the D and the D' involved in the cosine formula pass through *maxima* simultaneously and the general theorem does not follow.

Consequently we shall now outline the proof of a formula for D_0 as a function of a', i_1 and n in order to see explicitly what the properties of D_0 are. This formula may be obtained as follows: First, expand $\sin \frac{1}{2}(D'_0 + a')$ of equation (2) in terms of sines and cosines of the angles $\frac{1}{2}D'_0$ and $\frac{1}{2}a'$. Next, reduce all cosines to sines, except $\cos \frac{1}{2}a'$, and, after proper transposal of terms, square the members of the resulting equation. A quadratic in $\sin \frac{1}{2}D'_0$ results and this equation is then solved for $\sin \frac{1}{2}D'_0$, care being taken to retain only the

[*] R. S. Heath, Geometrical Optics, p. 32, 1887; or Czapski, Kayser, Winkelmann, etc.

proper sign before the radical. In this manner we find, after substituting in formula (1), that

$$\sin \tfrac{1}{2}D_0 = \{[+\sqrt{(n^2 - \sin^2 i_1) \cos^2 \tfrac{1}{2}a'}] - [+\sqrt{(n^2 - \sin^2 i_1) \cos^2 \tfrac{1}{2}a' - (n^2 - 1)}]\} \sin \tfrac{1}{2}a' \qquad (3)$$

Obviously, this equation could not have been obtained by substituting in " $\cos \tfrac{1}{2}D_0 = \cos \tfrac{1}{2}D'_0 \cos i_1$ ", and hence, if formula (3) is correct, the cosine equation must be erroneous.

Again, formula (3) leads to

$$\frac{dD_0}{di_1} = \frac{\sin 2i_1 \sin \tfrac{1}{2}a' \cos^2 \tfrac{1}{2}a'}{\cos \tfrac{1}{2}D_0} \times$$

$$\left\{ \frac{1}{+\sqrt{(n^2 - \sin^2 i_1) \cos^2 \tfrac{1}{2}a' - (n^2 - 1)}} - \frac{1}{+\sqrt{(n^2 - \sin^2 i_1) \cos^2 \tfrac{1}{2}a'}} \right\} (4)$$

Since D_0 cannot exceed π, and since the first fraction within the braces of equation (4) is larger than the second, it follows that D_0 decreases when i_1 diminishes in absolute value. Therefore, the minima D_0 of D decrease as i_1 approaches zero in magnitude until, when $i_1 = 0$, $D_0 = \triangle_0$. Thus we have shown formally that, although D_0 is always less than D'_0, D_0 is constantly greater than $\triangle_0$. The general theorem of minima quoted above from Heath is therefore established.

Equation (3) is interesting because the second radical indicates limitations upon a', i_1 and n in order that D_0 be real, that is, in order that a minimum of deviation may exist. For illustration, when a' and n are given

$$i_1 \gtrless \sin^{-1}\left[\pm\sqrt{1 - (n^2 - 1)\tan^2 \tfrac{1}{2}a'}\right],$$

which in turn requires $\cos a' > \dfrac{n^2 - 2}{n^2}$.

Furthermore, combining with equation (2) the condition that the second radical of formula (3) shall vanish, we find $\sin \tfrac{1}{2}(D'_0 + a') = 1$, so that D'_0 and a' are then supplementary in value. Of course, the same restricting conditions can be obtained directly from equation (2) by observing that $\sin \tfrac{1}{2}(D'_0 + a') \gtrless 1$.

Returning from this digression, attention may be called to the fact that when $a' = 0$ or when $n = 1$ formula (3), which is implicitly formula (1), gives $D_0 = 0$, whereas the relation " $\cos \tfrac{1}{2}D_0 = \cos \tfrac{1}{2}D'_0 \cos i_1$ ", combined with the auxiliary equation (2), leads to $D_0 = \pm i_1$ for both cases. For a plane-parallel layer of relative index n, or for a prism of finite angle but with the same refractive index as the surrounding medium,

it is obvious that D_0 cannot be a function of i_1. Hence, the cosine formula again leads to false conclusions.

In order to test the accuracy of the algebraic work which led to equation (3) as well as to get a concrete idea of the variations of D_0 and D'_0 with i_1, the numbers in the following table were worked out for the special case where $a' = 60°$ and $n = 1\cdot65$. The data in the second column were obtained from equation (2). The numbers in the third and fourth columns were found by substituting the corresponding values of D'_0 from the second column in equation (1) and in "$\cos \tfrac{1}{2}D_0 = \cos \tfrac{1}{2}D'_0 \cos i_1$" respectively. All the angles in the third column were also worked out from formula (3). The absolute agreement of all the values of the true D_0 obtained by these two independent modes of calculation verifies equation (3). The last row of the table exhibits the superior limits of the angles for minimum deviation. The first and fifth columns taken together show the obliquity of the incident ray.

i_1	D'_0	D_0	"D_0"	$\beta'_1 = \tfrac{1}{2}(D'_0 + a')$
0°	51° 10′ 37″	$\triangle_0$; 51° 10′ 37″	51° 10′ 37″	55° 35′ 18″.5
± 5°	51° 34′ 57″	51° 22′ 19″	52° 28′ 40″	55° 47′ 28″·5
± 10°	52° 49′ 54″	51° 58′ 7″	56° 14′ 6″	56° 24′ 57″
± 15°	55° 1′ 46″	53° 0′ 17″	62° 6′ 37″	57° 30′ 53″
± 20°	58° 22′ 54″	54° 33′ 21″	69° 45′ 36″	59° 11′ 27″
± 25°	63° 15′ 56″	56° 45′ 45″	79° 0′ 19″	61° 37′ 58″
± 30°	70° 24′ 58″	59° 54′ 29″	89° 55′ 13″	65° 12′ 29″
± 35°	81° 35′ 0″	64° 42′ 35″	103° 20′ 34″	70° 47′ 30″
± 40°	105° 23′ 7″	75° 4′ 45″	124° 40′ 17″	82° 41′ 34″
±40° 44′ 5″	120° 0′ 0″	82° 1′ 28″	135° 28′ 21″	90° 0′ 0″

The conclusion to be drawn from the preceding argument is that either the formula "$\cos \tfrac{1}{2}D = \cos \tfrac{1}{2}D' \cos i_1$" must be replaced by $\sin \tfrac{1}{2}D = \sin \tfrac{1}{2}D' \cos i_1$ or that the cosine formula may be retained, but, when the latter alternative is followed, the various writers should state explicitly, and lay special stress upon, the fact that the D and the D′ of the cosine relation are the supplements of the corresponding deviations as involved in the other equations of the subject. We think that, for sake of consistency and to avoid confusion of symbols, the formula $\sin \tfrac{1}{2}D = \sin \tfrac{1}{2}D' \cos i_1$ should be introduced in the text-books in place of the cosine equation.

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ART. XV.—*The Heat of Oxidation of Tin, and second paper on the Heat of Combination of Acidic Oxides with Sodium Oxides;* by W. G. MIXTER.

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

Tin.

THE heat of oxidation of tin obtained by different investigators varies widely and the work was done before calorimetry was perfected by Thomsen, Berthelot, and others. Moreover, the constants of oxidations are required in calculating the heat of formation of sodium stannate; hence it seemed desirable to make new determinations. Depretz* found for the heat of oxidation of the stannic oxide 170000^c. Dulong,† in 1838, determined the heat evolved by the union of one liter of oxygen with tin and obtained 6411^c, 6325^c and 6790^c; mean 6509^c, or for 32 grams of oxygen 145600^c. Andrews,‡ who first invented a calorimetric bomb, made in 1848 good determinations. He mixed tin with broken quartz in a copper bomb, ignited the metal with a milligram of phosphorus and found the gain in weight. His results for one gram of oxygen were 4235^c, 4244^c and 4210^c; mean 4230^c, or for 32 grams of oxygen 135360^c at constant volume and 136000^c at constant pressure. Likewise for the combustion of stannous oxide he obtained 4353^c, 4328^c and 4364^c; mean 4349^c, or for 16 grams of oxygen 69584^c at constant volume and 69900^c at constant pressure. The writer has used essentially Andrews' method.

Experiments were first made with tin from a sodium alloy. Dr. C. H. Mathewson, to whom the writer is indebted for much good material for use in investigations, made a considerable quantity of an alloy having approximately the composition Na_2Sn. This was pulverized and dropped into absolute alcohol. After the reaction had moderated, water was added gradually and then the metal was subjected to boiling water for several hours and washed thoroughly. The powder was grey and when magnified appeared to be made up of minute leaves. The stannic oxide from 1·616 grams of the metal weighed 2·060 grams, equivalent to 1·623 of tin. It was found to contain 0·12 per cent of sodium. This amount of impurity affects the heat result but slightly. For the calorimetric experiments the tin powder was placed in a weighed silver foil tray which was supported in the middle of a 500^{cc} bomb in order that, as the tray melted, the hot powder would fall through the oxygen. The weight of oxygen taken up was

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* Landoldt-Bornstein, Physicalisch-Chemische Tabellen, refer to Ann. Ch. Phys., xxxvii, 180. This reference the writer has not been able to find.
† C. R., vii, 871.   ‡ Phil. Mag. (3), xxxii, 321.

derived from the weight of tin taken, of oxides formed, and
of ferrous-ferric oxide from the iron used for ignition.   The
experimental data are as follows:

	1		2	
Tin _____	8·121	grams	11·070	grams
" equivalent to oxygen com-				
bined _____	7·122	"	9·364	"
Oxygen combined _____	1·910	"	2·518	"
Water equivalent of system ____	3631·	"	3482·	"
Temperature interval _____	2·366°		3·239°	
Heat observed_____	8591ᶜ		11279ᶜ	
" of oxidation of iron_____	−80ᶜ		−80ᶜ	
	8511ᶜ		11191ᶜ	
For 1 gram of oxygen_____	4456ᶜ		4444ᶜ	

The combustions were evidently incomplete as indicated by
the figures and by the fact that there was formed a considerable
amount of a black substance along with the white stannic
oxide.   The results are 4 per cent higher than those obtained
with tin foil in experiments 3 and 4.   It might be surmised
that tin separated from a sodium–tin alloy is an allotropic
form and it may be when the separation is made at a low
temperature, but the powder which had been heated to 100°
is the ordinary modification, for, as shown later, it gives the
same heat when burned with sodium peroxide as ordinary
crystalline tin.   The high result is evidently due to the forma-
tion of a considerable amount of stannous oxide.   But the
heat effect of $Sn+O$ is less than that of $SnO+O$, and hence it
appears probable that the two oxides formed in the com-
bustion had combined with evolutions of heat.   Moreover,
the sesquioxide of tin is known and is dark colored.

The next experiments were made with tin foil, which a
qualitative analysis showed to be quite pure.   It was also
tested as follows: 2·911 grams were treated with nitric acid,
the latter removed by evaporation, the residue digested with
dilute nitric acid and washed on a filter and finally heated
over a blast lamp until the weight was constant.   The stannic
oxide obtained weighed 3·700 grams, equivalent to 2 916
grams of tin.   ($Sn=119.$)   For the combustions the foil was
placed in loose rolls in the bomb, which was then filled with
dry oxygen at a pressure of 12 atmospheres.   The conditions
were the same as in experiments 1 and 2 except that the foil
exposed a larger surface to the oxygen.   The stannic oxide
resulting was in the form of a porous cake which was brown-
ish on the surface but white in the interior.   The entire cake

was a mass of elongated microscopic crystals. Professor W. E. Ford of the Mineralogical Laboratory has kindly examined the crystals and found them too small for measurement but having the optical properties of cassiterite. It should be stated that a small portion of the stannic oxide was deposited on the upper surface of the bomb in the form of white powder. After a combustion the oxide was transferred to a platinum dish and the water used in washing out the last portions was evaporated. The weight of the oxygen which combined the tin was found as already described. The following are the experiments:

	3		4	
Tin	15·168 grams		14·055 grams	
" equivalent to oxygen combined	15·042	"	13·919	"
Oxygen combined	4·045	"	3·743	"
Water equivalent of system	3548·	"	3658·	"
Temperature interval	4·893°	"	4·410°	"
Heat observed	17360^c		16132^c	
" of oxidation of iron	41^c		40^c	
	17319^c		16092^c	
For 1 gram of oxygen	4282^c		4293^c	

The average of the results is 4288^c for one gram of oxygen combining with tin to form stannic oxide. For 32 grams it is 137200^c at constant volume and 137800^c at constant pressure. It will be observed that the tin in the form of foil was almost completely oxidized. Andrews' result was 136000^c at constant pressure. In his experiments there may have been formed some amorphous stannic oxide which would lower the heat effect. His result, however, agrees well with the writer's.

Stannous Oxide.

A number of preparations of stannous oxide were made by different methods but only two appeared to be good enough for the purpose. The first used was made by adding an excess of ammonia to a solution of stannous chloride and then heating the mixture several days on a steam bath. The dark crystalline mass was washed thoroughly and dried at 100° and then heated in a current of dry carbon dioxide to about 400° as long as water and ammonia came off. The product was almost black, showing under the microscope minute crystals but no amorphous powder. It contained considerable stannic oxide, a trace of ammonia, and 0·09 per cent of water. Three determinations of the heat of oxidations gave respectively: 4668^c, 4667^c and 4632^c, a mean of

4656^c for one gram of oxygen taken up or 74500^c for sixteen grams. The result was thought to be high and therefore another lot of stannous chloride was prepared as follows: about 400 grams of pure stannous chloride were dissolved in four liters of hot water and a solution of pure sodium hydroxide was added in sufficient quanity to dissolve part of the stannous hydroxide formed. The mixture was kept hot until most of the white particles had disappeared. The product was washed by decantation in order to remove the smaller particles present. The stannous oxide was in the form of minute dark crystals. It was free from chlorine and sodium; dried at 100° it contained 0·41 per cent of water, which was determined as follows: a weighed portion was burned in dry oxygen in order to attain a high temperature and the water was absorbed in a chloride of calcium tube. The determination of stannous oxide was made thus: 1·1193 grams of substance were heated in air and oxygen. The stannic oxide formed weighed 1·2425 grams and the observed gain in weight was 0·123 gram. Adding to this last number 0·0046 gram of water present before burning we have 0·1276 gram of oxygen taken up, which is equivalent to 96·2 per cent of SnO.

For the calorimetric work the stannous oxide, dried at 100°, was placed on a silver foil tray which was supported at the top of the lower silver cup or lining of a 500^{cc} bomb and then the cup and contents were counterpoised on a balance. After a combustion the cup and contents were heated to expel moisture, allowed to cool and then the increase in weight noted. At the time of a combustion the tray melted and the oxide fell to the bottom of the cup, where it was found in the form of a porous white crystalline cake. The experiments were as follows:

	8	9	10	
Substance taken _____	30·06	30·89	30·58	grams
Amount + 0·962 = SnO___	28·92	29·72	29·49	"
SnO equivalent to oxygen consumed _____	28·74	29·74	29·4	"
Increase in weight _____	3·340	3·455	3·415	"
Water in substance taken _	0·123	0·126	0·125	"
Fe$_3$O$_4$ from iron _____	−0·056	−0·056	−0·056	"
Oxygen consumed_____	3·407	3·525	3·484	"
Water equivalent of system	3422·	3430·	3476·	"
Temperature interval _____	4·422°	4·541°	4·469	
Heat observed _____	15133^c	15576^c	15534^c	
" of oxidation of iron__	−64^c	−64^c	−64^c	
	15069^c	15512^c	15470^c	

For 1 gram of oxygen consumed	4423^c	4401^c	4443^c
" 1 gram of SnO in substance taken	521^c	522^c	521^c

The average is 4417^c for one gram of oxygen and for 16 grams it is 70672^c at constant pressure and 71000^c at constant volume. The mean for one gram of SnO in the substance taken is 521^c; for 135 grams 70335^c at constant volume. Evidently the stannous oxide was nearly all burned to stannic oxide. Andrews' result was 69000 at constant pressure.

Combustion of Tin with Sodium Peroxide.

The metal used in the next three experiments was from the same lot taken for experiments 1 and 2 and prepared from the sodium-tin alloy. Carbon was added to the mixture in experiment 10 to ensure a high temperature, but it was not required, as the other experiments prove. No metallic tin was found in the residues of the following determinations:

	11	12	13	
Tin	3·000	5·000	8·000	grams
Carbon	0·330	----	----	"
Sodium peroxide	10·	10·	18·	"
Water equivalent of system	3060·	3012·	2987·	"
Temperature interval	2·283°	1·871°	3·086°	"
Heat observed	6986^c	5635^c	9218^c	
" of oxidation of carbon	−3663^c	----	----	
" " " " iron	−30^c	−30^c	−40^c	
" " oxygen set free or taken up	+46^c	−48^c	+82^c	
	3339^c	5617^c	9260^c	
For 1 gram of tin	1113^c	1115^c	1157^c	

As the tin from the sodium-tin alloy gave more heat when burned with oxygen than that known to be the common modification, tin turnings were made by fastening a cylinder of tin in a lathe so that it rattled. Small chips came off which were separated from the coarser process by sifting. The following are the experimental data:

	14		15	
Tin	8·241	grams	10·175	grams
" not burned	0·243	"	0·064	"
" burned	7·998	"	10·111	"
Sodium peroxide	22·	"	25·	"
Water equivalent of system	3759·	"	3816·	"
Temperature interval	2·383°		3·020°	

Heat observed	8957^c	11525^c
" of oxidation of iron	—64^c	—64^c
" " oxygen taken up	0	—90^c
	8893^c	11371^c
For 1 gram of tin	1112^c	1125^c

The mean of the five results is 1124 ; the average for 119 grams of tin is 133756^c. Evidently the tin from the sodium-tin alloy is the common modification.

Amorphous stannic oxide used in the next two experiments was made by heating metastannic acid over a ring burner until the weight was constant. Sulphur was used to give the temperature requisite and to reduce the sodium peroxide to oxide.

	16	17
Stannic oxide, amorphous	9·955 grams	7·907 grams
" " unchanged	1·204 "	0·583 "
" " combined	8·701 "	7·324 "
Water equivalent of system ...	2987· "	2987· "
Temperature interval	2·500°	2·337°
Heat observed	7467^c	6961^c
" of oxidation of iron	—48^c	—48^c
" " " " sulphur ..	—5271^c	—5271^c
" " oxygen set free	+75^c	+75^c
	2223^c	1717^c
For 1 gram of stannic oxide ...	255^c	237^c

The mean is 246^c and for 151 grams of amorphous stannic oxide it is 37100^c.

Summary of results.

$Sn + O_2 = SnO_2$(crystalline) + ...	137200^c
Sn(crystalline) + O = SnO(crystalline) + ...	66200^c
SnO(crystalline) + O = SnO_2 (crystalline) + ..	71000^c
SnO_2(amorphous) = SnO_2(crystalline) + ...	1700^c
$2Na_2O_2 + Sn = Na_2SnO_3 + Na_2O$ + ...	133800^c
$2Na_2O + 2O = 2Na_2O$ + ...	38800^c
$Na_2O + Sn + 2O = Na_2SnO_3$ + ...	172600^c
$Sn + O_2 = SnO_2$(crystalline) + ...	137200^c
$Na_2O + SnO_2$(crystalline) = Na_2SnO_3 + ...	35400^c
$Na_2O + SnO_2$(amorphous) = Na_2SnO_3 + ...	37100^c

ART. XVI.—*Neptunite Crystals from San Benito County, California;* by W. E. FORD.

Historical.—In July, 1907, a new mineral, called benitoite, was described by Prof. G. D. Louderback in a bulletin of the Department of Geology of the University of California.* In the same article a short preliminary description of what was then thought to be another new species was given and to which the name carlosite was provisionally assigned. Mr. Lazard Cahn, in the summer of 1907, first called the writer's attention to the fact that this mineral was identical with the rare species neptunite found previously only in the Juliane-haab district, Greenland. This identity of carlosite with neptunite was announced by Prof. Louderback at the meeting of the Geological Society at Albuquerque in December, 1907,
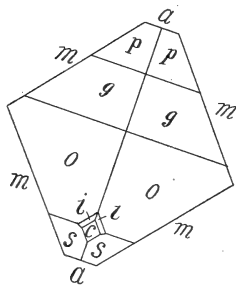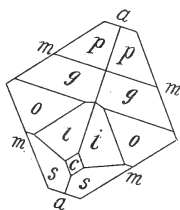
FIG. 1.   FIG. 2.   FIG. 3.
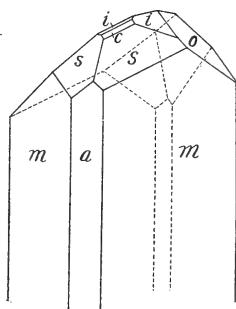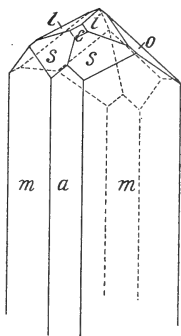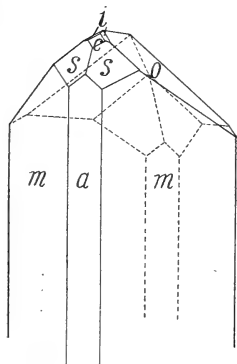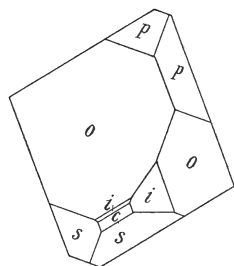
and a short note to the same effect was later published by W. E. Blasdale in Science for August 21st, 1908. But beyond this no description of the occurrence has so far been published. Through the courtesy of Mr. Cahn and Mr. Milton G. Smith,

* Vol. v, No. 9, 149, 1907.

the writer has been able to examine a large number of the neptunite crystals from this locality and it was thought that a brief description of them would be of interest.

Occurrence.—The neptunite crystals occur associated with those of benitoite, both minerals being embedded in a white matrix of crystalline granular natrolite. The neptunite crystals that are now in the Brush Collection vary in size from slender prismatic crystals of only a few millimeters in length to those of $2\frac{1}{2}^{cm}$ in length and as much as 7^{mm} in thickness. In general the crystals are brilliant black in color, but wherever they have been fractured they show by internal reflections the red-brown color which is characteristic of the mineral when in thin section.

FIG. 4.

Crystallographic.— T h e crystals from San Benito County are exceptionally uniform in their habit, the following series of forms being found on almost every crystal studied: $a(100)$, $m(110)$, $s(111)$, $i(\bar{1}12)$, $o(\bar{1}11)$, $g^*(\bar{2}11)$, $p(\bar{3}11)$. The crystals are prismatic in habit, quite different from those first described by Flink* from Greenland, but more like a later type described by him† and resembling still more a crystal figured by Wallenström.‡ The habit of development of the California crystals is represented in the figures which have been drawn from specimens in the Brush Collection. Figure 1 represents the commonest type in which the forms present are: prism, $m(110)$, prominent, $a(100)$ in narrow truncations, the base, $c(001)$ very small, as also $s(111)$ and $i(\bar{1}12)$. The prominent terminal faces are the negative pyramids $o(\bar{1}11)$, the new form $g(\bar{2}11)$ and $p(\bar{3}11)$. Figure 2 shows a slight modification in the development of these forms, and figure 4 shows the same forms, with the exception of g which failed, but in an unsymmetrical development which is unusual on the crystals. This figure was drawn by Mr. D. D. Irwin. Figure 4 is a doubly terminated crystal, like figure 2, half embedded in its matrix of white natrolite. The faces of the crystals studied were, as a rule, bright and gave excellent reflections on the goniometer with the exception of the new form $g(\bar{2}11)$. In every crystal

* Zeitschr. Kr., xxiii, 346, 1894.   † Medd. om Grönl., xxiv, 120, 1902.
‡ Geol. För. Förh., xxvii, 149, 1905.

observed this face was dull in luster and distinctly curved, and only approximate measurements could be obtained from it. Its symbol was determined, however, by its zonal relations, for it was found to lie at the intersection of the pyramid zone a (100) $-s$ (111) $-o$ ($\bar{1}$11) $-p$ ($\bar{3}$11) $-a$ ($\bar{1}$00) and the zone m (1$\bar{1}$0) $-i$ ($\bar{1}\bar{1}$2) $-m$ ($\bar{1}$10). This form g is new to the mineral, for although Böggild in Mineralogia Groenlandica, page 506, lists such a form as p ($\bar{2}$11) it is evidently a misprint, for in the original article by Wallenström* the form referred to is given as p ($\bar{3}$11). The various forms were identified by the following angles:

			Meas.	Calc.
a (100)	$\wedge$	m(110)	49° 52′	49° 53′
a (100)	$\wedge$	c (001)	64° 22$\frac{1}{2}$′	64° 22′
m(110)	$\wedge$	s (111)	38° 0′	37° 58′
m(100)	$\wedge$	c (001)	73° 49′	73° 49′
m($\bar{1}$10)	$\wedge$	i ($\bar{1}$12)	78° 26′	78° 23$\frac{1}{2}$′
m($\bar{1}$10)	$\wedge$	o ($\bar{1}$11)	55° 14′	54° 58′
m($\bar{1}$10)	$\wedge$	g ($\bar{2}$11)	40° 2′	40° 28$\frac{1}{2}$′
a ($\bar{1}$00)	$\wedge$	p ($\bar{3}$11)	39° 38$\frac{1}{2}$′	39° 27′

Figure 5 shows in stereographic projection all the crystal

FIG. 5.
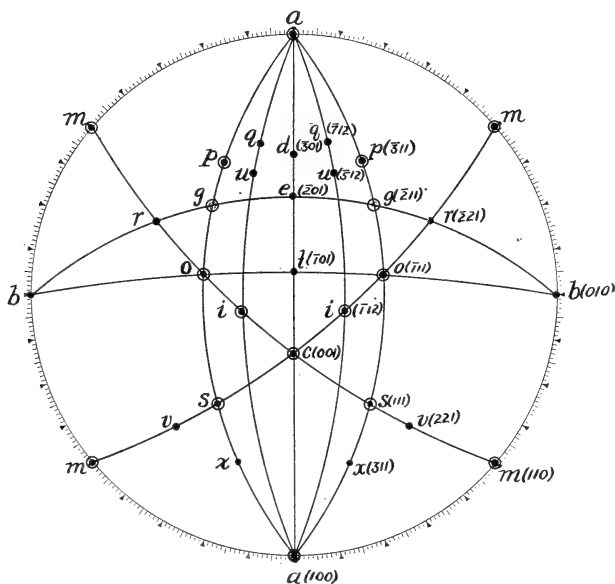
forms of neptunite that have been listed. Those observed on the Greenland crystals are indicated by solid dots, while the

* Loc. cit.

forms found on the specimens from California are indicated by open circles.

Optical.—For the optical study of the material a thin section was first cut parallel to the symmetry plane (010). On examination between crossed nicols it was found that one extinction direction was inclined to the c-axis of about 24° in the obtuse angle β, while the second direction of extinction very nearly coincided with the a-axis making an angle of 1° 38′ above it in front. The direction of greatest elasticity of the section corresponds to the extinction direction which nearly coincides with the a-axis. The section showed very strong pleochroism, the ray vibrating parallel to the direction a being colored yellow while the one vibrating parallel to c was a deep brownish red. These relations are shown in figure 6. Two other sections were cut, each being normal to one of the
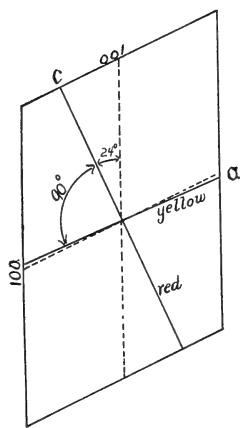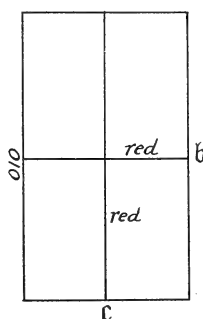
Fig. 6. Fig. 7. Fig. 8.
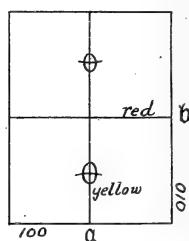
extinction directions of the section parallel to b (010). In the section normal to the a-direction, or nearly normal to the a crystallographic axis, it was noted that the extinction direction which was parallel to the b-axis was the direction of greatest elasticity in the section or the direction of intermediate elasticity b of the mineral. This section showed in convergent polarized light an interference figure with a large axial angle, the optical axes lying in the symmetry plane of the crystal. This section showed no marked pleochroism, rays vibrating parallel to the two extinction directions being both colored a dark red. These relations are expressed in figure 7.

The third section was cut normal to the direction c determined in the section parallel to b (010) and in its orientation was nearly parallel to c (001). This section showed an interference figure with the optical axes lying in the symmetry

plane of the crystal. As the angle between them was small
it follows that the direction c, the normal to the section, is the
acute bisectrix and the mineral is positive. Rays vibrating
parallel to the *b* crystallographic axis were colored red, while
those vibrating in the symmetry plane were yellow. These
relations are shown in figure 8.

The above results differ from those given in the original
description in the position assigned to the axial plane. Flink
describes the optical orientation of the Greenland neptunite as
follows:* "The plane of the optical axes is perpendicular to
the symmetry plane and the acute bisectrix forms an angle of
18° with the vertical axis in the obtuse angle *β*." A critical
reading of his description would suggest that the discrepancy
noted above was probably brought about by an accidental turn-
ing of one of his sections so that the true orientation was
reversed. To translate further from his description: "In the
first section orientated parallel to the symmetry plane one extinc-
tion direction forms with the vertical axis an angle of 18° in
the obtuse angle *β*. The rays vibrating in this direction show
the greatest absorption and the color is deep red brown.
The rays vibrating perpendicularly to this direction are less
absorbed and the color is yellow-red. The same section shows
also in convergent polarized light an axial figure with a large
angle between the optical axes." With the exception of the
last statement the description agrees with that given above for
the California mineral. Flink describes the second section
which he cut as follows: "In the second section, orientated
perpendicular to the symmetry plane, and making an angle of
72° with the orthopinacoid and 7½° with the base, the rays
vibrating parallel to the symmetry axis are the least absorbed
and the color is yellow-red. The rays vibrating perpendicu-
larly to the symmetry axis and in the symmetry plane are more
strongly absorbed and the color is dark red. This section
shows in convergent polarized light an axial figure with a
small angle between the optical axes." It will be noted that
the elasticity direction which is common to the two sections,
namely the one lying in the symmetry plane and making a
small angle with the *a*-axis, is said in the first case to show the
least absorption and to be colored yellow-red ; and in the
second case the greatest absorption with a dark red color.
This discrepancy could be explained and the optical orienta-
tion of the Greenland mineral be brought into conformity with
that from California, if Flink's second section was considered
to have been accidentally turned 90° from its true orientation.
The statement that an axial figure with large optical angle was

* Zeitschr. Kr., xxiii, 350, 1894.

obtained from the section parallel to (010) might be explained by the fact that often in biaxial crystals what appears to be an interference figure with a large axial angle can be obtained from sections that are cut parallel to the axial plane.

Attempts were made to measure the indices of refraction of the mineral, but on account of the dark color of the material they failed. The average index of refraction was obtained in the following manner: Small fragments were observed under the microscope immersed in various mixtures of *a* monobrom-napthalene and methylene iodide until one was obtained which by use of the Becke method was found to be very closely of the same index of refraction as the neptunite. The index of refraction of the liquid was then determined by immersing in it fragments of other minerals with known indices of refraction until the same result was obtained. In this way the average index of refraction of the neptunite was found to be close to 1·70.

An approximate measurement of the axial angle was made by immersing the section cut perpendicular to the acute bisectrix in *a* monobrom-napthalene ($n=1·6583$) and using a small axial angle goniometer placed on the stage of the microscope. The measured angle ($2H$) was approximately 50°, which would give $2E=90°$. Assuming that $\beta=1·7$, this would give the axial angle $2V=48° 40'$. Dispersion of the optical axes was noted, $v>\rho$.

Chemical.—A qualitative examination of the California neptunite shows its substantial agreement with the analyses given of the Greenland material. It is hoped shortly to be able to make a quantitative analysis and to present its results in a subsequent paper.

Art. XVII.—*The Gravimetric Determination of Silver as the Chromate ;* by F. A. Gooch and Rowland S. Bosworth.

It has been shown in a recent paper from this laboratory* that the precipitation of silver chromate from the solution of a soluble chromate made faintly acid with acetic acid may be carried to completion by the addition of silver nitrate in considerable excess; and that the exact determination of the chromium of a soluble chromate or dichromate may be effected by treating with silver nitrate the solution of either salt, adding ammonia to alkalinity and then acetic acid to faint acidity, transferring the precipitate and washing it in the filtering crucible with a dilute solution of silver nitrate until foreign material other than that reagent has been removed, finishing the washing with a small amount of water applied judiciously in portions, and weighing the dried or gently ignited residue of silver chromate. The success of this process turns upon keeping the chromium at the moment of precipitation essentially in the form of chromate rather than dichromate and in taking care that an excess of silver nitrate shall be present nearly to the end of the washing. The present paper deals with the conditions under which, in reversal of the process just described, silver may be precipitated completely as the chromate.

In the first experiments to be described, a solution of silver dichromate was added gradually, either in slight excess or in considerable excess, to a solution of silver nitrate maintained at the boiling point; the mixture was cooled and treated with ammonia until the precipitate first formed had been dissolved ; acetic acid was added to faint acidity ; and the precipitate was settled for a half-hour, filtered off on asbestos in a perforated crucible, washed with a little water, dried and weighed. In every case the weight of silver chromate found was deficient and the testing of the filtrate with hydrochloric acid showed the presence of a soluble salt of silver. The errors amounted to several milligrams, varying with the conditions. Dilution of the original solution and prolonged washing with water increased the error. Admixture of alcohol was without appreciable effect upon the solubility of the precipitate. Evaporation to dryness and transfer by a dilute solution of potassium dichromate, and a final washing with water used judiciously in small portions, tended to diminish the amount of soluble salt, but this treatment never reduced the error of loss

*Gooch and Weed : this Journal, xxvi, 85, 1908.

below two or three milligrams for volumes approximating a hundred cubic centimeters. Solution of the first precipitate in ammonia and reprecipitation by boiling to low volume to remove the excess of ammonia failed to overcome entirely the solubility of the silver salt, which appears to be due to a tendency on the part of the ammonium chromate to pass to the condition of dichromate with loss of ammonia from the boiling solution.

In the next experiments, therefore, potassium chromate was used as the precipitant. In Table I, A are given the details of experiments in which an excess of potassium chromate was added to silver nitrate, the solution boiled, the precipitate transferred to the asbestos filter in a perforated crucible by means of a dilute solution of potassium chromate and washed with small portions of water, and the residue after drying with gentle heat weighed as silver chromate. In these

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

Silver taken as AgNO$_3$		K_2CrO_4 used		Ag$_2$CrO$_4$ weighed	Silver found	Error in terms of silver
Volume of solution cm^3.	Weight of silver grm.	Volume of solution cm^3.	Weight grm.	grm.	grm.	grm.
			A			
		Precipitation by K_2CrO_4.				
15	0·1652	50	0·3	0·2536	0·1649	—0·0003
10	0·1101	50	0·3	0·1693	0·1101	0·0000
25	0·1437	50	0·3	0·2200	0·1436	—0·0001
25	0·1437	50	0·3	0·2210	0·1437	0·0000
			B			
		Precipitation by K_2CrO_4, treatment with NH_4OH and evaporation to dryness.				
25	0·1348	50	0·3	0.2077	0·1351	+0·0003
30	0·1618	50	0·3	0·2500	0·1626	+0·0008
30	0·1618	50	0·3	0·2520	0·1639	+0·0021
			C			
		Precipitation by K_2CrO_4, treatment with NH_4OH and boiling to a volume of 10–15^{cm3}.				
25	0·1576	50	0·3	0·2422	0·1575	—0·0001
25	0·1576	50	0·3	0·2414	0·1570	—0·0006
50	0·3152	50	0·3	0·4852	0·3155	+0·0003
50	0·3152	50	0·3	0·4843	0·3149	—0·0003
50	0·3152	50	0·3	0·4847	0·3152	0·0000
			D			
		Precipitation by K_2CrO_4, treatment with NH_4OH and boiling to a volume of 10—15^{cm3} in presence of 1 grm. of sodium nitrate.				
10	0·1101	50	0·3	0·1693	0·1101	0·0000
15	0·1652	50	0·3	0·2536	0·1649	—0·0003

experiments no silver was found in the filtrate, but the precipitate was not so coarsely crystalline and easily washed as when deposited by removal of ammonia from an ammoniacal solution. In the other experiments of Table I, therefore, the first precipitate was dissolved in ammonia and reprecipitated by boiling the solution : in those of B the evaporation was carried to dryness, and in those of C the concentration was stopped when a volume of 10–15^{cm3} had been reached. In all these experiments precipitation was complete, the filtrates giving no test with hydrochloric acid for a dissolved silver salt.

The high results obtained in the experiments of B are no doubt due to the inclusion of foreign matter in the silver chromate, which is left in caked condition by the process of complete evaporation. The better results in the experiments of C are apparently due to the fact that in them the evaporation was not pushed too far. The experiments of D show that the presence of a gram of sodium nitrate has no appreciable effect upon the solubility of the silver chromate. It is plain that the precipitation by potassium chromate in neutral solution is practically complete and that accurate determinations may be made by filtering at once, or by dissolving the precipitate in ammonia, reprecipitating by boiling to a volume of 10–15^{cm3}, and then filtering, drying, and weighing.

In many cases it is desirable to determine silver present in solutions containing free nitric acid. The effect of free nitric acid upon the process was therefore next studied. A few qualitative experiments showed that the solvent action of nitric acid may be obviated by taking care to use the precipitant, potassium chromate, in such amounts that an excess of it shall be present after taking up the nitric acid to form potassium dichromate. The details of a few of these experiments are giving in the accompanying table.

<div align="center">

TABLE II.

K_2CrO_4

</div>

Ag in $AgNO_3$ grm.	HNO_3 grm.	To form Ag_2CrO_4 grm.	To form $K_2Cr_2O_7$ with HNO_3 grm.	Theoretically required grm.	Present grm.	Ag in filtrate
0·1376	0·063	0·1241	0·1946	0·3187	0·3172	Found
0·1376	0·063	0·1241	0·1946	0·3187	0·3172	Found
0·0550	0·063	0·0496	0·1946	0·2442	0·3172	None
0·0550	0·063	0·0496	0·1946	0·2442	0·3172	None
0·1376	0·063	0·1241	0·1946	0·3187	0·3806	None
0·1376	0·063	0·1241	0·1946	0·3187	0·4758	None
0·1376	0·095	0·1241	0·2919	0·4160	0·4758	None
0·1376	0·126	0·1241	0·3892	0·5133	0·6344	None
0·1376	0·158	0·1241	0·4865	0·6106	0·7930	None

In Table III are given the results of quantitative experiments in which precipitation was effected in presence of nitric acid, with care to insure the necessary excess of potassium chromate. In the experiments of A the precipitate was filtered off at once, without solution by ammonia and reprecipitation by boiling: in those of B the ammonia treatment was made to convert the less crystalline precipitate to better form for filtration and washing.

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

Silver taken as AgNO₃		K₂CrO₄ used		HNO₃		Ag₂CrO₄ weighed grm.	Silver found grm.	Error in terms of silver grm.
Volume of solution cm.	Weight grm.	Volume of solution cm.	Weight grm.	Vol. cm³.	Weight grm.			
				A				

<div align="center">*Precipitation by K_2CrO_4 in presence of HNO_3.*</div>

25	0·1355	50	0·9	10	0·182	0·2091	0·1360	+0·0005
25	0·1355	50	0·9	10	0·182	0·2081	0·1353	−0·0002
25	0·1358	50	0·9	10	0·182	0·2090	0·1360	+0·0005
25	0·1355	50	0·9	10	0·182	0·2075	0·1349	−0·0006
25	0·1355	50	0·9	10	0·182	0·2090	0·1360	+0·0005

<div align="center">B'</div>

<div align="center">*Precipitation by K_2CrO_4 in presence of HNO_3, treatment with NH_4OH, and boiling to a volume of 10–15 cm³.*</div>

25	0·1348	50	0·6	10	0·063	0·2076	0·1350	+0·0002
25	0·1348	50	0·6	10	0·063	0·2068	0·1344	−0·0004
25	0·1348	50	0·6	10	0·063	0·2072	0·1347	−0·0001
25	0·1348	50	0·6	10	0·063	0·2074	0·1348	0·0000
25	0·1348	50	0·6	10	0·063	0·2070	0·1346	−0·0002

So it appears that from solutions of silver nitrate, containing free nitric acid, potassium chromate precipitates silver chromate completely, provided enough potassium chromate is present to take up the nitric acid with formation of potassium dichromate as well as to form the silver salt. The precipitate, filtered at once or brought to better crystalline condition by treatment with ammonia and boiling of the solution to small volume, may be transferred to the asbestos filter by dilute potassium chromate and washed by small portions of water without appreciable loss. The weight of the residue of silver chromate, dried at gentle heat, may be taken as a very fair measure of the silver originally present.

ART. XVIII.— *The Doppler Effect in Positive Rays;* by JOHN TROWBRIDGE.

THE discovery of canal rays by Goldstein, and that of the Doppler effect in these rays, marks an epoch in the study of the discharge of electricity through gases; for before these discoveries the multitude of confusing effects which arise in the space between the anode and the cathode made it difficult to observe any translation movement. The space, however, behind the cathode is comparatively free for the passage of the positive ions.

FIG. 1.

We now recognize, in addition to the positive rays behind the cathode— the canal ray—retrograde positive rays which are directed to the anode, or rather away from the cathode in the direction of the anode.* This later discovery leads one to expect that the Doppler effect should be found also between the anode and the cathode. The result of my study shows that the effect does exist in this region and indicates a movement away from the cathode and toward the anode.

The form of tube I have employed is represented in fig. 1. The slit of the Rowland grating was at X for the retrograde rays and at Y for the canal rays; A being the anode and C the cathode. The Rowland grating gave, in the order of spectrum I employed, six Angström units to nine-tenths of a millimeter. The effect was observed with respect to the hydrogen line 4861·5 and the change in refrangibility was measured by comparison with the solar spectrum, which was photographed immediately beneath the gaseous line without changing the jaws of the slit. The amount of the change in refrangibility was sensibly the same as in the canal rays.

The difference of potential between the anode and the cathode varied between five thousand and ten thousand volts; and the current from ten to five milliamperes furnished by a storage battery of ten thousand cells. A current of running water provided a large and steady resistance.

The appearance of the discharge at the cathode has often been described. The cathode appears to be the base of two

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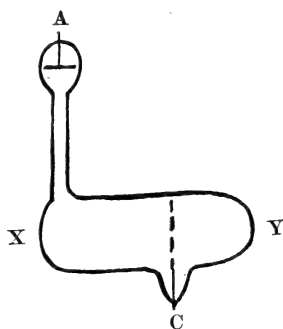
* Wehnelt, Wied. Ann., 1899, p. 421; Runge and Baschen, Wied. Ann., lxi, 1897, p. 644; Paschen, Wied. Ann., xxiii, p. 247; Villard, Comptes Rendus, cxliii, p. 673, 1906; Goldstein, Phil. Mag., March, 1906; Jacob Kunz, Phil. Mag., July, 1908, p. 161; J. J. Thomson, Oct., 1908, p. 657.

rose-colored cones of light, the apex of one directed to the
anode and the apex of the other toward the canal region.   The
body of the luminous cone in the space between the anode and
the cathode is, so to speak, a solid, while that in the canal
region, or back of the cathode, is made up of a collection of
tubes which in a short region come together at the apex of the
cone, and in a more extended region spread out in a diffused
manner.   When the cathode is unperforated the rosy glow,
which in the case of hydrogen characterizes the canal rays,
emanates from the central portion of the aluminium cathode;
it is no longer conical in form, or rather resembles a frustrum
of a cone, the base directed to the anode.   It does not extend
as far toward the anode as the conical discharge from the per-
forated cathode and is not so bright.   With the unperforated
cathode and the slit placed at X, no Doppler effect was seen.
When, however, the cathode was perforated the effect was very

FIG. 2.

a   b   c
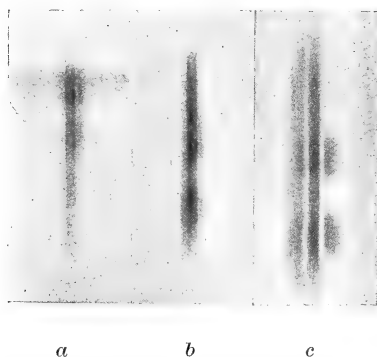
evident and indicated a movement toward X which was equal in
amount to that observed in the canal region toward Y.   More-
over, the photographs showed, when the light was observed at
X, a line on each side of the ordinary stationary hydrogen line;—
my observations were confined to 4861·5.   There was evidently
a movement toward the anode, and a movement away from it
at the cathode.

When the observations were conducted at Y, the same
phenomenon was observed: a stationary hydrogen line and a
diffuse line separated from the stationary line by a blank space
on each side of the stationary line—indicating a movement
toward the cathode and away from it.   In fig. 2, *a* and *b* are
photographs, *c* is a drawing which represents effects too feeble
to be strongly reproduced from the photographs—effects, how-
ever, which are very evident on the negatives *a* and *b*.   The

slit was a broad one in order to show differences of illumination. The light was strongest at the orifices.

When the observations were conducted by placing the slit of the spectroscope so that the light at the perforations did not enter the slit—in other words, placing it obliquely to the band of light—the companion of the stationary line which indicated a movement away in each case, from the slit, was not discernible. The effect took place at the orifices. The positive particles jostling through these orifices and mutually repellent transmit movements, like those resulting from elastic particles in impact, in opposite directions and those driven in the direction of the anode meet others coming toward the cathode. There results a maximum of radiation of greater refrangibility which is separated from the refrangibility of the stationary hydrogen line by a less luminous space.

When glass tubes are inserted in the orifices through which the canal rays pass and the back of the cathode is protected by glass connected to these tubes and to the wall of the discharge tube, the canal rays are still obtained. This proves that these rays are produced immediately in front of the cathode that is on the side toward the anode, or in the orifices. I incline to the belief, as I have stated, that the jostling in the narrow orifices accounts for the change in refrangibility.

In all discharge tubes striæ are seen opposite to the edge of the cathode on the glass. These striæ can be localized at a definite point by bringing the edge of the disc of the cathode near the wall of the tube ; and we then have a source of positive rays which is analogous to that formed by pushing a glass tube surrounding the anode into the Crookes space.*

The heating and oxidizing effect from the positive particles of these striæ is very marked, especially when the canal region is small, and is much greater than any effect produced by the canal rays in a possible rebounding from the end of the canal region. The photographs of cathode discs exhibit this effect of the positive rays coming from the striæ. In fig. 3, No. I is a photograph of the back of a cathode made of aluminium formed from as pure clay as could be obtained. The disc was ·75^{mm} thick and the hard surface formed by the iron rolls was left upon it. The heat from the positive rays coming from the striæ caused the occluded gases of the aluminium to form blisters on its surface. No. II represents the back of a cathode formed from the same quality of aluminium as in case I, except that the plate of aluminium was treated with nitric acid to remove any trace of iron coming from the rolls. The surface thus lost its polish and hardness. A very black deposit formed

* E. Wiedemann, Wied. Ann., lxiii, p. 242, 1897.

under the effect of the positive rays of the striæ, which was probably carbon from the aluminium. In III the cathode was formed from ordinary commercial aluminium 1·5^{mm} thick. It represents the blackening which results from long running of

Fig. 3.

I   II   III   IV
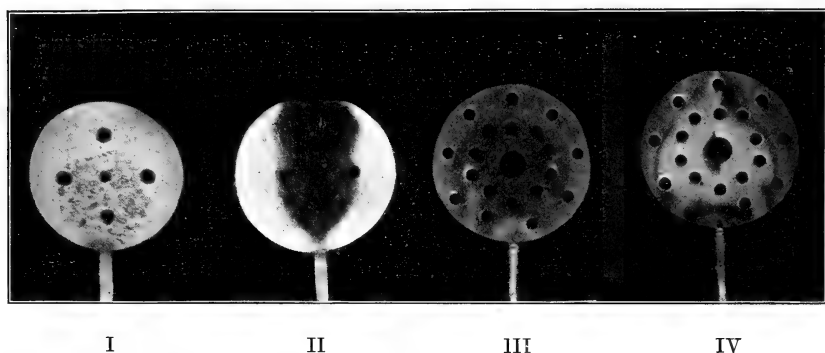
Fig. 4.
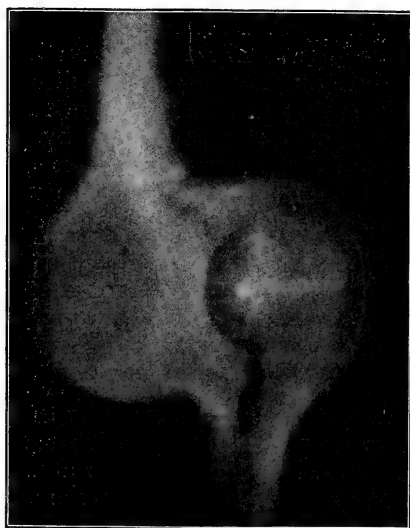
the discharge. At increased exhaustions and during this long use of the tube the striæ shift their position, and the back of the cathode shows a general discoloration. No. IV repre-

sents the front of the cathode of fig. 3. The center is bright, while the edges are discolored. Goldstein has noticed that positive rays remove deposits.

Fig. 4 is a photograph of the canal rays which shows also the luminosity on the back of the cathode produced mainly by the striæ.

The order of spectrum produced by the Rowland grating gave an interval of ·9 millimeter to six Angström units. The approximate interval between the Doppler effect on both sides of the stationary hydrogen line 4861·5 was three Angström units ; the difference of potential between the anode and the cathode varied from 6000 volts to 10,000. The current ran from 10 milliamperes to 5. A storage battery of 10,000 cells was employed. The internal diameter of the discharge tubes was 3^{cm}. The distance between X and C, fig. 1, was 6^{cm}. The distance between C and Y varied from 4^{cm} to 10.

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ART. XIX.—*A New Armored Saurian from the Niobrara ;* by G. R. WIELAND.

THE greatest American storehouse of fossil marine verte-brates is doubtless in the Niobrara chalk of western Kansas. But despite the fact that many of the diverse forms there rep-resented must have lived near and frequented the shores of the Niobrara sea, very little evidence of even presumably true land forms has thus far been obtained.

The best known form to be regarded as land, or at least lacustrine or fluviatile, is the *Hadrosaurus agilis* of Marsh from the Smoky Hill river. Though the type of this dino-saur includes considerable portions of the skeleton, only a single individual has ever been recovered. In fact, in the University Geological Survey of Kansas, vol. iv, Professor Williston says, in speaking of the Dinosauria : " But a single specimen (that is *Hadrosaurus agilis*) has ever been found in the state, so far as I am aware, though the animals must have lived here about the shores of the Cretaceous seas in great abundance."

And although collecting in the Niobrara has been especially active during the past ten years, no further examples even doubtfully referable to Dinosauria came within my knowledge until about two years ago. Then I noted amongst turtle material sent to the Yale Museum from the Hackberry Creek region by Mr. Charles H. Sternberg, and referred to me for study, the two paired and presumably caudal, or else cervical, dermal elements shown in figure 7, 7a.

On the basis of such slender evidence it was of course not possible to say whether a crocodilian was indicated, or even some remote progenitor of such a turtle as *Miolania*. Now, however, we are enabled to present some clearer evidence for the presence of a second Dinosaurian genus in the Niobrara.

This last season Mr. Sternberg secured, five miles south of Castle Rock and three miles south of Hackberry Creek, six dermal scutes of a form quite certainly dinosaurian. These plates later came into my possession and have been donated to the Yale Museum. The name *Hierosaurus Sternbergii* is assigned them in honor of their collector. It is thought that other fragmentary specimens have been observed, so that it is probable that further material will yet be obtained.

In the excellent figures 1–7a of the present fossil scutes, drawn by Mr. R. Weber, the principal characters may at once be discerned.

The scutes are all shown one-third the natural size in the figures 1–7a. The bones shown in figures 1–3 are odd, that of No. 3 being merely a tubercle with a fine right-angled stria-tion on its lower surface. Those shown in Nos. 4 and 5 are a pair, but other elements must have intervened ; while the two fused elements shown in No. 6 form an isolated asymmetrical

Figs. 1–7a.

1 1

2 2

2a 2a

2b 2b

3 3

4 4

5 5

6 6

7 7

7a 7a
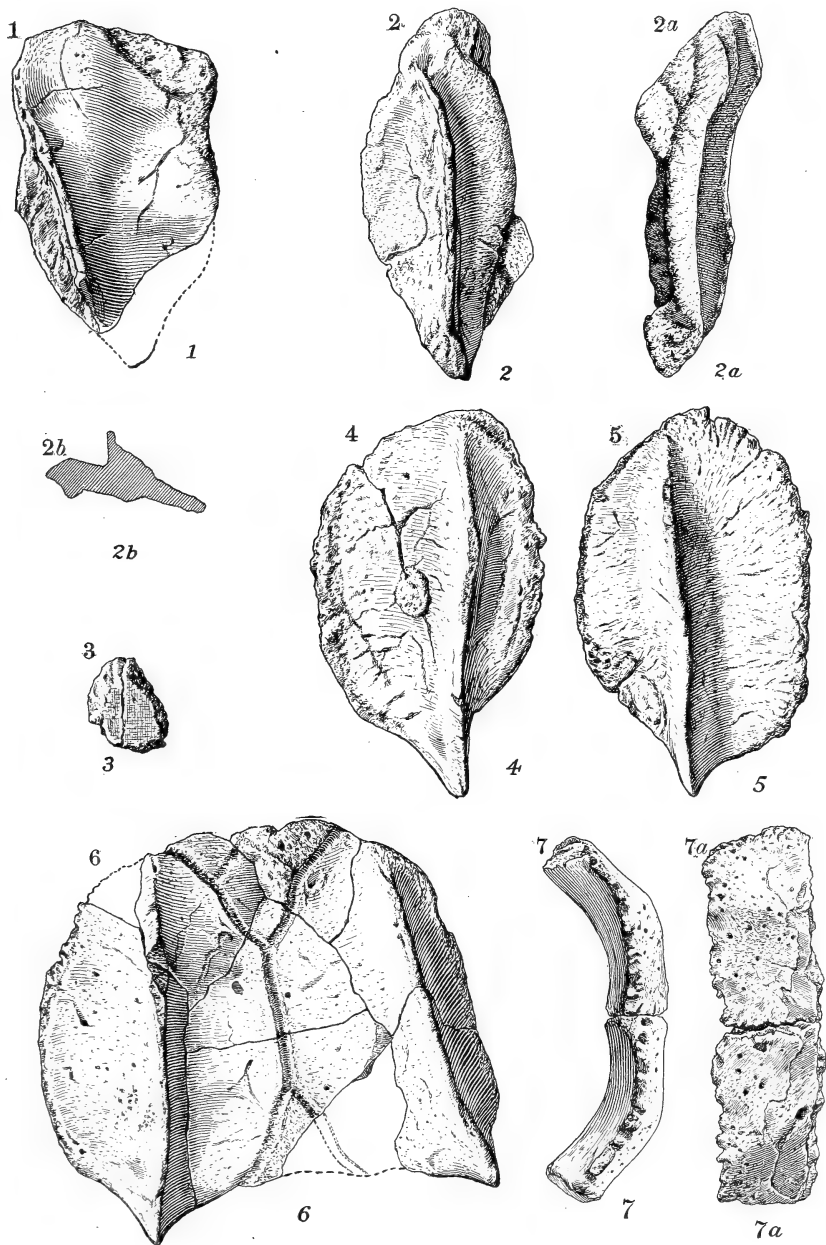
plate. In all the foregoing except the tubercle the thickness is much as seen in the transverse section No. 2*b*. The more or less median ridge is sharp and runs the entire length, being of much the same height throughout its course, and terminating as a sharp backwardly projecting slightly upturned spur. The height of the ridge is from one to one and a half centimeters. Nos. 1–6 are all plate-like and of much the same thickness as shown in the middle transverse section figure 2*b*.

The two elements shown in figure 7, 7*a* are probably a terminal pair that was seated on the proximal caudal or cervical region, as indicated by the broad flat front edge which formed a contact and the free thinner posterior edge which appears to end [if not begin] the series abruptly. But the animal to which these odd bones belonged may not even have been of the same species as that to which the scales of figures 1–6 belong and form the type.

It is pretty clear that the form before us is allied to the Stegosauridæ and is possibly included in the Ankylosauridæ of Brown* represented by Dinosaurs with large shields and a quite rigid turtle-like back from the Judith River beds near Gilbert Creek, 120 miles north of Miles City, Montana.

The closest relationship within the family Ankylosauridæ so far as the dermal armature affords comparison is afforded by *Polacanthus* as restored by Nopcsa and now on exhibition in the British Museum at South Kensington. As there restored there are first free plates and then a more or less perfectly developed carapace only extended as such over the lumbar and hip region.

From the fact that we see the large scales shown in figure 6 so completely fused a lumbar-hip carapace may be supposed present in the Niobrara form. But in the latter there is plainly indicated by heavy sulci the presence of a system of hornshields at least as large as the keeled plates. These characters evidently form a sufficient generic distinction.

It thus seems probable that the Dinosaurs actually paralleled the turtles in the development of keels of dermogene bones enclosed by horny shields and coming near to the formation of a true carapace with a clearly aligned bone and hornshield system primarily comparable to that of *Dermochelys* as it now exists. It is not to be forgotten, however, that the unusual structure of the *Archelon* carapace described in previous pages makes it very likely that ere long a turtle may be found with a neural, pleural and marginal series greatly reduced and mainly replaced by rows of large shields not greatly unlike those now described.

Yale University Museum, New Haven, Conn.

* The Ankylosauridæ, a new family of Armored Dinosaurs from the Upper Cretaceous; by Barnum Brown. Bull. Amer. Mus. Nat. Hist., vol. xxiv, Art. XII, pp. 187–201, New York, Feb. 13, 1908. [Though I fail to see why the Nodosauridæ of Marsh are ignored in this paper.]

WOLCOTT GIBBS.

WOLCOTT GIBBS, for many years an associate editor of this Journal, and during the last part of his scientific career the most commanding figure in American chemistry, was born in New York, February 21, 1822. His father, Colonel George Gibbs, was one of the earliest American mineralogists, and is commemorated in the mineral Gibbsite. He was a friend of the elder Silliman, and his fine collection, deposited in New Haven in 1812 and purchased in 1825, became the foundation of the mineral cabinet of Yale College. His mother, Laura Wolcott Gibbs, was the daughter of Oliver Wolcott, Secretary of the Treasury during part of the administrations of Washington and John Adams, and granddaughter of the signer of the Declaration of Independence of the same name. The child, who was the second son, was named Oliver Wolcott Gibbs, but, as he disliked the name of Oliver, he dropped it in early life, and is known to the scientific world as Wolcott Gibbs.

The taste for science inherited from his father was not slow in appearing, for, as he tells us, even in his early childhood, which was passed mostly at his father's large estate called Sunswick on Long Island a few miles from New York, " he was often occupied with making volcanoes with such materials as he could obtain, and in searching the stone walls on the estate for minerals and the gardens and fields for flowers."

At the age of seven he went to live with William Ellery Channing, the great Unitarian divine, who had married his aunt, but he was under the special care of another aunt, Miss Sarah Gibbs. The winters were passed in a fine house on Mt. Vernon street, Boston, and the summers at Oakland, a beautiful estate about five miles from Newport, R. I. The fame of Dr. Channing brought many foreign visitors, especially in summer, and this stimulating mental atmosphere, to which the boy was exposed for five years, had a marked effect on his intellectual development.

In 1837 he entered Columbia College, and his first original work dates from his junior year there. It consisted of a new

form of galvanic battery, in which carbon was used for the first time as the inactive plate. Upon receiving his degree of A.B. in 1841 he began his chemical education by taking a place as assistant with Dr. Robert Hare, professor of chemistry in the Medical School of the University of Pennsylvania. His long life, therefore, linked one of our earliest chemists with those of the present generation. After some months in this laboratory he entered the College of Physicians and Surgeons of New York with the intention of qualifying himself to hold the chair of chemistry in a medical school. It is certainly remarkable that at this early day he should have been able to work out so well-conceived a plan for chemical study; which he continued, after taking the degree of M.D. in 1845 and incidentally the A.M. in 1844, by going to Europe, where he entered the laboratory of Rammelsberg at Berlin. Some months here were followed by a year under Heinrich Rose, also in Berlin, a semester in Giessen with Liebig, and courses of lectures in Paris from Laurent Dumas and Regnault. Of this brilliant constellation of teachers, Heinrich Rose had by far the most influence on him, as is shown by his lifelong devotion to inorganic and analytical chemistry in spite of the fascinations of organic chemistry under Liebig and physical chemistry under Regnault. He always spoke of Rose with the greatest admiration and affection, and evidently regarded him as his chemical father.

In 1848 he returned to New York, and, after giving a short course of lectures at Delaware College, Newark, was elected in 1849 professor of chemistry and physics in the newly created Free Academy now called the College of the City of New York. For the next eight years there is little to record except his marriage to Josephine Mauran in 1853, and the fact that in 1851 he began a series of reports on chemical and physical progress for this Journal as associate editor, continued till 1873, which form 500 pages of succinct but clear and comprehensive abstracts of the most important papers of this period. He also carried on a similar work for American chemistry as correspondent of the German Chemical Society from 1869–1877. Until 1857 his papers, few in number and of no great importance, only show he was finding his feet, but in that year

appeared the account of his great investigation of the ammonia-cobalt compounds with F. A. Genth, which contained so full and thorough a study of the principal series of these puzzling bodies that very little in the way of experiment was left for future work, the analytical and chemical work being supplemented in many cases by crystallographic determinations by J. D. Dana. So exhaustive a research was a new thing in American chemistry, and at once established his reputation on a firm basis.

In 1861 appeared the first of three papers on new methods of separating the platinum metals, an important research on a most difficult subject, which was a worthy companion of his great work on the ammonia-cobalt compounds. These investigations led to his election in 1863 to the Rumford Professorship of the Application of Science to the Useful Arts in Harvard University, left vacant by the retirement of Professor E. N. Horsford, and accordingly, after he had established himself in Cambridge, he took charge of the chemical laboratory of the Lawrence Scientific School. The number of his students was small, but more were not to be expected or desired, as the object of the course was to educate professional chemists, and the supply was somewhat greater than the demand. His own work during this period is described in a number of short papers principally on chemical analysis ; the most conspicuous of which, introducing the electrical deposition of the metals as a means of their quantitative determination, laid the foundation of what has since become a new department of the science—electrical analysis. Another of these papers on the sand or glass filter is interesting as a forerunner of the Gooch crucible, and his experimental method for correcting the volumes of gases may also be mentioned.

In 1871 a reorganization of the Chemical Department consolidated the laboratory of the Lawrence Scientific School with that of Harvard College, and relegated Dr. Gibbs to the Department of Physics, where he taught a small advanced class in Light and Heat. Some papers on optical subjects inspired by the discovery of the spectroscope probably led to this assignment, which was justified on the score of economy, but its wisdom may be doubted, as it deprived the chemical

students of the university of the teaching of the best chemist in the country, and diminished the volume of his original work, since up to a certain point the amount of chemical production is directly proportional to the number of hands at the disposal of the master. Yet a study of his papers shows that, when his time was occupied by the administration of a laboratory and more elementary teaching, he did not produce those extended researches on which his fame principally rests, as these date from the earlier and later periods, when his whole energy was concentrated on work of his own with, in the later period, one skilled private assistant.

His two earlier investigations of this sort had to do with subjects so abstruse and difficult that most chemists would have shuddered at the idea of attacking them, but, as he once said, he was a pioneer, and seemed to enjoy nothing more than breaking a way through these tangled jungles on the frontier of the science. Accordingly he next took up a field of work— the complex acids of tungsten and molybdenum—even more terrible, for here it takes courage merely to read his papers, and follow his footsteps through the bewildering maze of series after series of compounds. What then must it have been to find the necessary clue to this labyrinth, and to establish the nature of these numerous compounds? Especially since in doing this it was necessary for him to work out some of the most difficult problems of analytical chemistry, as the separation of many of the elements involved had never been attempted before. In this great investigation over fifty new series of compounds were discovered by him, and the old series fully investigated and put on a solid foundation. The first paper appeared in 1877, and the last in 1896, this being the last paper published by him.

The invention of the ring burner, his most important contribution to the apparatus of analytical chemistry, dates from 1873, just after his transfer to the Department of Physics; and his porous diaphragms for heating precipitates in gases were described in the same year. In 1877 appeared his excellent method for preparing nitrogen.

In 1887 he became professor *emeritus*, and retired to Newport, where he continued his work on the complex acids in a

laboratory which he built for the purpose; and also invaded the only remaining department of inorganic chemistry, which could be ranked for complexity and difficulty with the three already occupied by him,—this was the cerium group, but advancing years prevented him from making more than a preliminary exploration in this field.

In these last years at Newport he also took up an extended study of the effect of isomeric organic compounds on animals, at first with Dr. H. A. Hare and later with Dr. E. T. Reichert. In addition to this work in physiological chemistry he had in his earlier papers made occasional excursions into theoretical chemistry, organic chemistry, mineralogy, and physics, an astonishingly broad field to be covered by one man. His fame, however, rests on his work in inorganic and analytical chemistry, and it seems to me that his two qualities, which make this preeminent, are thoroughness and accuracy. Next to these I should place his wonderful suggestiveness. His ideas flowed rather in a torrent than a stream, and occasionally bore him away from some good subject, after he had little more than broken the ground in it. Even old age did not check this current, his paper on the cerium metals published at 72 containing five new and ingenious suggestions for their separation. The criticism, which might be made on his work, is that he was content to prepare the experimental foundations, but left it to others to build the theoretical structures upon them. The reason for this, I think, was that before all else he was an experimentalist. His table was always covered with a multitude of test tubes each with a label in its mouth setting forth the substances reacting within, and it was beautiful to watch the sharpness of insight with which he seized on the favorable indications in these numerous experiments, and the rare skill and robust energy with which he followed any line of work that promised results of value.

As a teacher he had an especial faculty for imbuing his students with the enthusiasm and spirit of original work; and they felt the greatest admiration and affection for him. The only instruction I received from him was a single voluntary lecture in my senior year. In this his ideas came hurrying out with an impetuous speed, as if there were too many to be

forced into the narrow limits of an hour. The effect was wonderfully inspiring, when, as in this case, one did not have to take notes. As already stated, his teaching was confined to a few students, and it is a matter of regret that more did not have the opportunity of profiting by contact with this great mind.

Of the various societies, to which he belonged, he was most warmly attached to the National Academy of Sciences. He was one of its founders in 1870, and at his death the last survivor of the original members. He served it as foreign secretary, vice president, and from 1895 to 1901 president. He was also a member of the American Academy of Arts and Sciences and of the American Association for the Advancement of Science, of which he was a vice president in 1866, president in 1897. In addition to these his achievements brought him honorary membership in the Philosophical Society of Philadelphia, and the American, English, and German Chemical Societies, and corresponding membership in the British Association for the Advancement of Science, and the Royal Prussian Academy. The most striking of these appreciations of his merit was his election as honorary member of the German Chemical Society, as he was the only American on this list. The degree of LL.D. was conferred on him by Columbia University, Harvard University, the University of Pennsylvania *in absentia* as a special honor, and the Columbian University of Washington.

During the Civil War he proved himself a public spirited, patriotic citizen, devoting a large part of his time to service on the executive committee of the Sanitary Commission. The frequent meetings of this body suggested to him the idea of " a club which should be devoted to the social organization of sentiments of loyalty to the Union." A meeting to consider this plan was called at his house on January 30, 1863, and led to the formation of the Union League Club of New York. In later life, although he took no prominent part in public affairs, he always held his knowledge at the service of the government, as was shown by an extensive report on the instruments for physical research, prepared when he was a commissioner to the exposition at Vienna in 1873, another on the tariff as applied to seeds, and others on various chemical subjects.

His most engrossing pursuit, next to chemistry, was gardening, a taste inherited from his father, and he threw himself into this with the enthusiasm, skill, thoroughness, and success, which characterized his work in chemistry. It served as an excellent relief from his arduous labors, and, when old age brought these to an end, as a delightful occupation, until a short time before his death, which took place at Newport, December 9, 1908.

I wish I could bring before the reader the pictures which I like best to remember, when I think of him. The tall, handsome man brimming over with warm, cordial welcome as he hastened to meet you on your arrival at his house, and later, on the piazza overlooking the garden and the sea, the long inspiring talks, which kept you in a high clear country far above anything mean or questionable, and sent you back to your work with renewed energy and enthusiasm; his vivid enjoyment in the pursuit of his experiments in the laboratory; or best of all, to see him wandering from bed to bed in his sunny garden, rejoicing in each rare and beautiful plant in his rich collection.

C. L. Jackson.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *New Method of Forming Liquid Alloys of Sodium* and *Potassium.*—It has been found by JAUBERT that when metallic sodium acts upon potassium hydroxide, or when metallic potassium acts upon sodium hydroxide, there are formed in both cases, at a slightly elevated temperature, liquid alloys of the two alkali metals containing up to nearly 80 per cent of potassium. The very remarkable circumstance that both of these reactions take place and both give practically the same product appears to be due to the fact that these alkali metals combine to form the compounds NaK and NaK_2 with the liberation of a considerable amount of heat. The following equations represent the reactions :

$$K_3 + NaOH = KOH + NaK_2,$$
$$Na_3 + 2KOH = 2NaOH + NaK_2,$$
$$Na_2 + KOH = NaOH + NaK.$$
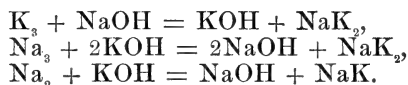
These reactions give almost quantitative yields, and they are brought about by heating the reacting substances to from 225° to 350° in the different cases. The operation may be carried out either under paraffine or in an exhausted vessel. The reaction corresponding to the second of the equations given above is one by means of which an alloy rich in metallic potassium is now being made cheaply on a commercial scale in France, and the product promises to have important industrial applications, since, as is well known, potassium in many cases gives reactions entirely different from those of sodium, and it often reacts where sodium is without action. In connection with these results the author points out the falsity of the statement, given in most works on chemistry, that the alkali metals react with their hydroxides to form their oxides ; for example,

$$Na + NaOH = Na_2O + H,$$
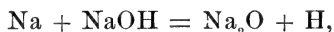
and that only the opposite reaction,

$$Na_2O + H = NaOH + Na,$$
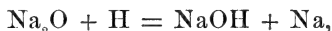
is possible, as has been shown by Becketoff.—*Bulletin,* IV, iii, 1126.   H. L. W.

2. *The Determination of Cerium and other Rare Earths in Rocks.*—It has been found by DIETRICH that when oxalic acid or ammonium oxalate is added to a cerium solution in the presence of ferrous sulphate, cerium oxalate is precipitated, but this precipitate contains a considerable amount of iron when a large quantity of this metal is present. When a neutral solution of a ferric salt is present no precipitate of cerium oxalate is produced

until the iron has been converted into the green complex oxalate, and then when an excess of oxalic acid or ammonium oxalate has been added the cerium oxalate is gradually precipitated in a pure white condition. Even when cerium oxalate has actually been precipitated it dissolves upon the addition of ferric chloride. The author advises, therefore, the use of a very much larger amount of ammonium oxalate than is customary in analytical work when cerium is to be separated from iron. He prefers to use ammonium oxalate rather than oxalic acid for this purpose, as the latter makes the liquid too acid. When ammonium oxalate is employed in this way, however, all the calcium present is precipitated with the rare earth oxalates, but the latter may be separated by igniting the precipitate, dissolving the residue in acid and precipitating twice with ammonia.—*Berichte*, xli, 4373.

H. L. W.

3. *Solubility of Metallic Gold in Hydrochloric Acid in the presence of Organic Substances.*—But few solvents for metallic gold have been known up to the present time. These are chlorine, bromine, iodine, cyanides, and selenic acid. AWERKIEW has now observed that finely divided metallic gold is soluble to some extent in hydrochloric acid in the presence of many organic substances. Among the organic compounds showing this property to a notable extent are the following, which are arranged according to diminishing effectiveness in this respect: methyl alcohol, amyl alcohol, chloroform, ethyl alcohol, chloral hydrate, phenol, cane sugar, glycerine, trioxymethylene, formaldehyde. The action takes place very slowly at ordinary temperature, but it is more rapid upon boiling, although the duration of the boiling appears to have no essential influence. The gold must be very finely divided to show such solubility, and large amounts of solvent dissolve small amounts of gold. For instance, 1000^{cc} each of methyl alcohol and hydrochloric acid when boiled for 5 hours with ·1154 g. of gold precipitated with ferrous sulphate dissolved ·0128 g. of it. The results indicate the existence of a new class of gold compounds, which it is the author's intention to investigate.—*Zeitschr. anorgan. Chem.*, lxi, 13. H. L. W.

4. *The Composition of Matter.*—The following contribution to theory has been put forth by E. MULDER : The conception that the atoms, which form the molecules, are compound has been advanced many times. But as yet he has not observed the hypothesis that these atoms of the second order are composed of atoms of the third order, and so on *to infinity*, a view which he advanced long ago. The ether, a particular and hypothetical form of the same matter (differing only in condensation), has, according to this idea, an analogous constitution. In the case of matter there are presented then, at the end of ends, infinitely small atoms, a conception not easily grasped.

A theory such as this, which explains no known phenomena, appears to be unprofitable. Many others besides Mulder have doubtless indulged in just such a speculation, and it is easy to

carry the idea upward as well as downward ; to assume that the planets and fixed stars are atoms of the next higher order, that there are many orders on beyond, so that at the end of ends there would be infinitely large atoms, a conception which is likewise not easy to grasp.—*Recueil*, xxvii, 418.   H. L. W.

5. *Introduction to the Rarer Elements*, by PHILIP E. BROWN-ING, 8vo, pp. 200.   New York, 1908 (John Wiley & Sons).— This is the second edition, thoroughly revised and considerably enlarged, of a book which first appeared five years ago and is well known to the chemical public.   Among the additions found in the new edition is a chapter by Dr. Boltwood, giving an excel-lent and concise account of the Radio-Elements.   H. L. W.

6. *Feste Lösungen und Isomorphismus*, by GIUSEPPI BRUNI. 12mo, pp. 127.   Leipzig, 1908 (Akademische Verlagsgesell-schaft).—The author of this book has taken an active part in the development of modern views regarding solid solutions.   In this volume, he gives an exceedingly clear account of the work that has been done and the results that have been obtained.   The first part consists essentially of a lecture delivered at Breslau and this is supplemented with an appendix containing additional notes and references.   H. W. F.

7. *The Production of Helium from Uranium.*—F. SODDY refers to his previous work on the production of helium from thorium and extends his work by a study of the production of this gas from uranium.   He concludes that this gas is produced from uranium with an approximate velocity of $2 \cdot 10^{-12}$ (year)$^{-1}$. That is, out of 1,000,000 kg. of uranium 2 mg. of helium are produced per year.   Preliminary results with sylvine give a production velocity of $2 \cdot 5 \times 10^{-12}$ (year)$^{-1}$.—*Physik. Zeitschrift*, Jan. 15, 1909, p. 41.   J. T.

8. *The Charge and Nature of the α-Particle.*—E. RUTH-ERFORD and H. GEIGER review the work upon this subject, comparing the charge on the α-particle with that on the hydrogen atom—finding it between $2e$ and $3e$.   They compare various methods of determining this charge and discuss the accuracy of different methods of determination.   It is maintained that the quantity of helium formed from a gram of radium is $5 \cdot 0 \times 10^{-9 \text{ccm}}$ per second.   The life of radium is 1760 years.— *Physik. Zeitschrift*, Jan. 15, 1909, pp. 42–46.   J. T.

9. *Amount of Water in a Cloud formed by Expansion of Moist Air.*—In the celebrated experiments of C. T. R. Wilson and Professor J. J. Thomson—on the determination of the number of ions by means of condensation of vapor—it is assumed that the air is cooled to the full extent by the adiabatic expansion before the drops begin to form.   Professor W. B. MORTON has investigated the conditions which would result if the expansion and condensation kept pace with each other, the process being a reversible one, and find that Thomson's results and his own differ only by six per cent.   The assumption of complete adia-batic cooling of the air does not introduce an error comparable

with other inaccuracies in the experiment.—*Phil. Mag.*, Jan., 1909, pp. 190–192. J. T.

10. *Permanent Magnetism of Copper.*—J. G. GRAY and A. D. Ross have studied the behavior of pure copper in strong magnetic fields under various conditions of temperature varying from bright red heat to that of liquid air. The traces of remanent magnetism are recorded. Ordinary and electrolytic copper were investigated together with the traces of iron.—*Physikal. Zeitschrift*, Jan. 15, 1909, pp. 59–61. J. T.

11. *United States Magnetic Tables and Magnetic Charts, for 1905;* by L. A. BAUER. Pp. 154, 1 figure, 7 charts. Washington, 1908 (Department of Commerce and Labor, Coast and Geodetic Survey).—The latest results obtained for the magnetic elements of the United States and the immediately adjacent countries are presented together in this volume, which appears independently instead of being attached as an appendix to the reports of the Coast and Geodetic Survey. The author states that he resigned his position in connection with the survey on September 1, 1906, but that the matter was essentially complete at that date except as regards the determination of the corrections for secular variation. In order that these may be as accurate as possible, the charts now issued are made out for January 1, 1905, instead of a subsequent date, as for 1910.* Recent experience has shown that unexpected changes have taken place in the variation and that they have not progressed in accordance with the predictions from the empirical formulæ established earlier, hence the necessity of great care to insure accuracy. The number of stations in the country for which the magnetic elements are tabulated is 3311 (2869 C. and G. Survey Stations), or, in other words, there is one magnetic station for about 973 square miles. Furthermore, magnetic work at sea was begun on Coast Survey vessels in 1903, so that the results obtained by them from 1903 to 1907, as well as by the Carnegie Institution along the Pacific coast, have been available for this work. In addition to the various tables, the report includes seven charts giving the declination, inclination, horizontal intensity, vertical intensity, total intensity, also the magnetic meridians, and, finally, the secular motion curves and horizontal intensity secular variation curves.

II. GEOLOGY AND NATURAL HISTORY.

1. *Die Fossilen Insekten und die Phylogenie der Rezenten Formen;* von ANTON HANDLIRSCH. In nine parts, pp. 1430, many plates and text-figures. Leipzig, 1906–08 (Wm. Engelmann).—This monumental work reviewing 7640 species of fossil insects is now completed. (An earlier review appeared in April, 1907, of this Journal.) On pages 1142–1192 is given a summary of the paleontologic results, a chapter of the greatest interest not only

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* It is proposed that the magnetic charts of the Carnegie Institution, with which Dr. Bauer is now connected, be also referred to the same period.

to entomologists but as well to all paleontologists. The first insects found fossil occur at the base of the Pennsylvanian or Lower Coal Measures. Of Paleozoic forms there are 884 species, Mesozoic 965 and of Cenozoic 5802. Rather a small showing when compared with the 380,000 known recent species, and yet a number sufficiently large to give a clear insight into the chronogenesis of the winged insects.

In Chapter VII a review is given of the more important classifications of recent insects beginning with that of Aristotle 300 years before Christ. In the eighth chapter the author establishes a new classification based on the principles of phylogeny and chronogenesis. There are two classes of insects, the winged or Pterygogonea, and the wingless or Apterygogonea. The former is here divided into 12 subclasses and 39 orders. The oldest subclass, restricted to the Pennsylvanian, is the radical stock Palæodictyoptera and out of it are derived 11 primary orders, all but one of these being restricted to the Paleozoic. The exception is Blattoidea. Either late in the Permian or in the Triassic originate 16 terminal orders, followed by 3 in the Jurassic, 7 in the Cretaceous and 2 in the Cenozoic.

The phylogeny of the Arthropoda is discussed on pages 1293–1318. The Trilobita is regarded as the radical from which most of the Arthropoda phylæ are directly derived. Finally, on pages 1318–1344, the author presents his "descendance conclusions." A Nobel prize might well be the reward for the energy and insight here displayed. c. s.

2. *Connecticut Geological and Natural History Survey.* Third Biennial Report ; Bulletin No. 12, 1907–1908. WILLIAM NORTH RICE, Director. 30 pages. Hartford.—The report of the Survey shows an unusual amount of high grade work accomplished with a very small annual appropriation. In addition to the eleven bulletins already published, the following have been accepted : The Lithology of Connecticut ; the Flowering Plants and Pteridophytes of Connecticut ; the Hymeniales of Connecticut ; the Triassic Fishes of Connecticut ; the Insects of Connecticut. The work in progress includes researches in glacial geology, study of peat deposits, and the preparation of reports on fresh waters, protozoa and algae, echinodermata, and birds of Connecticut.

H. E. G.

3. *Mississippi State Geological Survey.* ALBERT F. CRIDER, Director. Bulletin No. 1, Cement and Portland Cement Materials of Mississippi. 70 pp., 6 pls. Bulletin No. 2, Clays of Mississippi, pt. 1, pp. 249, pls. 42, figs. 14. Bulletin No. 3, The Lignite of Mississippi, pp. 66. Bulletin 4, Clays of Mississippi, pt. ii, pp. 64, pls. 17.—The Mississippi survey is justifying its existence from an economic standpoint by giving its first attention to the resources of the state, as shown by the above titles. Bound with each bulletin is a copy of the new Geologic and Topographic Map, which "represents the present knowledge of geologic boundaries of Mississippi"—a publication which will be welcomed by geological students. H. E. G.

4. *The Interpretation of Topographic Maps;* by ROLLIN D. SALISBURY and WALLACE W. ATWOOD. U. S. Geological Survey, Professional Paper No. 60. Pp. 78, pls. 170, figs. 34. Washington, 1908.—The use of the topographic maps published by the United States Geological Survey will doubtless be greatly extended as the result of this publication. The interpretation of 156 maps is given and they are grouped, with reference to the features they represent, under the following heads : The work of wind ; stream erosion; alluviation ; topographic effects from unequal hardness of rocks ; erosion cycles ; stream piracy and adjustment ; effects of ground water ; glaciation ; coast lines ; volcanism ; faults ; lakes of special types. From the standpoint of the teacher, this paper is one of the most valuable ever issued by the Geological Survey. Its value could have been increased, however, by more complete explanations of the various topographic types. H. E. G.

5. *The Zonal Belt Hypothesis, a New Explanation of the Causes of the Ice Age;* by JOSEPH T. WHEELER. Pp. 401. Philadelphia and London, 1908 (J. B. Lippincott Co.).—An attempt is made, in this book, to account for the great changes of climate through geological time, on the assumption that the earth has been, until recent times, surrounded by belts of "planetesimal or gaseous matter." The author has apparently read widely, in search of geological and meteorological phenomena which might be explained by this hypothesis. On the theory that the last zonal belt was in existence during the early history of man, the myths of the various races, together with Genesis and Plato, are called in as proofs of this phenomenon. Although the book contains much interesting matter, it can hardly be classed as a scientific treatise. H. E. G.

6. *Handbuch der Mineralogie;* von CARL HINTZE. Erster Band. Zwölfte Lieferung. Pp. 1761–1920; 43 text-figures. Leipzig 1908 (Veit & Co.).—The twelfth part of the first volume of Hintze's great work on Mineralogy has recently been issued. This is largely devoted to exhaustive descriptions of the species hematite and ilmenite ; also of several of the protoxides, including cuprite. This part is the twenty-fourth of the entire work begun in 1889 ; a title page is issued with it to be used in binding the first part of Vol. I (pp. 1–1208), embracing the elements and sulphides. H. E. G.

7. *Chemische Krystallographie;* von P. GROTH. Zweiter Teil. Die anorganischen Oxo- und Sulfosalze. Pp. 914, 522 text-figures. Leipzig, 1908 (W. Engelmann).—The scope of the important work on Chemical Crystallography undertaken by Prof. Groth was discussed in a notice of the first part published in 1906 (volume xxiii, p. 153). We have now the second instalment of the work, a volume of more than 900 pages, embracing the Inorganic Oxy- and Sulphosalts. This volume will be of especial interest to mineralogists, as well as to chemists, since it contains so large a part of the well-known mineral com-

pounds, as well as the allied artificial salts. The descriptions are liberally illustrated, and the statement of the crystallographic data leaves nothing to be desired. The work, however, is much more than a compilation of the crystallographic and optical prop - erties of chemical compounds, for the author's breadth of view and philosophical insight into the relations of these compounds give great value to the introductory remarks with which each division is introduced. The friends of the author will wonder once more that he is able, in connection with so many other works of importance, to carry through so stupendous a labor as is here represented. Two more parts are in preparation, which will embrace the organic compounds.

8. *Notes of a Botanist on the Amazon and Andes, being records of travel on the Amazon and its tributaries ; as also to the cataracts of the Orinoco, along the eastern side of the Andes of Peru and Ecuador, and the shores of the Pacific, during the years 1849–1864 ;* by RICHARD SPRUCE, Ph.D. Edited and condensed by ALFRED RUSSEL WALLACE, O.M., F.R.S., with a biographical introduction, portrait, seventy-one illustrations, and seven maps. In two volumes. London, 1908 (Macmillan & Co).— This treatise is exceptional in many respects. It is the record of botanical exploration about half a century ago, which is almost as fresh and important as if it was made during the last year. Furthermore, it is full of physiographical and ethnological memoranda of extraordinary interest, edited by a thoroughly sympathetic friend and fellow-naturalist. Everybody knows the range of the journeys made by Wallace in South America, and is familiar with the hardships attending them. Spruce not only passed over a great deal of territory which was practically like that investigated by Wallace, but he was in the equatorial belt at the very time when Wallace was there and knew of his serious illness.

Spruce is best known for his copious contributions to our knowledge of the Bryophytes. Beginning their study during his life in Yorkshire, he carried on explorations in the Pyrenees, where he discovered mosses and liverworts in places which had been thought to contain none, and afterwards he collected exten- sively in South America. With scarcely any means, and with only enfeebled health, he managed, by dint of an iron will, to carry his work on in a manner which has always commanded respect.

He has been most fortunate in his editor. No one could have condensed the voluminous notes more skillfully, or connected them with more instructive remarks than Mr. Wallace.

Our readers will enjoy in the perusal of this absorbingly inter- esting volume the proofs of Spruce's sagacity which led him to interpret many structural features in the Tropics as indicative of a certain drifting of specific characters, vaguely pointing towards descent through variation. After Spruce's return to England, he became an ardent Darwinian, going so far as to state unequivo-

cally that " if we had all the forms now in existence, and that have ever existed, of such genera as Rubus, Asplenium, Bryum, and Plagiochila, we should be unable to define a single species— the attempt to do so would only be trying to separate what Nature never put asunder—but we should see distinctly how certain peculiarities had originated and become temporarily fixed by inheritance ; and we could trace the unbroken pedigree of every form. " G. L. G.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Carnegie Institution of Washington. Year Book No. 7, 1908.* Washington, 1909.—The following is an authorized statement of the contents of the seventh Year Book of the Carnegie Institute of Washington, for 1908 : It consists of reports of the President and the Executive Committee, and of Directors of Departments and other grantees who, with the assistance of the Institution, have been carrying on investigations during the year.

The President's report gives the following salient facts and figures indicating the growth and extent of the work thus far undertaken and accomplished by the Institution. Since its organization, in 1902, about 1,000 individuals have been engaged in investigations under the auspices of the Institution and there are at present nearly 500 so engaged. Ten independent departments, each with its staff of investigators and assistants, have been established. In addition to these larger departments of work, organized by the Institution itself, numerous special researches, carried on by individuals, have been subsidized. Six laboratories, for as many different fields of investigation, and in widely separated localities, have been constructed and equipped. Work in almost every field of research, from archeology and astronomy to thermodynamics and zoology, has been undertaken, and the geographical range of this work has extended to more than thirty different countries.

At the end of the fiscal year, October 31, 1908, 120 volumes of researches in nineteen different fields of research, with an aggregate of more than 30,000 pages, had been published, and 27 volumes of research were in press. In addition to these publications issued by the Institution, about 1,000 shorter papers have been published in the current journals of the world by department investigators, by associates, and by assistants. The total amount of funds appropriated for expenditure to November 1 was $3,683,840.00, which included $293,928.37 reverted and afterward reappropriated. The total amount expended was $3,359,236.17.

During the past year the Nutrition Laboratory in Boston has been equipped, and systematic investigations are already in progress.

The construction of a building in Washington, D. C., at the corner of Sixteenth and P streets, N. W., was begun a year ago. This building is for administrative offices and the storage of

records and publications, and when completed will cost about $220,000.

The plans and specifications for the construction of a specially designed ship for ocean magnetic work have recently been completed. These plans call for a non-magnetic sailing vessel with auxiliary propulsion, and the contract for her construction has been let to the Tebo Yacht Basin Company, of Brooklyn, N. Y. She will be classified as a yacht, will be called the "Carnegie," and will, upon completion, proceed upon a magnetic survey of the Atlantic Ocean under the direction of the Department of Terrestrial Magnetism of the Institution.

A temporary observatory for supplementary measures of the positions of the fixed stars of the southern hemisphere is now being built at San Luis, Argentina, under the direction of Professor Lewis Boss, head of the Department of Meridian Astrometry of the Institution. Professor R. H. Tucker will be resident astronomer in charge of the work of observing and computing in South America, which will require three to five years for completion. The meridian instrument of the Dudley Observatory, whose constants have been thoroughly investigated, will be transferred to San Luis and used in securing the desired measurements of the positions of stars in both hemispheres.

Work in the other departments of the Institution has progressed rapidly and successfully. The investigations of Dr. G. E. Hale, Director of the Solar Observatory on Mount Wilson, California, are of great interest. During the year, with the aid of his exceptional equipment, certain discoveries with regard to sun-spots have been made which will probably prove of as great importance to terrestrial and molecular physics as to solar physics. The progress inaugurated may be confidently expected to lead rapidly to definite and important results. Under the direction of the Department of Historical Research, work upon manuscript materials for American History has been pursued in France, Italy and England, and next year will be extended to Germany. Many remarkable experiments and investigations are in progress under the Department of Botanical Research at the Desert Laboratory at Tucson, Arizona.

In addition to the work carried on in the departments of the Institution during the year, 31 grants were made to individuals and organizations, in aid of researches conducted by them, and many other researches begun in former years have been carried forward. The publication of 20 volumes was authorized, and 27 volumes and an atlas have been published. These latter include the report upon the California Earthquake of April 18, 1906, a Handbook of Learned Societies and Institutions of North and South America, and a reproduction of the "Old Yellow Book," the source of Browning's "The Ring and the Book." These volumes and others issued by the Institution are offered for sale at the cost of printing and transportation to purchasers.

At the annual meeting of the Board of Trustees on December 8, 1908, Mr. Martin A. Ryerson, of Chicago, was elected a

Trustee, to fill a vacancy in the Board. At the same meeting the sum of $636,300 was appropriated to carry on work of investigation, publication and administration during the year 1909.

2. *Report of the Librarian of Congress and Report of the Superintendent of the Library Buildings and Grounds for the fiscal year ending June 30, 1908.* Pp. 143. Washington, 1908. —The Library of Congress is so far a model in its work and methods for the other large libraries in the country that the annual report of the Librarian, Mr. HERBERT PUTNAM, possesses particular interest. The total amount expended by the Library, in 1908, was $615,000, while the appropriations for 1909 are somewhat more than $100,000 greater than this sum. The increase in number of books for the year is slightly over 100,000. The important purchase of the year was that of the Huitfeldt-Kaas collection of 5000 volumes of Scandinavian literature, made by the state archivist of Norway, who died in 1905. A portrait of Mr. A. R. Spofford, who was for 32 years Librarian in Chief, and who died on August 11, forms the frontispiece of the volume.

3. *Harvard College Observatory;* EDWARD C. PICKERING, Director.—Recent publication are noted in the following list (continued from vol. xxvi, pp. 99):

ANNALS.—Vol. LIV. A Catalogue of Stars fainter than the magnitude 6·50 observed with the 4-inch Meridian Photometer; forming a supplement to the Revised Harvard Photometry. Pp. 280.

Vol. LVI, No. IV. Classification of 1,477 Stars by means of their Photographic Spectra; by ANNIE J. CANNON. Pp. 65–114.

Vol. LVII, Part II, Comparison Stars for 252 Variables of Long Period. Prepared for publication by LEON CAMPBELL, Assistant, under the direction of EDWARD C. PICKERING, Director. Pp. 213–288.

Vol. LIX, No. II. Photographic Photometry on a Uniform Scale; by EDWARD S. KING. Pp. 33–62, 6 figures.

Vol. LX, No. IX. A Catalogue of Photographic Charts of the Sky. Pp. 231–251.

Vol. LXIV, No. I. Observations with the Meridian Photometer during the years 1902 to 1906. Pp. 32. No. II. The Variable Star SS Cygni. 213843; by LEON CAMPBELL. Pp. 33–53. I Plate. No. III. Schönfeld's Comparison Stars for Variables. Pp. 55–89.

CIRCULARS.—No. 137. 25 New Variable Stars in Harvard Map, Nos. 31–43.

No. 138. 060547. The Variable Star, 31,1907. Pp. 6.

No. 139. 26° 179. A New Variable of the Class of β Lyræ. 003226. Pp. 7.

No. 140. 16 New Variable Stars in Harvard Map, Nos. 4 and 13. Pp. 3.

No. 141. 29 New Variable Stars near Nova Sagittarii. Pp. 4.

No. 142. 28 New Variable Stars in Harvard Map, Nos. 30 and 33. Pp. 3.

4. *Publications of the Allegheny Observatory of the University of Pittsburgh.*—The following have recently appeared :

Vol. I, No. 6. The determination of the orbit of a spectroscopic binary by the method of least squares ; by FRANK SCHLESINGER. Pp. 33–44.

No. 7. The orbit of θ Aquilæ ; by ROBERT H. BAKER. Pp. 45–66.

No. 9. A partly graphical method for predicting solar eclipses; by FRANK SCHLESINGER. Pp. 57–64.

5. *Washburn Observatory of the University of Wisconsin,* GEORGE C. COMSTOCK, Director.—The following volume has been recently issued :

Vol. XII. Determinations of Proper Motion, 1902–1907. Part I. Proper Motions of Faint Stars ; by GEORGE C. COMSTOCK, Director. Pp. 317. The observations here given have been made with the 40 cm. equatorial of the Washburn Observatory; to a considerable extent they repeat, after a period of more than fifty years, the measurements made by Struve at Pulkova, on stars fainter than the ninth magnitude.

6. *A Treatise on Spherical Astronomy;* by Sir ROBERT BALL. Cambridge, 1908 (The University Press).—The present treatise by Sir Robert Ball, the distinguished Lowndean Professor of Astronomy at Cambridge University, covers quite an amount of ground not included in the classical works of Brünnow, Chauvenet and later writers and thus seems a valuable addition to our text-books. Thus it gives a glimpse into the theory of map making and into the rudiments of theoretical astronomy besides the usual applications of spherical trigonometry to celestial problems. An interesting feature are the numerous exercises, though some of these seem more a test of algebraic ingenuity than of astronomical insight. Among the novelties of the book may be cited the nomenclature "nole" and "anti-nole" for the poles of a great circle, corresponding to the North and South Poles ; to us it hardly seems that there was a crying need for further designations, also, perhaps, the similarity to "node" is unfortunate.

The presentation, as is usual with Sir Robert Ball, combines great lucidity and directness and we may again add our best wishes for the adoption of the work for class and private study.

W. L. E.

7. *Bulletin of the Mount Weather Observatory,* WILLIAM J. HUMPHREYS, Director.—Prepared under the direction of WILLIS L. MOORE, Chief U. S. Weather Bureau. Vol. I. Part 4, pp. 207–77 ; 3 charts, 3 figures.—This number contains the following articles : Pyrheliometer and polarimeter observations, by H. H. Kimball ; recent auroral displays and magnetic disturbances, by W. R. Gregg ; magnetic declination, by E. R. Miller ; upper air temperatures for April, May and June, with charts of upper air isotherms, by W. R. Blair.

8. *National Antarctic Expedition, 1901–1904, Album of Photographs and Sketches with a Portfolio of Panoramic Views.* Pp. 303, 4to ; 165 plates and 2 maps. London, 1908. (Published by the Royal Society and sold by Harrison & Sons, St. Martin's Lane, W. C., and Oliver & Boyd, Tweeddale Court, Edinburgh.)—The two volumes giving the results of the meteorological and physical observations made by the National Antarctic Expedition were noticed in the December number (p. 588). We have now an additional volume presenting in most attractive form views of the life and scenery of the region visited. The photographic work was in charge of Lt. Skelton, and most of the admirable views here reproduced were taken by him ; the name of L. C. Bernacchi is also frequently associated with his. The volume and accompanying portfolio contain 165 plates, of which 128 are from photographs. The life of the southern ocean is well shown in the interesting series of photographs of the Adélie and Emperor penguins, also of the seals, whales and albatross. The scenic views present a vivid impression of the striking features of the land and ice of the Antarctic, particularly of its capes and lofty mountains. Especial interest attaches to the photographs of the Great Ice Barrier, the abrupt cliffs of which extend for many miles from King Edward VII Land to Ross island. The height is as great as 280 feet at some points, and the surface comes down at others to within 18 feet of the water level. This Great Barrier sheet moves northward at the rate of 45 yards per month, but in consequence of its recession by breaking up the sea face is now some 10 to 15 miles farther south than sixty years ago. A special portfolio contains an interesting series of sketches, largely panoramic, due to the artistic work of the Junior Surgeon, Edward A. Wilson.

9. *The Chemical Constitution of the Proteins ;* by R. H. ADERS PLIMMER, D.Sc. In two parts. Part I, pp. xii + 100 ; Part II, pp. xii + 66. London and New York, 1908 (Longmans, Green and Co.).—The development of biochemistry as a separate department of study has been so rapid and fruitful that the entire field is already too large for exhaustive treatment in a single volume. The unique importance of the proteins has always made them favorite subjects for investigation. In recent years particularly, the literature on these compounds has increased to an extent that makes timely an exhaustive compilation like Dr. Plimmer's. The monographs are concerned with the chemical composition of the protein molecule and the chemical characteristics of its component units, rather than with the behavior of individual protein substances. The organic chemist as well as the physiologist will have occasion to consult such a review, in considering the historic development of the study of the amino-acids as well as the interesting attempts at the synthesis of complex protein-like compounds (with which Part II especially deals). In accord with the intent of this series of monographs, an extensive bibliography is published in each part.　　L. B. M.

10. *Standard Algebra ;* by WILLIAM J. MILNE, New York
State Normal College, Albany, N. Y. Half leather, 12mo, 464
pages. New York, 1908 (American Book Company).—This use-
ful text-book follows the method of the Inductive Algebra pub-
lished in 1881 by the same author. The new ideas that have been
brought into the teaching of elementary algebra in the interval
are presented, such as the remainder theorem for purposes of
factoring, and the graph, which is used for illustration to a limited
degree. It is a handy volume, bound and trimmed to carry
in the pocket, and the exercises are numerous, fresh and well
chosen.   w. b.

11. *Kraft, ökonomische, technische und kulturgeschichtliche
Studien über die Machtentfaltung der Staaten ;* von E. REYER.
8°, pp. 380, many diagrams in text. Leipzig, 1908.—The work of
Professor Reyer, who is well known for his studies in theoretical
geology, has always been characterized by great originality, both
in his views and in his mode of presenting them. He has also
been widely interested in matters humanistic, and it is, there-
fore, not strange to find a volume coming from his pen which
relates to subjects outside of his especial field.

The volume before us is a conspectus of the economic develop-
ment of the chief nations in matters relating to their main indus-
tries, those upon which their material prosperity depends. Such
comprise iron and steel, coal, precious metals, manufactures,
commerce on land and sea, agriculture, and a great variety of
others in which power is an element of first importance. The
history of the growth of power, its various sources of supply, its
relation to the topics mentioned above, and its future are thought-
fully treated. The book is illustrated by many diagrams and,
written in a clear and well-poised manner, it presents an interest-
ing and popular exposition of a most important subject..
                                                          L. V. P.

12. *International Congress of Applied Chemistry.*—The seventh
International Congress of Applied Chemistry will be held
in London from May 27 to June 2. The Honorary Secretary is
William Macnab, address 10 Cromwell Crescent, S.W.

OBITUARY.

PROFESSOR HARRY G. SEELEY, the well-known English geolo-
gist and vertebrate paleontologist, died on January 8, in his
seventieth year.

New Circulars.

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THE

AMERICAN

JOURNAL OF SCIENCE.

EDITOR: EDWARD S. DANA.

FOURTH SERIES

No. 160—APRIL, 1909.

VOL. XXVII—[WHOLE NUMBER, CLXXVII.]

NEW HAVEN, CONNECTICUT.

1909.

RARE CINNABARS FROM CHINA.

We would call attention to these remarkable Cinnabars, some of which still remain. They are beyond doubt the most beautiful and interesting crystals of Cinnabar ever discovered. They were described and illustrated in this Journal, Nov. '08. The prices range from $5, $7.50, $10, $15, $18, $25, $35, and $50.

NEW ARRIVALS.—RARE FINLAND MINERALS.

Wükit, Idocrase, Gigantolite, Tantalite, Skapolite, Sordavalite, Pitkaran-dite, Columbite, Monazite, Magnetite, Pyroxene, Sundvikite, Amphibole, Chrysoberyl, Muscovite curved, Epidote, Cassiterite with Pyrite, Beryls, Garnets, Tourmaline, Pyrites, Chondrodite, Quartz, Rose Quartz.

RARE MINERALS—FROSSNITZ ALPS, TYROL.

Bornite, largest crystal found, 1¼ by 1 in., slightly altered. Bornite, altered to malachite, with gold, loose and in matrix. Brookite, flat loose crystals, rare form ; Eisenrose, large rare crystals ; Anatase, small loose crystals and in matrix ; Smoky quartz with Byssolite ; Smoky Quartz crystals, Habachthal ; Albite, choice rare crystals ; Sphene, Habachthal ; Apatites, in matrix, beautiful white, Untersulzbachthal ; Emeralds doubly terminated in matrix, Habachthal ; Epidote, large gem crystal, 5 in. long.

RARE MINERALS FROM OTHER LOCALITIES.

Euclase, Capo do Lane, Brazil ; Columbite, Conn. ; Monazite, large loose xls. and in matrix, Conn. ; Uraninite, crystal in matrix, Conn. ; Benitoite and Neptunite, San Benito Co., Cal. ; Lievrite, Elba ; Polybasite, Hungary and Mexico ; Herderite, Poland, Maine ; Cobaltite, loose xls. and in matrix, Cobalt, Ont., and Sweden ; Vivianite, large crystals, Colo. ; Olivinite, Utah ; Sartorite, Canton Wallis ; Jordanite, Binnenthal ; Crocoite, Siberia and Tasmania ; Cinnabar, China, Cal., and Hung. ; Gypsum, twin xls., Thuringia ; Diamond in matrix, New Vaal River Mine, South Africa ; Argentite, Mex.; Freiberg, Sax. ; Pyrargyrite, Sax. and Mex. ; Pyromorphite, Ems, Germany, Phoenixville, Pa. ; Tourmalines, beautiful sections from Brazil, Mesa Grande, Cal., all shades, in matrix and loose xls. ; Pink Beryl, small and large, Mesa Grande, Cal. ; Kunzite, small and large, Pala, Cal. ; Titiantite, Tilly Foster; N. Y.; Tetrahedrite, Utah and Hungary ; Realgar, Hung. ; Opal, Caribou River, Queensland ; Bismuth, native, Cobalt, Ont. ; Zircon xls., loose, Ural ; Green and Cinnamon Garnets, Minot, Maine ; Vesuvianite, Poland, Maine, Italy and Tyrol ; Zeolites, beautiful specimens from Erie Tunnel, Patterson, and Great Notch.

Reconstructed Rubies, Blue and White Sapphires.

Do not fail to secure one of these beautiful scientific gems ; the blue and white sapphires are the latest discovery ; they have the same specific gravity and hardness as the genuine ; the brilliancy and color equal to the genuine and better.

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AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

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ART. XX.—*On the Permeabilities and the Reluctivities, for very Wide Ranges of Excitation, of Normal Specimens of Compressed Steel, Bessemer Steel and Norway Iron Rods;* by B. OSGOOD PEIRCE.

WHEN a rod or a closed frame of iron becomes magnetized under the action of a steady electric current in an exciting coil of insulated wire wound about it, the flux of magnetic induction (B) through any cross section of the iron can be easily determined with the aid of a small testing coil, but it is often very difficult to tell just what the value of the exciting magnetic field (H) is at any given point within the metal. In a few familiar cases, however, the difficulty disappears.

If, for instance, a homogeneous round rod of soft iron the length of which is, say, five hundred times the diameter, be placed in a solenoid of narrow bore, somewhat longer than the rod and uniformly wound with n turns of insulated wire per centimeter of its length, and if a steady current (C) be sent through the solenoid, the demagnetizing effects of the ends of the rod become inappreciable near the center, O, and we may assume without sensible error that the value of H at every point of a cross section in the neighborhood of O is equal to the value ($4\pi n C/10$) of H just without the rod at O.

In the case of a soft iron toroid, uniformly wound with N turns (in all) of insulated wire, the value of H is, of course, not the same at every point of a meridional section of the metal, but if the material is perfectly homogeneous, there is practically no leakage of induction into the air. Under these circumstances, the magnetomotive force is the same ($4\pi N C/10$) around all closed non-evanescible paths in the iron, and the value of H is inversely proportional to the distance from the axis of revolution of the toroid. In practice,

such a toroid must be turned out of a solid piece of the metal, for it is almost impossible to make a ring out of iron rod, bent and welded together at the ends, which shall be sufficiently homogeneous to prevent serious leakage of lines of induction, and H is often very different in such a ring at different points of a circumference in the iron coaxial with the ring. If a closed magnetic circuit be made by putting a piece of soft iron rod lengthwise between the jaws of a massive yoke of any of the common forms, there is usually such an amount of leakage through the surface of the rod that the induction flux has very different values at different sections of it. However carefully the joints are made between the jaws and the specimen, it is very difficult to compute, from previous determinations of the magnetic properties of the rod and the yoke, what portion of the whole magnetomotive force of the circuit is used in the rod ; indeed the fraction is very different for different excitations, and for the same soft yoke may depend very much upon the hardness of the piece to be studied. For comparatively low excitations up to say $H = 100$, a slender yoke may be used so that the cross section of the magnetic circuit is not very different at different places, and the exciting coils can then be so arranged on the yoke and the specimen, if the joints are well made and the whole circuit is magnetically fairly homogeneous, that the induction flux is nearly the same throughout. It is understood that this procedure* has been brought to great perfection in the National Bureau of Standards at Washington. For excitations of $H = 2000$ or more, however, the arrangement seems hard to manage.

A magnetic field in air near a magnet is both solenoidal and lamellar, and if in any portion of such a field the lines are sensibly straight and parallel, we may infer that in that region the field is practically uniform. If within a piece of perfectly soft iron the magnetization vector (I) has everywhere the direction of the exciting magnetic force, H, and an intensity expressible in terms of H alone, the induction in the metal is a solenoidal vector which has the same lines as the lamellar vector H. If throughout any region within such a piece of iron the lines of force are straight and parallel, the magnetic force and the induction are both uniform in that region. At the surface of separation between iron and air, the tangential components of the force are continuous, but the normal component of the force is generally discontinous ; if the lines of force in air just outside the surface are parallel to it, the lines of induction in the metal at this surface are parallel to the surface. If, then, the magnetic field around a slender rod of

* Burrows, Proc. American Soc. for Testing Materials, viii, 1908.

iron magnetized lengthwise, has, near the surface of the rod, lines parallel to the rod's axis, we may inquire whether the lines of force and of induction within the rod are not in this neighborhood all parallel to the axis, so that the value of H throughout a cross section of the rod is the same as the value just outside the iron.

The assumption that the value of H in the air just about a slender neck of iron of proper form held between the jaws of a highly excited electromagnet is the same as the value in the neck itself, lies at the foundation of the "Isthmus Method" of determining permeabilities under very high excitations introduced by Ewing and Low.[*] According to my some what extended experience the so called "maximum value of I" may be determined by the Isthmus Method to within 1 or 2 per cent of the truth if the poles and the test-piece are of the proper shape and are properly connected, and if the jaws as well as the isthmus are fairly soft; but these conditions are not always easy of attainment, and if one assumes them to be satisfied without investigating each case by itself, one may be led into grievous error. The field about a hard steel isthmus between soft jaws is usually far from uniform, and for some specimens of hard steel which I have studied I have not yet succeeded in obtaining by the Isthmus Method trustworthy determinations of I_∞. In some instances the values of H in the air were manifestly smaller or larger than in the isthmus, and sometimes they were smaller for one excitation and larger, for the same isthmus, for another excitation. Nevertheless the method is, of course, a most valuable one.

This paper describes a long series of determinations of the permeabilities of normal brands of compressed steel, Bessemer steel, and Norway iron in the form of half-inch rods, over a wide range of excitation, and it considers especially a method of measurement in a massive yoke in the interesting region from $H = 400$ to $H = 2500$ which lies above the limits of most permeameter observations and below those of the Isthmus Method. The work was undertaken in order to determine the magnetic behavior, in the region just mentioned, of an important specimen of soft iron of which only a single short piece was available, and it was necessary to test the trustworthiness of the method to be used by applying it to some soft metals which could be obtained in large pieces and the permeabilities of which could be otherwise found, at least approximately.

If the rod to be experimented upon can be kept cool artificially, it is not very difficult to determine accurately in a very

[*] Ewing, Magnetic Induction in Iron and other Metals ; Ewing and Low, Philosophical Trans., clxxx, 1889.

long solenoid, the permeability of a soft, homogeneous rod four or five hundred diameters long, for excitations up to $H = 400$. Here the value of I is probably between 95 per cent and 97 per cent of the final value (I_∞), which can be found by the use of the Isthmus Method. If, then, any other method of measuring permeability be used on the specimen between $H = 300$ and $H = 2000$ and if this method yields the proper values of I at both ends of the interval, it is comparatively easy to judge, from a graphical representation of all the observations, whether the short interval corresponding to from 3 to 5 per cent of I_∞ is properly bridged. The principal difficulty with this procedure is that several isthmus specimens of a metal and several testing coils must be used before one can be satisfied that the resulting value of I_∞ is correct to within 1 per cent; for, as Ewing has shown, the separate results of a series of determinations of I_∞ by the Isthmus Method may differ from the mean on either side by as much as 4 per cent. As a matter of fact, in all the materials I have tested the final value of I obtained by the Isthmus Method does not differ by so much as 1 per cent from the final value as obtained by the other method I have used. This second method, however, gives in any case a series of determinations of I_∞ which do not as a rule range over so much as 1/3 per cent of the mean, while the Isthmus Method in my hands is much less satisfactory in this respect.

The Bessemer and the compressed steel were procured in specially long pieces from which lengths of about 450 centimeters were cut, and these, under the severest test which I could conveniently apply, seemed to be practically uniform throughout. The Norway iron, on the contrary, was not everywhere of the same temper and could not be used satisfactorily until it had been carefully annealed by Mr. George W. Thompson, the mechanician of the Jefferson Laboratory, who has had much experience in work of this kind. Upon each of these rods at its center a test coil of fine wire was wound by Mr. John Coulson, who has made all the test coils and has helped me in every part of the work, and then the coil and its leads were carefully covered by pieces of rubber and rubber tape to make the whole waterproof. The rod thus prepared was placed inside a horizontal solenoid nearly 500 centimeters long, placed perpendicular to the meridian. This solenoid was uniformly wound with 20,904 turns of well insulated wire and a stream of tap water could be kept running through the bore around the rod to prevent any appreciable rise of temperature. The rod was demagnetized in situ by means of a long series of currents in the solenoid, alternating in direction and gradually decreasing in intensity, and then a curve of ascending

reversals was obtained in the usual manner. It is to be noticed that the demagnetizing process does not succeed unless the rod is practically homogeneous throughout its length.

The ballistic galvanometer employed in this work has been already described* in a previous paper, and it is only necessary to say here that its period was so long that no detectable error was introduced into its indications by the fact that four or five seconds were necessary to make the magnetic changes corresponding to a reversal of current in the exciting coil of the yoke. For the largest currents a battery of about 120 large storage cells was used; a battery of 30 or 40 cells furnished the weaker currents.

When it is necessary to create inside an iron rod a fairly uniform magnetic field of intensity much greater than, say 500, some kind of yoke† is almost indispensable, and many kinds of yoke-permeameters are now used successfully in studying the magnetic properties of short rods at commercial excitations. For very high excitations, at which the air is nearly as permeable as the metal, the leakage becomes very troublesome and depends upon matters which cannot be easily controlled. I hoped, notwithstanding this fact, to be able to calibrate the yoke we had (figure 3) by means of standard pieces and thus make it available for studying short pieces of iron at excitations of about $H=1000$, but Mr. John Coulson and I worked for a long time on this problem without finding any satisfactory solution. We found it possible, however, to determine the length of a half-inch rod of iron which, mounted between the jaws of this particular yoke, would cause the magnetic field in the air just without the iron near the middle of the specimen to be practically straight and parallel to the rod for a considerable distance. A piece about 15 centimeters long, accurately fitted for about 3·5 centimeters at each end into the taper holes in the jaws and leaving 80 millimeters of the rod free, satisfied the conditions, and this length might be slightly varied, but a much shorter rod violated the conditions in one direction (the determination of μ being too large) and

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* Peirce, Proc. American Academy Arts and Sciences, xliv, 1908.

† H. E. J. G. DuBois, Phil. Mag. 1890, The Magnetic Circuit in Theory and Practice; Shuddemagen, Proceedings American Acad. of Arts and Sciences, xliii, 1907; J. Hopkinson, Philosophical Transactions, clxxvi, 1885; Drysdale, Electrician, xxviii, 1901; Thornton, Electrician, xlix, 1902; Ewing, Electrician, xxxvii, 1896; Schmidt, Ann. der Physik, liv, 1895; Chattock, Electrician, xxxvii, 1896; Lamb and Walker, Electrician, xlvii, 1901; Baily, Electrician, xlviii, 1901; Köpsel and Robinson, Electrische Zeitschrift, xv, 1894; Kath, Electrische Zeitschrift, xix, 1898; Kennelly, Electrische Zeitschrift, xiv, 1893; Blondel, Comptes Rendus, cxxvii, 1898; Stoletow, Ann. der Physik, cxlvi, 1872; Rowland. Phil. Mag., xlvi, 1878; Ewing, Magnetic Induction, 1892; Behn–Eschenberg, Electrische Zeitschrift, xiv, 1893; Kapp, Electrical Engineer, xxiii, 1894.

a longer rod in the other.   If, then, a testing coil (K) of very
fine wire were wound in a single layer over a centimeter or
two of the middle of a rod of the standard length, and a second,
similar, coil (L) of radius about two millimeters greater than
that of K, upon an extremely thin non-magnetic spool slipped

Fig. 1.
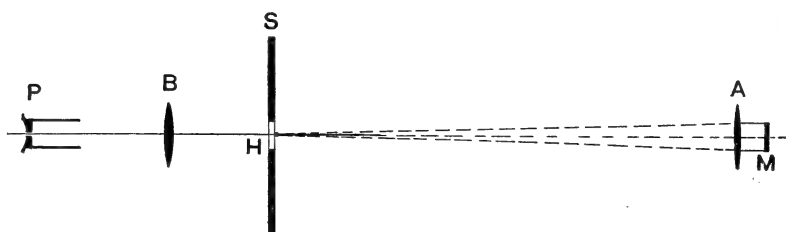
over K, it was to be expected that a knowledge of the whole
amounts of the currents induced in K and L when the exciting
current of the yoke was reversed would determine, as in the
Isthmus Method, corresponding values of *H* and *B*.   This
assumption was fully justified by experiment.   The radii of

Fig. 2.
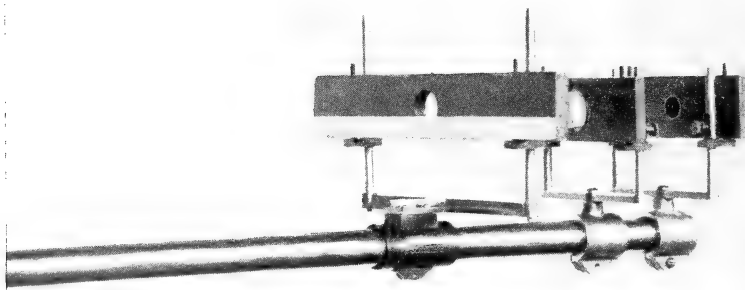
the coils and the diameter of the wire were measured with the
help of a Zeiss comparator (No. 3196).   The coil L was
wound upon a very dry piece of boxwood, and was carefully
baked in shellac.   Paraffine wax is inadmissible as an insulator
on the wire because of its magnetic properties, and for the
same reason a vulcanite spool cannot be used for L.

Fig. 3.
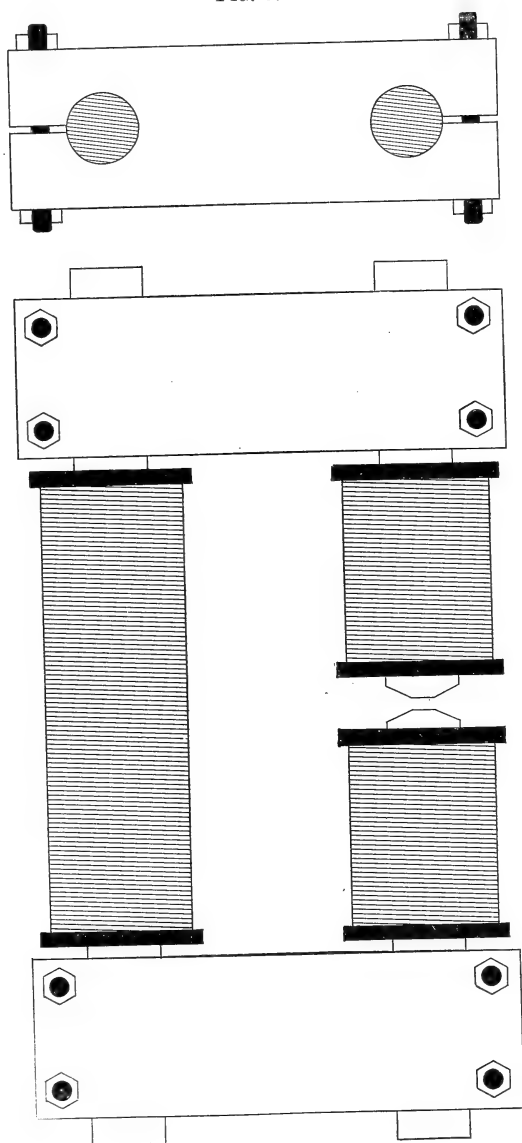
The moment of inertia of the suspended coil of the long period ballistic galvanometer used for the work was so great that at low excitations the instrument was rather insensitive when used to measure the difference of the fluxes through

K and L, and it became necessary to make the scale distance nearly four meters. Under these circumstances it was practically impossible with a very large reading telescope of the very best make (Clark's) to get a bright image of the scale sufficiently magnified to render ballistic determinations easy, so we had recourse to the simple device* represented by figures 1 and 2, and this has given great satisfaction. In front

Fig. 4.
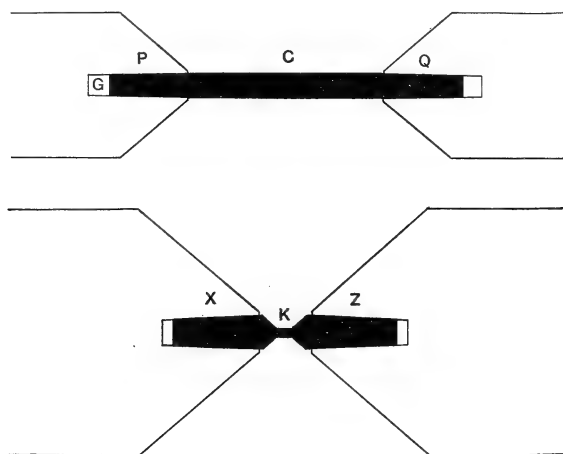
of the reasonably plane mirror (M) of the galvanometer, instead of the usual cover glass, was placed a convex spectacle lens (A) of about four meters focal length. At a distance in front of A equal to its focal length was a horizontal scale (S) mounted in the usual manner on a thin strip of wood at least twice as wide as the scale itself. Through the middle of this strip above the scale was bored a round hole (H) rather more than 20 millimeters in diameter, and just behind the scale a fine vertical wire or silk fiber (W) was stretched across the opening to serve as a cross hair. Behind H, and at a distance suited to its focal length and to the eye of the observer, was placed another spectacle lens (B) to serve as an eyepiece. This had a focal length of about 20 centimeters. A peephole (P) on the common axis of H, A, and B, so placed that B's aperture appeared wholly filled with a large clear uncolored image of the scale with the crosswire running vertically across it, completed the arrangement. If different persons used the device the position of B had to be changed to suit the eyes of the

* Peirce, Proc. American Academy Arts and Sciences, xlii, 1906.

observer, but the position of H was fixed. In setting up apparatus of this sort, one should remember that if the distance between B and P is not properly chosen, only a small round portion of the image of the scale will be visible, not nearly large enough to fill the aperture of B.

The electromagnetic yoke used in the experiments described here is represented in figure 3. The three exciting coils are wound upon brass spools and these are mounted upon pieces

FIG. 5.
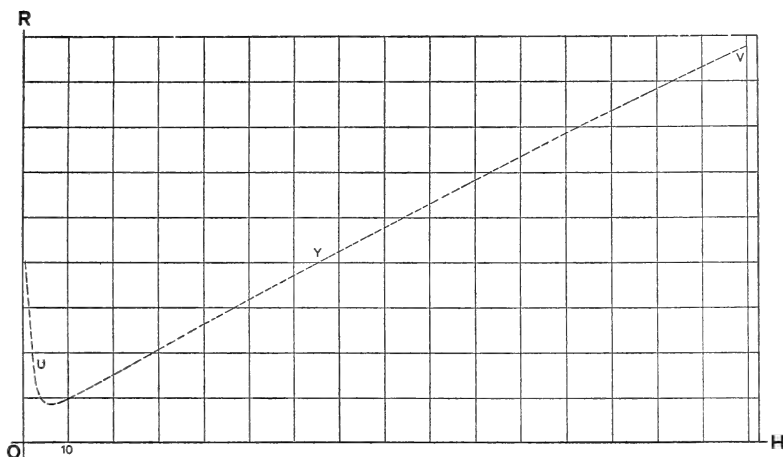
FIG. 5. Curve showing the reluctivity of the soft Bessemer steel rod for values of *H* between 3 and 160.

of soft steel shafting carefully turned to fit the holes in the heavy castings which complete the frame. The coils have together 2956 turns and the wire of which they are made is large enough to carry a current of 50 amperes for a few minutes at a time without undue heating. The whole yoke weighs about 300 kilograms. The apparatus is supplied with jaws of a number of different forms, but for the results recorded below conical jaws of the form shown in figure 4 with taper holes to receive the tapered ends of the specimen to be tested were used. All the joints were made by Mr. Thompson and seemed to be mechanically perfect. Before each piece was tested the jaws were driven together with the test-piece between, and then the whole was clamped.

For very low excitations the field about the test-piece did not seem to be quite uniform, but this difficulty disappeared when the exciting current became as strong as one ampere.

The intensities of the exciting currents were measured with the help of a set of five Weston amperemeters of different

ranges, all but one of which could be shunted at pleasure out of the circuit. The currents passed through a rack of three rheostats specially made for the purpose by the Simplex Electric Company : these had a range of about 8000 ohms.

The ballistic galvanometer was calibrated at short intervals by means of a coil (X) of 13·6 ohms resistance always in its circuit. This coil, X, consisted of 534 turns of fine insulated wire wound in a single layer upon a very accurately cylindrical wooden core which was hung within a uniformly wound vertical solenoid 176·2 centimeters long consisting of 5526 turns.

FIG. 6.
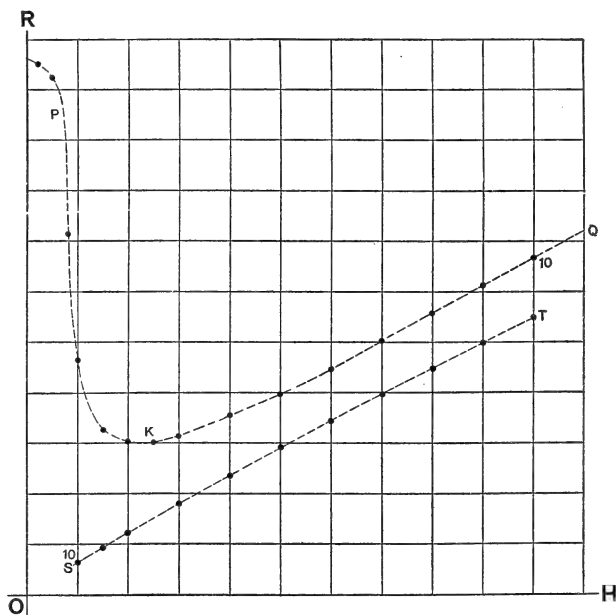
FIG. 6. The ordinates of the upper curve show the values of the reluctivity of the annealed Norway iron for values of H between 0 and 10. The ordinates of the lower curve represent, on a scale one-tenth as large, the reluctivities of this iron for excitations between $H = 10$ and $H = 100$.

The effective area of the turns of X was 22,720 square centimeters and a current of one ampere sent through the solenoid caused a flux of 895,400 maxwells through X.

The remarkable solenoid, nearly five meters long, in which the permeabilities were determined for values of H below 410, was constructed by Mr. Thompson and his assistants in a lathe the bed of which had been temporarily lengthened. The core was a thick-walled solid-drawn brass tube of about one

inch inside diameter made by the American Tube Works. The solenoid was mounted on a long oak truss which kept it from buckling.

Every specimen was tested in the solenoid several times over to make sure that the demagnetizing process was so effective that at low excitations, where differences are often apt to appear, the same results were obtained at every trial. Until the Norway iron had been specially annealed, it was impossible

Fig. 7.
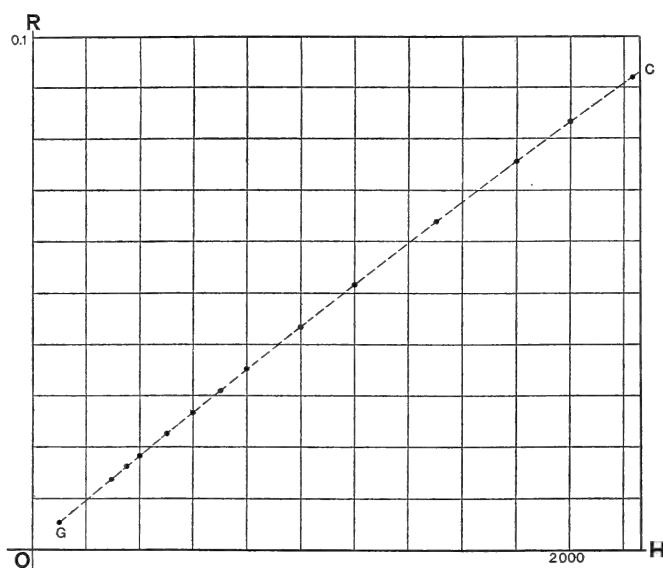
Fig. 7.   This curve shows the reluctivity of the annealed Norway iron for values of H between 100 and 2200.

so to demagnetize the rod that for low currents the induction should always be exactly the same. As Shuddemagen* has shown, the "end correction" for a round straight rod is a function of the absolute dimensions of the rod and not merely of the ratio of the length to the diameter, but the correction in the case of a half-inch rod of the length used in the work here described, is very small.

No other explanations seem necessary to make the following tables intelligible.

* Shuddemagen, Proc. Amer. Acad. Arts and Sciences, xliii, 1907; DuBois, The Magnetic Circuit, § 31.

TABLE I.—*Bessemer Half-Inch Rod in Long Solenoid.*

H	B	H	B
0	0		
0·5	115	10·5	10650
1·0	280	11·	10890
1·5	465	15·	12400
2·0	730	20·	13360
2·5	1180	30·	14480
3·0	1935	40·	15200
3·5	2800	50·	15720
4·0	3760	60·	16120
4·5	4830	70·	16460
5·0	5700	80·	16750
5·5	6410	90·	17000
6·0	7060	100·	17220
6·5	7650	120·	17640
7·0	8130	160·	18240
7·5	8600	200·	18800
8·0	9040	240·	19200
8·5	9420	270·	19620
9·0	9760	300·	19800
9·5	10070	350·	20240
10·0	10390	400·	20660

TABLE II.—*Half-Inch Bessemer Rod in Massive Yoke.*
(Free length about 80ᵐᵐ)

H	B	I
400	20660	1613
500	21250	1652
600	21660	1676
707	21900	1686
800	22020	1688
1000	22230	1689
1208	22470	1692
1500	22770	1692
2090	23550	1692
2590	23860	1693

Numerous observations were made for values of H lying between 350 and 1600 and these were used to draw a curve from which some of the numbers given above were taken. Above 1600, I had only two observations and the results of these for $H=2090$ and $H=2590$ appear at the end of the table. The observations for $H=707$ and $H=1208$ were the only ones in these neighborhoods and are given as they stand. The value of I for $H=2590$ happened to come out 1693, but a study of the observations shows that this number is really uncertain by about two units in the last place, for B is not determined in the fourth significant place.

An isthmus. cut from this rod gave for a long series of observations for values of H up to 16300, the same final value for I, within a fraction of 1 per cent, as the results tabulated above.

In view of the importance of Fröhlich's Law for magnetic metals at commercial excitations, figure 5, which shows the

FIG. 8.
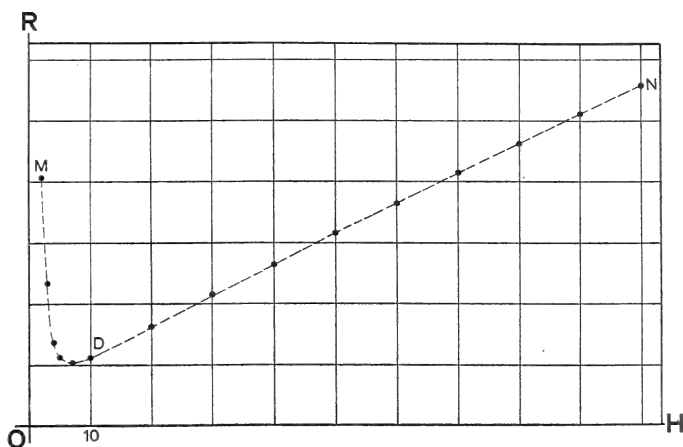
FIG. 8.   This curve shows the reluctivity of the compressed steel between $H = 3$ and $H = 100$.

reluctivity of this specimen of soft Bessemer steel for values of H up to 160, is of some interest.

TABLE III.—*Half-Inch Rod of Norway Iron in Long Solenoid.*

H	B	H	B
0	0		
1·0	1960	24·	16180
2·0	6950	28·	16320
3·0	9780	30·	16400
4·0	11380	40·	16650
5·0	12400	50·	16920
6·0	13080	60·	17180
7·0	13640	70·	17400
8·0	14140	80·	17600
10·	14800	100·	17940
12·	15200	120·	18220
14·	15460	160·	18800
16·	15620	200·	19100
18·	15780	240·	19840
20·	15960	280·	20200

At low excitations, the determinations of B for this rod were a little uncertain because of the difficulty of demagnetiz-

ing the specimen completely.   Investigation showed that
there were very slight differences of temper at different parts
of the rod, and it seemed best to have the iron thoroughly
annealed.   This process increased the permeability for almost
all excitations, very materially, as a comparison of Tables III
and IV will show.

TABLE IV.—*Annealed Half-Inch Norway Iron Rod in Long Solenoid.*

H	B	H	B
0	0		
0·2	190	9·5	14800
0·5	395	10·	14940
0·8	1120	11·	15100
1·0	2160	12·	15360
1·5	4600	14·	15540
2·0	6600	16·	15700
2·5	8240	18·	15900
3·0	9480	20·	16040
3·5	10460	25·	16320
4·0	11280	30·	16520
4·5	11980	35·	16740
5·0	12560	40·	16920
5·5	13000	45·	17100
6·0	13400	50·	17220
6·5	13700	60·	17450
7·0	13900	70·	17630
7·5	14100	80·	17820
8·0	14300	90·	18020
8·5	14490	100·	18210
9·0	14660	105·	18300

TABLE V.—*Annealed Norway Iron Rod in Massive Yoke.*
(Free length about 80^{mm})

H	B	I
295	21120	1657
350	21550	1687
400	21850	1707
450	22100	1723
500	22220	1729
600	22480	1741
700	22630	1745
800	22770	1748
900	22880	1749
1000	23000	1750
1500	23500	1751
1800	23810	1751
2000	24010	1751
2350	24360	1751

Figures 6 and 7 show the reluctivity of this iron at different excitations.

Two other half-inch specimens of very pure Norway iron turned from two-inch bars obtained from different sources gave as maximum values of the magnetization vector (I) 1732 and 1738. These were in the condition in which they were bought and had not been specially annealed.

TABLE VI.—*Half-Inch Rod of Compressed Shafting in Lon Solenoid.*

H	B	H	B
0	0	13·	10400
0·5	70	14·	10690
1·0	155	15·	10970
1·5	290	20·	12300
2·0	490	25·	13260
2·5	800	30·	13950
3·0	1280	40·	15150
3·5	2010	50·	15850
4·0	2880	60·	16480
4·5	3210	70·	16950
5·0	4450	80·	17320
5·5	5120	90·	17640
6·0	5730	100	17900
6·5	6270	120	18200
7·0	6780	140	18560
7·5	7200	160	18800
8·0	7610	180	19080
8·5	8020	200	19320
9·0	8380	240	19700
9·5	8690	280	20000
10·	9010	320	20360
11·	9540	360	20600
12·	10100	400	20820

TABLE VII.—*Short Piece of Half-Inch Compressed Shafting Magnetized in Massive Yoke.*

(Free length about 80ᵐᵐ)

H	B	I
300	20220	1585
370	20630	1612
400	20820	1625
500	21200	1647
600	21500	1663
700	21670	1669
800	21810	1672
1000	22080	1678
1200	22340	1682
1600	22800	1687
1854	23080	1690

Figure 8 shows the reluctivity of this steel for excitations below $H = 100$.

Table VIII gives the results of an interesting study made by Mr. Coulson of the magnetic properties of a piece of Kidd's polished tool steel, for excitations between $H = 250$ and $H = 2500$.

TABLE VIII.

H	B	μ	R	I
300	17470	58·2	0·017	1364
350	17750	50·7	0·020	1385
400	17980	44·9	0·022	1399
500	18370	36·7	0·027	1422
600	18710	31·2	0·032	1441
800	19240	24·0	0·042	1468
1000	19680	19·7	0·051	1487
1200	20050	16·7	0·060	1500
1400	20440	14·6	0·068	1515
1600	20790	13·0	0·077	1527
2000	21400	10·1	0·094	1544
2500	22010	8·8	0·114	1549

The line obtained by plotting the reluctivity (R) against H has only a very gentle curvature between these limits for this annealed tool steel.

I wish to express my obligations to the Trustees of the Bache Fund of the National Academy of Sciences for the loan of some of the apparatus used in making the measurements recorded in this paper.

The Jefferson Physical Laboratory,
    Harvard University, Cambridge, Mass.

ART. XXI.—*Ice Movement and Erosion along the South-western Adirondacks ;** by WILLIAM J. MILLER.

Introduction.

WHILE engaged in field work along the southwestern border of the Adirondacks during the past three summers, the writer has had occasion to study some of the glacial features so well

FIG. 1.
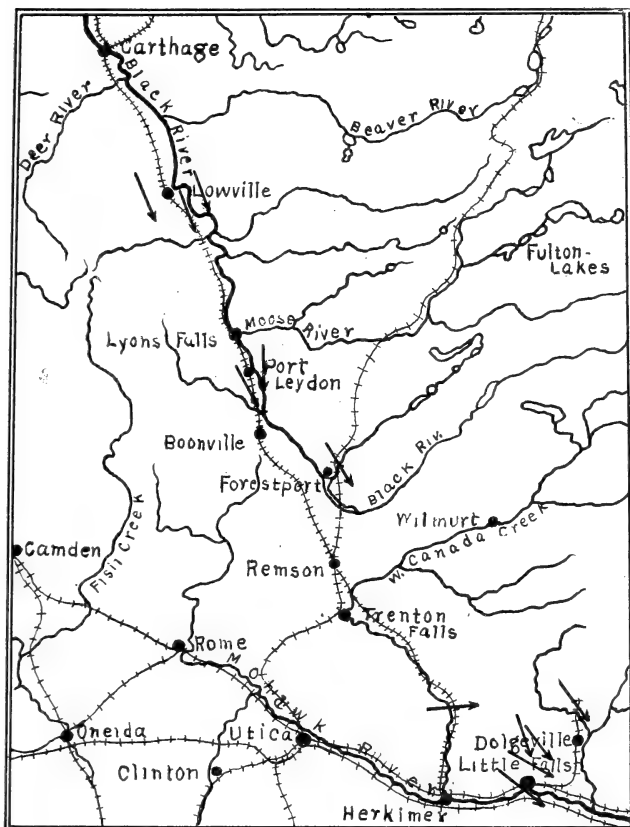
FIG. 1. Sketch map of the southwestern border of the Adirondacks. Arrows indicate direction of ice movement.

shown in that region. The area here described extends from Lowville, Lewis Co., southwestwardly past Boonville, Oneida Co., to Dolgeville, Herkimer Co., a distance of about 60 miles.

The width varies greatly but averages about 15 miles. The following topographic maps of the U. S. Geological Survey cover most of the region : Port Leyden (and northward and eastward), Remsen, Little Falls, together with portions of the Wilmurt, Boonville, and Utica quadrangles. (See sketch map.)

The chief topographic feature of the northern portion of the area is the Black river valley through which Black river flows in a northwesterly direction. This valley is from 10 to 15 miles wide and shows a maximum depth of about 1300 feet. West Canada creek, the principal tributary of the upper Mohawk river, traverses the southern part of the area. This southern part is very hilly and shows a general slope towards the Mohawk river. The watershed separating Black river and West Canada creek represents one of the principal divisions of drainage in this part of the state. Leaving the Mohawk river at Utica (elevation 400 ft.), and passing northward along the R. W. & O. R. R., there is a gradual ascent to the divide (elevation 1280 ft.) south of Alder creek. From this point northward there is a gradual descent along the railroad to near Lowville, where Black river shows an elevation of 740 ft. The common range of altitudes along both the eastern and western sides of the district is between 1200 ft. and 2000 ft.

The Paleozoic-Precambrian boundary line passes lengthwise through the region. The Precambrian rocks comprise chiefly the highly metamorphosed Grenville sediments, the post-Grenville syenite-gneiss, and large areas which are more or less intimate mixtures of the Grenville and syenite. The Paleozoics overlap on the Precambrians and exhibit an excellent section showing the Pamelia sandy limestones, Lowville limestones, Black river shales and limestones, Trenton limestones, Utica shales, Lorraine shales and sandstones and the Oswego sandstone. The type localities of the Lowville, Black river and Trenton are found here.

The full significance of the glaciology of this territory will not be known until the contiguous areas have been carefully studied. The discussion here presented is local in its character, the purpose being to record observations and to offer some conclusions which may aid in the solution of the broader problem. So far as the writer is aware, nothing has been published regarding the northern portion of the district, while Chamberlin,* Brigham,† and Cushing‡ have each referred to the southern portion. Brigham is now engaged in the study of the Mohawk valley region.§

* Third Annual Rep. U. S. G. S., 1881–2, pp. 360–365.
† Bull. Geol. Soc. Am., vol. ix, pp. 183–202, 1898.
‡ N. Y. State Museum, Bull. 77, pp. 73–81, 1905.
§ Since the above was written several papers bearing on the glacial history of Central and Northern New York have been read by H. L. Fairchild before the 1908 meeting of the Geological Society of America.

DIRECTION OF ICE MOVEMENT.

Chamberlin, in the report above referred to, makes the tentative statement "that massive ice currents having their ulterior channels in the Champlain valley, on the one hand, and the Saint Lawrence on the other, swept around the Adirondacks and entered the Mohawk valley at either extremity, while a feebler current, at the height of glaciation, probably passed over the Adirondacks and gave to the whole a southerly trend." Observations by later investigators have tended to bear out this view, and the evidences from the southwestern Adirondacks herewith presented have an important bearing upon the proposition.

The direction of flow is best shown by the glacial striæ which have been observed at a number of different places through the district. The striæ are best preserved upon the hard Precambrian rocks, but these are mostly drift-covered except along the chief stream courses. The limestones are next most favorable, while upon the shales none have been found. Striations are present only upon those surfaces from which the drift has been recently removed, because even the hardest rocks exposed during postglacial times have been weathered enough to cause an obliteration of the glacial marks.

Striæ pointing from south 25° to 40° east have been located as follows : On Trenton limestone one mile south of Martinsburg and also one-third of a mile east of Martinsburg (S. 25° E.) ; on Precambrian near the mouth of Roaring brook ; on Precambrian one and one-half miles northeast-north of Glenfield, and also one-third of a mile southwest and three-fourths of a mile southeast-south of the same village ; on Precambrian one mile northeast of Denley station, one-third of a mile northeast of Hawkinsville, on Big Woodhull creek two miles northeast of Forestport, and one mile north of Salisbury centre (Cushing). Other striæ, bearing nearly south, occur on Precambrian one mile east of Port Leyden and still others bearing N. 80° E. on the Trenton limestone two and a half miles north of Middleville (Cushing). Beside these the observations of Chamberlin, in the Mohawk Valley near Little Falls, are quoted : " On the western slope of the ridge that stands athwart the valley of the Mohawk at Little Falls are two sets of striæ. The course of the main series is S. 50° E. and of the minor cross-set S. 45° W. North of Little Falls, two-thirds of the way up the slope of the valley the course of the striæ is S. 60° E., the movement being apparently from the west. A little farther up the slope, on an eastward inclined rock surface, the main set runs S. 50°–55° E. crossed by feebler and later ones S. 70° W. Four miles north of Little Falls, a varying group runs S. 18°–28° E. and about six miles north S. 37° E."

The striæ described above and plotted on the map (fig. 1) indicate that in the northern part of the region here discussed the southeasterly movement changed to the more nearly easterly movement farther south, and this is just what would be expected according to the statement of Chamberlin. It should be noted that the Black river and upper Mohawk valleys, which are the chief topographic features of the district, had much to do with determining the direction of the flow of the ice. Both of these valleys existed in preglacial times and the close parallelism between the directions of the striæ and the directions of the valleys shows the influence of the latter in determining the ice movement.

There is other evidence, derived from the distribution of the drift, to show the general southeasterly ice movement in the region. Thus, within the Remsen quadrangle north of Hinckley, fragments of Utica shale and Lorraine sandstone may be found at least five or six miles east of the nearest parent ledges. This strongly suggests a southeasterly current of ice. Also the presence of marginal morainic materials and delta deposits extending many miles along the southwestern Adirondacks show that a border ice mass existed there during the time of melting. Along the northwestern border of the Adirondacks the ice undoubtedly moved southwestwardly. The writer has seen magnificent displays of glacial grooves and striæ bearing southwestwardly, especially near Clayton. Along the eastern border of the Adirondacks, the general southerly movement of the ice has been well established, as has also the westerly movement up the Mohawk valley towards Little Falls. Thus the statement of Chamberlin, regarding ice flow around the Adirondacks, harmonizes almost perfectly with observed striæ.

But the question still arises, what was the direction of the current during the height of glaciation ? We have abundant evidence to prove that this main current was a southwesterly one. The Long Lake quadrangle is located in the midst of the Adirondacks and upon the geological map of that area Prof. Cushing[*] has recorded a number of striæ, all of which point toward the southwest. Over the region south of the Adirondacks and the Mohawk valley the numerous observations of both Brigham[†] and Chamberlin[‡] show that the ice moved in a general southwesterly direction. Along the southwestern Adirondacks the writer has seen a number of good examples of rochés moutonnées, all of which bear southwestwardly. Among these one forms a narrow ridge about two miles long which crosses Moose river above Fowlersville (Port

* N. Y. State Museum, Bull. 115, p. 495, 1906.
† This Journal, vol. xlix, p. 216, 1895.   ‡ Op. cit., p. 365.

Leyden sheet), while other good ones occur at an elevation of 1700 feet, two miles northwest of Reed's Mill (Remsen sheet). Another strong evidence favoring the southwesterly current is the distribution of glacial bowlders over the region southwest of the Adirondacks. Most of the common Adirondack rock types are strewn over the region and they gradually diminish in number as the distance from the mountains becomes greater. This subject has been discussed in a paper by Brigham.*

Thus, bearing in mind all the facts, the writer is strongly of the opinion that when the ice in its movement (during the last invasion) struck the Adirondacks, it was divided into two currents flowing around the mountains and meeting in the Mohawk valley; that during the time of maximum glaciation there was a strong general current, but that the border currents continued as under currents (more or less checked in velocity); and that, after the disappearance of the ice sheet from the central Adirondacks, border currents were maintained.

Ice Erosion.

It seems to be generally agreed upon by those who are familiar with the region that the topography of northern New York was not profoundly affected by ice erosion. Certainly no valleys of any consequence have been formed by ice action. Prof. Fairchild gave the testimony of Cushing, Smyth, and Gilbert to this effect in a paper read before the Geological Society in 1905.† The writer is in agreement with this general view, but he could not consent to the idea that the ice did practically no work of erosion in northern New York.

1. Erosion of the Precambrian Rocks.

As the ice moved across the region discussed in this paper, the preglacial rock surface was more or less scratched, polished, and eroded. In the case of the Precambrian rocks, it is doubtful if the ice did any very deep cutting. The work of erosion involved mostly the removal of joint blocks of the decayed and weathered rock materials near the surface. The evidence is conclusive that the weathered materials were rather thoroughly scraped off the Precambrians, as shown by the remarkable freshness of the rocks wherever exposed and by the smoothed and rounded character of the outcrops. Wherever the streams have cut through the mantle of drift and into the underlying Precambrians the surfaces of the latter are very hard and fresh. The highly jointed character of these rocks no doubt greatly aided the ice in its work of erosion. In this connection men-

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* This Journal, vol. xlix, pp. 213–228, 1895.
† Bull. Geol. Soc. Amer., vol. xvi, pp. 50–5, 1905.

tion should be made of the great number of large, more or less jointed, to somewhat rounded and fresh erratics of Precambrian rock material strewn over much of the region, especially the central portion of the Remsen quadrangle. It is very common to find erratics ranging from five to twenty feet in diameter, one at least measuring seventeen feet high and twenty-seven feet across. The larger ones are mostly of the hard, homogeneous syenite or granite. Probably the greatest amount of ice erosion of the Precambrians occurred along Black river between Lyons Falls and Lowville; but this matter will be referred to below.

2. Erosion of the Sedimentaries.

Turning our attention to the sedimentary rocks, we find that ice erosion was much more effective upon them. In fact, the writer believes that in the Black river valley we have one of the best examples of ice erosion in northern New York. One factor favoring the ice work here was the comparative softness and the highly jointed character of the rocks, while another factor was their position with reference to the ice current (see below). The writer has found no sign of considerable ice erosion in the southern part of the region here described.

Fig. 2.
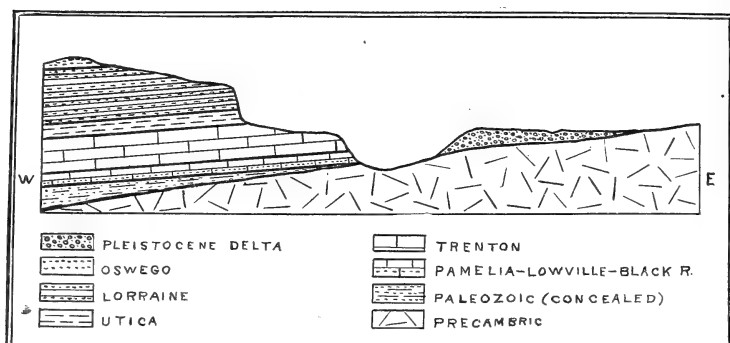
FIG. 2.   Section across the Port Leyden quadrangle two and one-half miles north of Lyons Falls.   Vertical scale 8·8 times the horizontal scale.

The accompanying figure shows the profile and the geologic structure across the Black river valley two and one-half miles north of Lyons Falls. One of the striking features is the terraced character of the sedimentaries, particularly from Port Leyden northward. (See topographic map.) Along the river course there is a slight notch in the Precambrians and just west of this, on the northern part of the Port Leyden sheet, there is

a steep slope rising three hundred feet above the Precambrians. The formations outcropping on this slope are shown in the section. Resting upon the Precambrians are several feet of weak sandstones which are followed by the sandy limestones of the Pamelia; then come the hard Lowville and Black river limestones, followed by weak lower Trenton shales and limestones; while the summit is capped by the hard, crystalline Trenton limestones. The streams passing over this slope are characterized by gorges with waterfalls and rapids. From the summit of this slope and extending for several miles westward is a well defined terrace developed upon the limestone.

Rising from the western side of the above-named terrace there is a second slope higher and much steeper than the first. The rise is commonly about 450 feet within a third of a mile. The soft Utica shales outcrop at the base of this slope and they are followed by the Lorraine shales with an upward increasing sandstone content. The summit of this terrace, known as Tug Hill, is more irregular and stream-dissected than the limestone terrace below. All streams flowing across the steep slope of this terrace have high gradients and have cut deep narrow gorges locally called "gulfs." A third terrace, much less well-defined, is formed by the Oswego sandstone capping. The much higher gradients of the eastward flowing streams from Tug Hill and the much steeper slope and greater height of the eastern front of Tug Hill, as compared to other parts of the district, all argue for a recent and considerable cutting back (westward) of the Paleozoics here.

At first these terraces, in their present form, were thought to have been due entirely to water action, but an examination of the region shows that some other explanation must be sought. The steep fronts of the terraces are certainly young topographic features, which precludes the possibility of their having been formed during the long preglacial period of erosion in this ancient region. On the other hand, Black river has done very little work of erosion, between Lyon Falls and Lowville, in postglacial times, as proved by the fact that the stream has not yet cut its way through the alluvium and reworked drift filling the valley bottom, and also because glacial striæ and kames near the river level have not been disturbed. Thus also the slight trench cut into the Precambrians along here could not have been postglacial in origin.

There is still the possibility that glacial waters might have developed the terraces, but the writer has looked in vain for evidence of any such vigorous water action, especially along the higher part of the limestone terrace where records would surely be left. Even if a large stream had flowed along the ice edge and under the steep front of Tug Hill, its gradient

would have been too low to be compatible with much cutting power. No doubt there was some movement of water along the edge of the waning Black river ice lobe, but the only current of any importance was a northerly one between the eastern edge of the limestone terrace and the ice margin. The limestones here are somewhat waterworn, but this stream was about 200 feet below the top of the terrace and thus clearly could not have done the work of erosion over the whole terrace. Also the presence of the glacial striæ high up on the terrace shows that no great amount of water erosion could have taken place there since the ice retreat.

The Black river valley certainly existed, in its broader outline, in preglacial times. The Paleozoic-Precambrian boundary line had for a long time been gradually moving westward by wearing away of the Paleozoics. It seems certain that the lowermost Paleozoic layers must have extended farther eastward, by overlap on the Precambrians, immediately preceding the glacial period. This means that Black river was some distance farther eastward and that the western tributaries, from Tug Hill, entered it with lower gradients. As above shown, the lowest sedimentary layers could not have been cut-back in pre- or post-glacial times nor were they cut back by glacial waters. Evidently they were cut back by the ice to develop the steep slope now shown. This allowed Black river to shift westward to its present position. Thus the slight trench of the Precambrians here shown could not have been preglacial. As already stated, it is clearly not post-glacial and apparently it was formed by ice cutting. The concave character of this inner portion of the valley is well shown in the figure and strongly suggests ice work.

Also we should consider the fact that we are here dealing with unaltered sedimentaries with slightly upturned edges resting upon a rather smooth surface of igneous and metamorphic rocks, and that the lowest sediments are weak sandstones and sandy limestones, which greatly favored the stripping off power of the ice. Robert Bell[*] has noted the same thing in Canada, and he says: " When unaltered strata lie at low angles upon a nucleus of crystalline rocks, there is a marked difference in the effects produced by the action of the passing ice-sheet according as the latter moved from the overlapping strata onto the solid nucleus or off the latter against the upturned edges of the stratified rocks, . . . in the latter (case), great erosion has always taken place and valleys and basins are formed whose width depends upon the angle of dip and the softness of the strata which have been scooped out. The strata

[*] Bull. Geol. Soc. Amer., vol. i, p. 296, 1890.

are presented in the most favorable attitude for abrasion.   The wearing down would go on until the resisting rock front had attained a height and weight sufficient to counterbalance those of the glacier." In the Black river valley the ice moved from the crystallines against the slightly upturned edges of the sediments.

In much the same way the soft shales were stripped off the surface of the hard limestones to form the broad terrace and the steep front of Tug Hill. Such a stripping off of the shales occurred, but to a less extent, over the southern part of the Port Leyden quadrangle (except at Locust Grove); over the northwestern part of the Boonville quadrangle; and over the western part of the Remsen quadrangle. This power of erosion diminished southward. The maximum thickness of shale thus removed was probably several hundred feet, but not over a wide area. The total amount of shale removed was not nearly as much as may at first sight be supposed. Then, too, the shales were soft and highly jointed, even to a considerable depth, as may now be seen in the Whetstone gulf section.

It may be fairly asked, what became of the materials thus removed? The very resistant Precambrians ought to be present in considerable force as erratics somewhere in the region and this is the case especially in the townships of Boonville and Remsen, where a vast number of such erratics may be seen strewn over the country. Shale and limestone is also present in great abundance in the till and other drift of the Remsen quadrangle. However, much of the shale must have been ground up and carried away by glacial waters.

Two other factors which greatly aided the work of the ice in the Tug Hill region must not be overlooked. One of these is the fact that the ice moved up hill as it advanced southward along the valley and so had its cutting power increased. On reaching the divide between Black river and West Canada creek the cutting power was lessened and till and other drift materials were deposited in great quantities as the ice moved down hill toward the Mohawk river. Another factor which the writer regards as important in this connection is the angle at which the ice current entered the Black river valley in its sweep around the Adirondacks. The greatest amount of erosion was along the eastern side of Tug Hill, and it was just here where the ice current must have struck with greatest force as it was crowded into the valley. In harmony with this idea is the fact that the glacial striæ near Martinsburg bear more towards the south than does the steep front of Tug Hill.

It appears to the writer that, even under these favorable circumstances, the ice did not show itself to be such a great

erosive agent as claimed by some geologists. The conclusion seems to be that the only considerable ice erosion was along the eastern side of Tug Hill and the valley eastward, where the ice caused channel-straightening accompanied by some deepening. The very soft shales were considerably cut away; the harder limestones were less affected; while the very hard Precambrians yielded least. Gilbert[*] in speaking of ice erosion in western New York, near Lockport, says: " The district exhibits a marked contrast between the extent of erosion from a broad mass of limestone on the one hand and a broad mass of shale on the other, the ratio being, roughly, as 1 to 10 or 1 to 20 ." Thus in the Black river valley we also have a good example of differential ice erosion.

Hamilton College, Clinton, New York.
January, 1909.

[*] Bull. Geol. Soc. Amer., vol. x, p. 130, 1899.

Art. XXII.—*The Estimation of Vanadic and Arsenic Acids and of Vanadic and Antimonic Acids, in the Presence of One Another ;* by Graham Edgar.

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

Arsenic and Vanadium.

The almost constant association of arsenic and vanadium in the mineral sources of both elements presents the frequent problem of their separation and estimation and has led to the development of numerous analytical processes to accomplish the desired end. Carnot[*] precipitates all arsenic acid by boiling with a salt of strontium in weakly ammoniacal solution in the presence of ammonium salts. Gibbs[†] precipitates the arsenic as trisulphide from a solution previously reduced with sulphur dioxide, the vanadium being determined in the filtrate by titration with potassium permanganate. Schmitz-Dumont[‡] uses hydrogen sulphide under pressure to effect the separation. Friedheim and Michaelis,[§] after reducing with sulphur dioxide the solution containing arsenic and vanadic acids, separate the former by repeated distillation with methyl alcohol and hydrochloric acid. Field and Smith[‖] volatilize the arsenic by heating the dry sulphides of arsenic and vanadium in a current of hydrochloric acid gas at a temperature between 100° and 250° Centigrade. Friedheim, Decker and Diem[¶] recommend the volatilization of the arsenic by distillation with potassium iodide and hydrochoric acid, a current of hydrogen being kept up through the apparatus during the process.

In the present investigation any separation of arsenic and vanadium is avoided by the use of a process of differential reduction to determine these elements in the presence of one another.

If a solution containing arsenic and vanadic acids is boiled with tartaric or oxalic acids, the vanadic acid is reduced to tetroxide and may be reoxidized in alkaline solution by iodine[**] according to the equation

$$V_2O_4 + I_2 + H_2O = V_2O_5 + 2HI$$
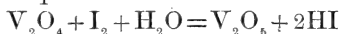
If a solution containing arsenic and vanadic acids is reduced with sulphur dioxide under proper conditions, the arsenic acid

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[*] Compt. Rend., civ, 1803. [†] Chem. Jour., vii, 230.
[‡] Inaug. Diss., Berlin, 1891.
[§] Berichte der Deutsch. Chem. Gesellsch., xxviii, 1414.
[‖] Journ. Amer. Chem. Soc., xviii, 1051.
[¶] Zeitschr. Anal. Chem., xliv, 648.
[**] Browning: Zeitschr. anorg. Chem., vii, 158 ; Browning and Goodman, this Journal, ii, 355.

is reduced to arsenious acid and the vanadic acid to tetroxide, so that after boiling off the excess of reagent the reoxidation by iodine in alkaline solution should proceed according to the equation

$$As_2O_3 + V_2O_4 + 3I_2 + 3H_2O = As_2O_5 + V_2O_5 + 6HI$$

and the iodine thus used should correspond to the sum of the two oxides. If then aliquot parts of the same solution are treated in the manner described above, it is evident that the titration of the solution reduced by tartaric acid should determine the vanadium present and that the titration of the solution reduced by sulphur dioxide should determine the sum of the arsenic and vanadium, the difference in the number of cubic centimeters of iodine used in the two cases being the amount required to oxidize the arsenic.

In Table (I) are given the results of experiments performed upon solutions containing arsenic and vanadic acids in varying proportions. The method of treatment in detail was as follows : The solutions were divided into two portions and one of these was boiled with one to two grams of tartaric or oxalic acid until the blue color of the vanadium tetroxide indicated complete reduction. The solution was then cooled, nearly neutralized with potassium bicarbonate and an excess of standard iodine solution was added. Neutralization was then completed, an excess of bicarbonate added, and the solution allowed to stand for from fifteen minutes to one half hour. The excess of iodine was then removed with standard arsenious acid and the solution titrated to color after the addition of starch. The results of this titration are given under (I), Table (I).

The second portion of the solution was placed in a small pressure flask and slightly acidified with sulphuric acid. Twenty-five cubic centimeters of a strong solution of sulphurous acid was then added and the flask was closed and heated for one hour on the steam bath.* After cooling, the flask was opened and the solution transferred to an Erlenmeyer flask and boiled to remove the excess of sulphur dioxide, a current of carbon dioxide being passed into the liquid to facilitate the removal of the last traces. The solution was then cooled, nearly neutralized with potassium bicarbonate and an excess of iodine added as before. After completing the neutralization, adding an excess of bicarbonate and allowing to stand for one half hour, the excess of iodine was determined by arsenious acid as before. The results are given in (II), Table (I).

As before stated, the results in (I) determine the vanadium, and these figures, subtracted from (II), determine the arsenic.

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* McCay : Amer. Chem. Jour., vii, 273.

TABLE (I).

Taken V_2O_5 grm.	Found V_2O_5 grm.	Error V_2O_5 grm.	Taken As_2O_5 grm.	Found As_2O_5 grm.	Error As_2O_5 grm.	(I) N/10 Iodine cm³.	(II) N/10 Iodine cm³.
0·1183	0·1181	−0·0002	0·0960	0·0961	+0·0001	12·95	29·65
0·1183	0·1183	±0·0000	0·0960	0·0962	+0·0002	12·97	29·70
0·1183	0·1182	−0·0001	0·0960	0·0962	+0·0002	12·96	29·70
0·0591	0·0593	+0·0002	0·0480	0·0480	±0·0000	6·50	14·85
0·0591	0·0594	+0·0003	0·0480	0·0482	+0·0002	6·52	14·90
0·0591	0·0589	−0·0002	0·0480	0·0483	+0·0003	6·45	14·86
0·1774	0·1779	+0·0005	0·1440	0·1438	−0·0002	19·50	44·50
0·1774	0·1774	±0·0000	0·1440	0·1440	±0·0000	19·45	44·50
0·1774	0·1776	+0·0002	0·1440	0·1442	+0·0002	19·47	44·45
0·2366	0·2371	+0·0005	0·0480	0·0478	−0·0002	26·00	34·31
0·2366	0·2366	±0·0000	0·0480	0·0480	±0·0000	25·95	34·30
0·0591	0·0593	+0·0002	0·1440	0·1439	−0·0001	6·50	38·90

Antimony and Vanadium.

Since antimonic acid is reduced by sulphur dioxide on heating in a pressure flask* there seemed no reason to suppose that antimony and vanadium should not be determined in the presence of each other by a process similar to the one used for arsenic and vanadium. Accordingly a series of experiments was made in which solutions containing vanadic acid and antimonic acid were treated in a manner exactly similar in detail to the preceding. The results are given in Table (II).

TABLE (II).

Taken V_2O_5 grm.	Found V_2O_5 grm.	Error V_2O_5 grm.	Taken Sb_2O_5 grm.	Found Sb_2O_5 grm.	Error Sb_2O_5 grm.	(I) N/10 × 0·9375 Iodine cm³.	(II) N/10 × 0·9375 Iodine cm³.
0·1183	0·1185	+0·0002	0·0757	0·0759	+0·0002	13·85	23·69
0·1183	0·1186	+0·0003	0·0757	0·0764	+0·0007	13·87	24·05
0·1183	0·1183	±0·0000	0·0757	0·0760	+0·0003	13·83	23·95
0·1774	0·1777	+0·0003	0·1261	0·1258	−0·0003	20·80	37·55
0·1774	0·1777	+0·0003	0·1261	0·1258	−0·0003	20·80	37·55
0·1774	0·1773	−0·0001	0·1261	0·1260	−0·0001	20·75	37·50
0·2366	0·2376	+0·0010	0·1261	0·1257	−0·0004	27·80	44·52
0·2366	0·2369	+0·0003	0·1261	0·1263	−0·0002	27·70	44·50
0·2366	0·2369	+0·0003	0·1261	0·1260	−0·0001	27·70	44·45

Summary.

In the preceding paper it has been shown that vanadic and arsenic acids, or vanadic and antimonic acids, may be readily determined in the presence of one another by a method based upon the differential reducing action of tartaric or oxalic acid and sulphur dioxide, the reoxidation being in each case effected with iodine in alkaline solution under the conditions described above.

* Von Knorre : Zeitschr. angewandte Chem. 1888, 155.

Art. XXIII.—*A Method for the Iodometric Estimation of Silver Based upon the Use of Potassium Chromate as a Precipitant;* by F. A. GOOCH and ROWLAND S. BOSWORTH.

IT has been shown in a previous paper that with proper precautions silver may be precipitated and accurately estimated as silver chromate. It was found that the addition of a sufficient excess of potassium chromate to a solution of silver nitrate, even in the presence of small amounts of nitric acid, brings about a complete precipitation of the silver as silver chromate, and that the precipitate thus obtained may be transferred to the asbestos filter by means of a dilute solution of potassium chromate and washed with small amounts of water without appreciable loss of silver chromate. Upon the basis of such exact precipitation of silver chromate by potassium chromate it should be possible to establish a method for the iodometric estimation of silver either by the estimation of the chromic acid ion of the precipitated and washed silver chromate or by the determination of the chromic acid ion of the potassium chromate which remains after the precipitation of the silver salt by a known amount of standard potassium chromate.

In studying the latter procedure a known amount of standard potassium chromate in excess of the amount needed to precipitate the silver was added to the solution of silver nitrate. The precipitate was dissolved in ammonia and reprecipitation brought about by boiling to a volume of $10–15^{cm^3}$. The second, crystalline precipitate was filtered upon asbestos and washed with the least possible amount of water applied in small

TABLE I.

Silver taken. Volume of solution cm³.	Weight grm.	K_2CrO_4 used grm.	$Na_2S_2O_3$ used cm³.	Silver found grm.	Error in terms of silver grm.
20	0·1261	0·3039	26·54	0·1262	+ 0·0001
25	0·1576	0·3039	22·61	0·1575	— 0·0001
15	0·0946	0·3293	30·51	0·0946	0·0000
15	0·0946	0·3293	30·60	0·0940	— 0·0006
15	0·0946	0·3293	30·57	0·0941	— 0·0005
15	0·0946	0·3293	30·55	0·0945	— 0·0003
19·98	0·1260	0·3293	32·20	0·1255	— 0·0005
20	0·1261	0·3293	32·09	0·1263	+ 0·0002
20	0·1261	0·3293	32·10	0·1263	+ 0·0002
25	0·1576	0·3293	27·30	0·1576	0·0000

portions successively. The filtrate was treated with potassium iodide and acidified with sulphuric acid. The iodine set free was titrated with sodium thiosulphate. The difference between the silver value of the iodine thus found and that of the potassium dichromate used was taken as the measure of the silver present. In Table I are given the details of experiments performed in accordance with this procedure.

In Table II are given the details of similar experiments in which the precipitation was effected in the presence of sodium nitrate.

TABLE II.

Silver taken. Volume of solution cm³.	Weight grm.	K₂CrO₄		NaNO₃ present grm.	Na₂S₂O₃ used cm³.	Silver found grm.	Error in terms of silver grm.
		Volume cm³.	Weight grm.				
10	0·1101*	37	0·2436*	1	20·47*	0·1107	−0·0006
10	0·1101	37	0·2436	1	20·53	0·1103	+0·0002
10	0·1101	25	0·1647	1	9·07	0·1097	−0·0004
10	0·1101	27	0·1778	1	11·02	0·1096	−0·0005
15	0·0862†	+30	0·1974*	2	17·14*	0·0859	−0·0003
15	0·0862	30	0·1974	1	17·05	0·0865	+0·0003
15	0·0862	30	0·1974	1	17·14	0·0859	−0·0003
25	0·1437	50	0·3294	10	28·53	0·1435	−0·0002

* Approximately N/10.   † Approximately N/20.

Since, as has been shown in the paper previously referred to, relatively large amounts of potassium chromate are necessary to bring about complete precipitation of the silver chromate in the presence of nitric acid, the above procedure seemed less adapted to the determination of silver in a solution containing that acid than the method whereby the precipitated and washed silver chromate is determined. The following is an account of the results obtained in the study of this latter procedure. To the silver solution containing free nitric acid, potassium chromate was added in excess of the amount necessary to take up the nitric acid with formation of potassium dichromate. The precipitate was dissolved in ammonia and reprecipitation effected by boiling to a volume of 10–15$^{cm^3}$. The second, crystalline precipitate was transferred to an asbestos filter by means of a dilute solution of potassium chromate, washed with the least possible amount of water applied in small portions successively, and dissolved in a few cm³ of a strong solution of potassium iodide. The solution in potassium iodide was diluted and acidified with sulphuric acid. The iodine set free was titrated with sodium thiosulphate and taken as the measure of

the silver present.   In Table III are given the details of exper-
iments made in this manner.

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

Silver taken. Volume of solution cm³.	Weight grm.	HNO₃ present grm.	K₂CrO₄ weight grm.	Na₂S₂O₃ used cm³.	Silver found grm.	Error in terms of silver grm.
25	0·1348	0·063	0·60	18·35	0·1342	−0·0006
20	0·1078	0·063	0·65	14·67	0·1073	−0·0005
15	0·0808	0·063	0·65	11·06	0·0809	+0·0001
15	0·0808	0·063	0·65	10·96	0·0802	−0·0006
20	0·1078	0·063	0·65	14·67	0·1073	−0·0005
30	0·1618	0·063	0·75	22·02	0·1610	−0·0008
20	0·1078	0·063	0·65	14·71	0·1075	−0·0003
25	0·1348	0·063	0·65	18·41	0·1347	−0·0001
25	0·1348	0·063	0·65	18·41	0·1347	−0·0001
20	0·1078	0·063	0·65	14·74	0·1078	0·0000

The results obtained justify the conclusion that silver can be
accurately estimated by precipitating as silver chromate with
the use of a sufficient excess of potassium chromate, dissolving
the precipitate formed in ammonia, reprecipitating by boiling
to low volume, and determining iodometrically either the chro-
mate ion in combination with the silver or the chromate ion
of the potassium chromate remaining after precipitation of
the silver with a known amount of standard potassium
chromate.

Art. XXIV.—*The Brown Artesian Waters of Costilla County, Colo., their Relations to Certain Deposits of Natron or Soda, and what they teach ;* by Wm. P. Headden.

The San Luis Valley, in the southern part of this state, presents several interesting questions, among them its drainage and its artesian wells. The fact that there is an artesian basin in this valley was discovered by accident in 1887. I have no official figures at my command in regard to the number of such wells in the valley, but I have heard it estimated at more than 3000. They are put down with such ease that it is difficult to obtain accurate records, either in regard to their number or the strata passed through by the borings. The strata consist of alternate layers of clay and sand which scarcely attains to the size of fine gravel. The depth at which flows are met with varies exceedingly. South and west of La Jara, water is struck at very shallow depths ; a four-inch, cased well on the place of Mr. Ormond is 77 feet deep, the water rises a few inches above the casing and is very cold, 44° F. Even shallower wells than this are recorded, which is no cause for surprise as it is very probable that some of the springs in the eastern and southern parts of the valley are due to the artesian pressure in the valley and not to surface waters finding an exit in the usual manner. The ground and surface waters of the valley are, so far as my knowledge goes, of bad quality, whereas these springs and the artesian wells yield excellent waters. Even wells of 1000 feet depth yield waters carrying less than 16 grains to the imperial gallon and 45 per cent of this mineral matter is silicic acid. The springs and wells agree in the amount of total solids carried in solution, ranging from 5·8 to 20·7 grains to the gallon, and are characterized by a high percentage of silicic acid, namely, from 26 to 46 per cent of the total solids.

The percentage of flowing wells obtained is very large ; failures are very rare, but an occasional one is met with. Mr. W. K. Hapney informs me that he put down a well, a few miles west of Alamosa, to the depth of 1004 feet, without obtaining a flow—at least the well was a failure. This is certainly remarkable, for at Alamosa they have two of the strongest flows in the valley. It is difficult to obtain full enough data to justify one in venturing a suggestion in explanation of such a failure. There are no reasons for supposing that the strata are not continuous throughout this section, nor have we any reason, except perhaps this failure itself, for assuming that a fold may exist at this place.

The supply of water is furnished by the streams descending from the surrounding mountains. The artesian basin has a length of about 75 miles and a width from 40 to 45 miles. The Rio Grande del Norte enters the valley at a point about the middle of its western side and then flows easterly and southerly out of the valley by way of its canyon. All of the streams which enter the valley north of the Rio Grande are wholly lost in the sands of the valley, their waters do not at any time join those of the Rio Grande by overground courses and it is a question whether they do so, at least within the limits of the valley, by underground circulation. So complete is the disappearance of the waters of these northern streams that it is only very rarely that the united waters of the Saguache river and the San Luis creek have been known to reach so far south as the San Luis lake, 14 miles north and 7 miles east of the town of Alamosa. The Rio Grande loses from 75 to 100 second feet of water on its entrance to the valley. The streams to the south also lose large quantities of water as they enter the valley or during their course through it. These sources are probably quite sufficient to supply all the artesian waters of this basin.

In the eastern part of the northern half of this basin we find a water wholly different from any of the springs or wells previously mentioned. The water heretofore described has been a colorless, tasteless water, carrying but small amounts of mineral matter in solution and the chief constituent of these mineral matters is silica. In this area, which begins about eight miles north of Alamosa, and extends almost to the town of Moffat, a distance of 25 to 30 miles from north to south and extending from 5 or 6 miles west of the town of Mosca almost to the San Luis lake on the east, a distance of about 14 miles east and west, the water has a decidedly "red" or brown color, generally smells of hydrogen sulphide, is often accompanied by marsh gas, has an alkaline reaction and is rich in sodium carbonate. The wells sunk in this area show these characteristics throughout. The flows struck at about 200 feet are slightly brown, taste of hydrogen sulphide, and contain about 22·0 grains of solid matter per imperial gallon, which is wholly sodium carbonate. The intensity of the color deepens with the depth of the wells till at about 500 feet it attains its maximum; from this point the color diminishes till at about 880 feet it has become somewhat fainter but still decidedly colored. The mineral matter, in this case sodium carbonate, increases with the depth; at 200 feet it is 22·0 grains, at 500 feet 76·0 grains, and at 800 feet 103+ grains in each imperial gallon. No well sunk in this section has passed through this zone of red or brown water and obtained white or colorless water beneath

it. On the southeastern limit of this area there seems to be one instance in which an area of colorless water is overlapped by this area of brown water, but this is exceptional and while easily explicable if true, needs confirmation.

The brown water area is surrounded by an area of colorless water and the limits, at some points, are fairly well defined. I observed two wells near the southern limit of the brown water; one 500 feet deep yielding a brown water carrying 104·0 grains total solids per gallon; less than two miles to the south of it another, 880 feet deep; here the water was scarcely colored at all and carried only 38 grains per gallon; this well emitted a considerable quantity of combustible gas, but was free from hydrogen sulphide, and the water was nearly taste-less. The wells which yield gas most freely seem to be at the outer edge of the brown water area and have considerable depth. I do not know of any well close to the San Luis lake on the west side, but the nearest one that I now recall yields a brown water and a fair quantity of gas; its depth is, according to my information, upwards of 900 feet. At the northeast corner of the lake and close to it there is a 500-foot? well, which yields a white water, tasting slightly of hydrogen sul-phide but otherwise of good quality. A short distance south of this, and directly east of the lake, is a well 300 feet deep, which furnished a colorless water, but this well is no longer flowing.

It is as good as impossible to obtain the logs of these wells, for they have been sunk through clay and sand with such ease and rapidity that it would be somewhat difficult for anyone to make an accurate record, which may be more fully appreciated when it is considered that wells as much as 400 feet deep have been begun and finished in a day. Some fragmentary informa-tion is furnished by the debris washed out of the drill holes such as is shown by the presence of fish vertebræ and, within the brown water area, fragments of wood. The presence of the wood suggests an explanation for the brown color of the water, i. e., that there is enough vegetable matter buried here to give rise to a sufficient quantity of humus to color it.

One of the questions arising in connection with this valley is, what becomes of the water flowing into it? This valley receives the water from a large drainage area, but the visible discharge of water from it amounts to only 540,000 acre feet annually or about 75 second feet, which is less than the loss of the Rio Grande as it enters the valley. I have not been able to obtain even an approximate idea of the total amount of the water entering the valley, but it is evidently very much in excess of the visible outflow.

These conditions, stated imperfectly and in general terms, raise the question of a general underground flow out of the valley.

We have, in the case of these brown waters, an artesian basin of approximately 420 square miles. The water, finding its way into this area, must be brought into the valley by the streams descending from the surrounding mountains which carry only snow and rain water. In the other portions of the valley the artesian waters are not only pure, but have the characteristics of the water which we find in mountain streams; in this area we find them characterized by a decided color, the presence of hydrogen sulphide, accompanied in some cases by marked quantities of combustible gases, probably marsh gas, and containing sodium carbonate. Further, these waters are not confined to one or more horizons within this area, but all flows, from the most shallow to the deepest, bear the same characteristics, and the area itself has quite sharply defined limits. If there be any general movement of these waters, it must be to the southward, for the valley is completely enclosed by mountains except on the south. The pressure shown by these wells is in no case great. The Denver and Rio Grande R. R. had a well put down at Alamosa to a depth of about 1,000 feet. The flow is excellent, but the pressure is not sufficient to force the water into the tank for supplying the engines, so it is probably less than 25 feet. Such a pressure with a head of 360 feet, this being the approximate difference of level between Alamosa and the western portion of the valley, is not incompatible with an outflow to the southward, perhaps a hundred or more miles away.

As the characteristics of these brown waters may aid in the solution of these general questions, I have paid some attention to their study.

If these waters were to pass through strata very different from those of the section in which they occur, the brown color would in all probability be removed, but not so with the sodium carbonate, for even clayey soils have but a limited power to retain sodium carbonate, as is shown by the fact that it passes quite freely into drain waters from soils which contain but little of this salt.

The sanitary analysis of the brown water presented some difficulty due to the organic matter present, but less than the water from the San Luis lake. In the former case the organic matter is probably humus, in the latter it is entirely different, as it is without color and at most imparts a slight milkiness to the water. The question of a possible connection of the San Luis lake with the reservoir of artesian water is a proximate one; indeed it is said that the water has been seen

to well up in the middle of the lake, accompanied by a gurgling sound. It is easy to conceive of such a connection, especially if the springs in the eastern and southern parts of the valley owe their origin to the artesian pressure in the basin rather than to individual local causes. This view, on the other hand, has but little plausibility when applied to the Head lake, a small adjacent lake, for this lake becomes almost entirely dry at times. These lakes fill up in the spring time, occasionally receiving water from the Saguache river and the San Luis creek, though this is of very rare occurrence, and have no visible outlet. I do not know the rate of evaporation from a quiet surface at this place, but it must be high, because the sunshine is almost continuous and the temperature in the summer season is high, and high winds are of frequent occurrence.

I have observed differences of level in the waters of the San Luis lake, varying to possibly 10 feet. The cause of this is not entirely clear; it seems too great a difference to attribute to surface evaporation. If the water of this lake is supplied from an underground source, it probably owes its origin to more immediate surface drainage, rather than to artesian pressure. This inference is drawn from the character of the mineral matter held in solution rather than from knowledge of stratigraphical relations. The analysis of this lake water gives the following characteristics: First, it is comparatively rich in mineral matter, 54·2 grains of fixed residue in each imperial gallon. Second, it is exceptionally rich in potash salts, potassium carbonate constituting one-fifth of the total, while the corresponding soda salt constitutes one-fourth. Third, the determination of saline and albuminoidal ammonia present exceptional difficulties.

While the amount of the total solids, 54·2 grains per imperial gallon, seems high, a little consideration of the conditions removes this impression. This lake has no visible outlet; it is not known how long it has already existed here, and the accumulation of salts, due to the concentration of pure mountain or snow water, might account for all of the salts that we find. Prof. L. G. Carpenter informs me that the evaporation from the surface of this lake may reasonably be estimated at sixty inches per annum, at which rate the water contained in the lake at any one time would be wholly evaporated in about three years. This is allowing an average depth of about 15 feet, a much greater depth than the lake possesses. Such considerations lead to the conclusion that the mineral matter held in solution is not sufficiently large to preclude their having been wholly derived from surface waters. The presence of so large a percentage of potash salts is more consistent with a

surface origin than a deep-seated one, for while the waters of our mountain streams are not so rich, even relatively, in potash salts as this lake water, they approach it much more nearly than any others known to me. In cases where the watersheds are composed of granites, gneisses and schists, in which the predominant feldspar is orthoclase, we find the waters characterized by a low mineral content consisting of much silicic acid and a relatively large amount of potash. These two characteristics are present in this water, the former, however, not in a very marked degree, but the latter strongly so.

The question whether the silicic acid may have separated from this water as a difficultly soluble silicate is one on which the deportment of similar water under pressure, for instance when used in steam boilers, may throw a little light. In several cases which have come under my observation I have found the incrustation formed to consist very largely of silica. In one case in which the boiler had been in service for four years and had been fed with artesian water coming from two different flows but of essentially the same character, the incrustation formed on the boiler tubes was one quarter of an inch in thickness and consisted of silicic acid and lime, 76 per cent of the former and 24 per cent of the latter, including a small amount of alkalies. Some such separation may have removed a part of the silicic acid from the lake water, in which there is at the present time only a small amount of lime, one grain per gallon.

The ammonia determinations in the sanitary analysis of this water presented peculiar and greater difficulties than I had ever met with in a water. The water is colorless and not strongly alkaline. There is no suggestion of the presence of humus : the slowness and persistency with which the ammonia distilled over was the only suggestion of its presence. It has been suggested that when successive, equal portions of the distillate show about one half as much ammonia as the preceding one, the probable presence of humus is indicated. According to this criterion the first three portions indicated the presence of humus, but each of the next six portions contained equal amounts of ammonia and no end of the reaction was obtained. In the distillation of the albuminoidal ammonia distilled water (ammonia free) was added, and 14 portions of 50^{cc} each were distilled over without obtaining an end to the reaction. The organic matter indicated by the slow and persistent evolution of ammonia may have come from a variety of sources, for the lake abounds in vegetation and, as I am credibly informed, in other aquatic life, a small fish attaining a length of five or six inches being especially abundant. As there is no outlet to this lake, it is evident that the water must become heavily charged

with organic matter. These points in the composition and deportment of this water distinguish it from the spring and well waters.

The well waters to the east of the lake are, so far as I know, white waters and of fairly good quality, but the wells to the west of it but not close to it yield brown waters ; those of the lower flows are so rich in sodium carbonate that they are no longer potable waters and but poorly adapted for boiler use owing to the fact that they foam badly. I have previously stated that these brown waters are characteristic of an area of approximately 420 square miles, and that all of the flows within this area have the same characteristics, namely, they are all more or less colored and all carry sodium carbonate. The flow met with at a depth of about 200 feet, in the town of Mosca, is used for domestic purposes. This water is slightly colored, tastes of hydrogen sulphide, and carries 22·4 grains of sodium carbonate in each imperial gallon. There are no sulphates and only traces of chlorides present in this water. This flow is not strong, and shows a diminution as the number of wells tapping it is increased. The water from the town well, which was originally something over 800 feet deep, but in which the casing was subsequently pulled to the 500 or 600 foot point, is strongly colored, has a decided alkaline reaction, and contains 72·6 grains of fixed residue per gallon, of which over 90 per cent is sodium carbonate. This is probably the most strongly colored water with which I have met. The mill well in the same town is from 780 to 800 feet deep, cased to the bottom ; the water from this well differs from the preceding only in containing more sodium carbonate or total solids per gallon, 102·8 grains, and in not being nearly so deeply colored. The sanitary analysis of these colored brown waters presented difficulties of the same nature, but much less serious than those presented by the San Luis lake water. They were so serious in both cases that I resorted to defecation by means of milk of lime, to which they were readily amenable.

These brown waters are wholly different in their properties from the lake water, and also from other artesian water flowing from wells in comparatively close proximity ; for instance, the " soda well," a brown water, carried 103·0 grains per gallon ; the " gas well," supposed to be on the southern limit of the brown water area, carried 37·6 grains ; while the white water wells, a few miles south or east, carry only 6 grains. These brown waters also differ from the spring waters of the eastern part of the valley, which as a rule correspond closely in their character to the artesian waters of the basin. As an illustration of this statement we have the Washington Springs, which carry 5·958 grains per gallon, and the nearest artesian well, of whose water I have an analysis, carries 6·698 grains per gallon.

The composition of these total solids is remarkably similar, especially in their high content of silicic acid. The residue from the well water contained 28·25 per cent, and that from the spring water 29·25 per cent of silicic acid. This similarity between the spring and well waters is not always so striking as in this case, but is, as a rule, very evident. The brown water area also has its springs, which are located immediately east of the San Luis lake, but the pressure is not sufficient to produce freely discharging springs, but instead small lakes of intensely alkaline water from which is deposited, both in winter and summer, considerable quantities of sodium carbonate, natron associated with a little trona.

I have given the characteristic differences between the lake water and the brown artesian waters and shown that they are distinct waters. The lake water is colorless, and contains notable quantities of silicic acid and almost as much potash as soda salts. The brown waters are distinguished from the other artesian waters of the basin by the presence of humus, the practical absence of silicic acid, and the presence of large quantities of sodium carbonate, from 23 to 103 grains to the imperial gallon. Further, these brown waters, or such as are rich in sodium carbonate, are confined to a quite sharply limited area, while the colorless waters are general throughout the rest of the artesian area.

The colorless artesian waters of the basin carry only a very moderate amount of dissolved substances; even the water from the deepest wells contains less than 16 grains of total solids to the gallon, 46 per cent which is silicic acid. These facts lead us to conclude that these brown waters are the source of the natron found in these soda lakes, because neither the ordinary artesian waters of the valley nor the lake water nor the spring waters are either rich enough in soda or pure enough to, in any easily explainable way, give rise to such deposits of natron, while the brown waters might easily do so.

The facts already adduced seem sufficient to justify the assumption that the natron found in these depressions owes its origin to the brown waters, but there are also other facts which support this view. I have submitted the water of the mill well, also those of the town well at Mosca, and of the mill well at Hooper, to examination with the purpose of comparing them with the mother liquor, collected in the so called Soda lake. Carefully made analyses of the residues from the three wells show that they are identical, so that I am justified in using a larger quantity of residue obtained from the mill well at Hooper for the detection of iodine, bromine, lithia, titanic and boric acids and in considering it as representative of the brown waters in general. The substances named were found in both the mother liquor from the natron and in the brown waters,

but it was necessary to use as much as 20 grams of the residue to establish the presence of lithia and bromine. The iodine, titanic and boric acids, on the other hand, were easily detected.

We have thus added to the fact that the brown waters are the only ones in the valley which, to our knowledge, carry sodium carbonate as the principal salt in solution, this further consideration, i. e., that the mother liquor from the crystals of natron resemble the brown waters in that it contains small quantities of iodine, lithia, titanic and boric acids. The potassium salts in the mother liquor of the lake are no more abundant than might be expected due to their concentration in this liquor as the soda salts crystallize out; but there may be a question as to whether the iodine, etc., show an increase corresponding with the degree of concentration which has taken place.

Apropos to the extent of these soda deposits. I may state that there are, to my knowledge, four depressions in which crystallized sodium carbonate, natron, is found. Three of these are quite small but the fourth is larger. When I last saw this there was probably a third of an acre entirely covered with a layer of natron, but it has at times been considerably larger than this. Mr. W. H. Falke, the present owner, tells me that he has measured the crystalline mass when it had a maximum thickness of forty-eight inches. There would have been no trouble in finding spots where the mass of crystals would have measured thirty inches in thickness when I last visited the place.

There is a question which will certainly suggest itself to everyone in any way familiar with our western conditions, i. e., whether the surface waters of the section may have contributed to the formation of these deposits. It is well known that water percolating through our surface soils gives rise to efflorescences and incrustations on evaporation. I have never seen deposits owing their origin to this source, comparable to this in extent or thickness; still it remains to show that these salts—this carbonate of soda did not come from the surface soil. I have analyzed the surface and also the ground waters from a territory which I believed would be most likely to give me results favorable to the assumption that such might be the source of the carbonate. The surface waters contain principally sulphates and chlorides with some carbonates; the ground waters contain the same mixture, the sodium chloride being rather more abundant. The efflorescences occurring in this section are essentially sodium sulphate with subordinate quantities of calcium and magnesium sulphates. The aqueous extract of the soil contains large quantities of sulphates with only a little carbonate. We have then in the surface waters, the ground waters, the water-soluble portion of the soil, and in the efflorescent salts gathering on the soil an entirely different mixture of salts and one which, were it to flow through or over the soil

into a basin and evaporate, would not give the pure sodic carbonate found in this deposit.

The natron was found in August, 1907, forming a mass of crystals five inches thick covered by an inch or more of a yellowish mother liquor. The upper part of the crystalline mass showed a thin layer of bright needles or thin prismatic crystals: these did not effloresce, yielded water in the closed tube and consisted of sodium carbonate. It was not feasible to select material pure enough for analysis. I took this layer as consisting of the mineral trona.

The mass of crystals had effloresced so badly by the time I was able to analyze it, that I dried the material thoroughly before analyzing it. A water determination, however, was made on some of the best material that I could, under the circumstances, select and yielded 59·161 per cent of water.

Analysis of thoroughly dried salt-mass from Soda Lake.		Analysis of the residue from the mother liquor.*	
SiO_2	0·128	SiO_2	0·405
SO_3	0·184	SO_3	2·235
Cl	0·138	Cl	2·409
CO_3	41·060	CO_3	36·016
Na_2O	57·875	Na_2O	46·991
K_2O	0·824	K_2O	12·347
	100·209		100·403
O=Cl	·030	O=Cl	·543
	100·179		99·860

* This residue contained traces of iodine and lithia, also of titanic and boric acids.

The conditions obtaining in this artesian basin which permit of the confinement of these waters to a somewhat sharply limited area are certainly not clear. There are no reasons for assuming the existence of a separate basin in this section though its waters are very distinct in their properties. There is no evident source of the sodium carbonate, for granting, as we must, that vegetation may have at some time been abundant in this section, which is indicated by the fossil wood, the humus and the marsh gas, it does not suffice to explain the presence of the sodium carbonate. We might assume that beds of carbonate exist somewhere in this territory, but we have no proof that this is a fact. No observations indicating such deposits have been made in putting down the numerous wells of this section. The small deposits mentioned in this article are the only known ones and these are confined to the surface, or within a few feet of it. I have understood that borings have been made with the idea of finding such deposits, but without success.

Analyses of Residues from Artesian Wells.

	Mosca. Town well 500–600 feet deep.*	Mosca. Mill well 780 feet deep.	Hooper Mill well 750 feet deep.
Carbon	0·365		
SiO_2	5·537	4·821	4·160
SO_3	0·342	0·046	0·063
Cl	0·425	0·284	0·470
P_2O_5	0·247	0·148	0·168
CO_2	37·603	37·104	37·365
Na_2O	53·077	53·665	54·045
K_2O	0·982	1·148	1·433
CaO	0·413	0·651	0·282
MgO	0·153	0·391	0·219
Fe_2O_3	0·086 }	0·031	0 039
Al_2O_3	0·121 }		
Mn_3O_4	0·086	0·054	0 048
Li, I, Br } $TiO_2.B_2O_3$ } each trace	Li, etc. plus Org. matter [1·721]	Li, etc. plus Org. matter [1.814]
	99·437	100·064	100·106
O=Cl	0·096	0 064	0·106
	99·341	100·000	100·000

* This residue was heated till the organic matter was charred but not wholly destroyed. The deficit of 0·6597 in the analysis is probably due to organic matter.

If this water is characteristic of a subordinate basin independent of the rest of the valley, as I at one time thought, it is peculiar that we have no area surrounding it barren of artesian water. Further, that they have not succeeded in getting below the water carrying sodium carbonate in solution. There is no indication, of which I have been able to learn, that they have approached the downward limit of the sodium carbonate. The deepest well in this section, whose waters I have analyzed, was 880 feet deep and this water was the richest of all I have examined in sodium carbonate. On the other hand, if it forms a part of the general basin and there are no changes in the inclination of the strata, it is hard to see how the lateral limits of the sodium carbonate can be so sharply defined. There can certainly be no general lateral movement of the waters through the valley in which this water participates. Such a movement is possible, but it must take place at a greater depth than has yet been attained by the wells of this section. The floor of this valley has not, to my knowledge, been reached by any of the drill holes. The sheet of lava forming a portion of the southern margin of the valley is of later origin than some of the sedimentary strata and is evidently no part of the real floor of the valley.

Fort Collins, Colorado.

ART. XXV. — *The Volumetric Determination of Small Amounts of Arsenic;* by LAUNCELOT W. ANDREWS and HENRY V. FARR.

THE problem of the analytical determination of small amounts of arsenic, present as an impurity in products of the most varied character, is a constantly recurring one. The comparison of mirrors formed in the Marsh test in its several modifications and a few colorimetric processes have solved the problem for the special case in which the arsenic is present in traces only and in which a merely approximate estimation of the amount suffices. We have been led to seek a solution covering a wider range of cases, in which, for example, the arsenic may be present in any quantity from 0·1 mg., or possibly less, to 100 mg. and in which the accuracy of an ordinary quantitative analysis is required.

Often, but not always, the distillation of the arsenic, after Fischer as arsenious chloride, furnishes satisfactory results under these conditions as a method of separation, but it always has the disadvantage of being rather time-consuming. It is better adapted for the determination of larger than for smaller amounts, since the distillate contains its arsenic in a highly dilute state and much contaminated with foreign salts,* or else in the form of arsenic acid,† which is not particularly well suited to quantitative determination. A method, in order to be perfectly satisfactory for the purpose in view, should comprise : (A) a process for the direct separation of the arsenic in a concentrated form, applicable to the greatest possible number of cases ; (B) a simple, rapid procedure for determining the arsenic in the form in which it is furnished by step (A).

It is obvious that none of the existing methods can meet these demands. The well-known Bettendorff test,‡ in which the arsenic is precipitated in the metallic state by a mixture of hydrochloric acid and stannous chloride, appeared to us to possess possibilities of development for the process we were looking for. This test has been used by E. S. Peck§ for the colorimetric determination of arsenic in metallic iron. According to Bettendorff (l. c.) the sensitiveness of the reaction is such that it will show " most definitely " the presence, in one cubic centimeter, of two millionths of a milligram of ammonium-magnesium arsenate, that is, of less than a millionth milligram of metal. Our own observations on this point con-

* Alkali chloride, if the distillate is received in alkali hydroxide solution.
† When the distillate is received in nitric acid or other oxidizing agents.
‡ Fres. Zeitschr., ix, 105, 1869.
§ Pharm. Jour. (4), xiii, 130, 1901.

firm the statement quoted, provided, naturally, that a layer of sufficient thickness be examined and that the liquid is otherwise absolutely colorless.

The arsenic as thrown down in the Bettendorff test, although finely divided, settles in two or three hours and can be filtered on the expiration of that time through an asbestos filter without exhibiting any tendency to run through, and can be washed with concentrated hydrochloric acid and with water, without undergoing oxidation. As pointed out by Bettendorff, it contains more or less tin. Bettendorff found 95·86 to 98·56 per cent of arsenic. The amount of tin, present as basic chlorides, varies, however, over a much wider range than these figures would indicate, depending on the amount of oxidation undergone by the stannous chloride, the temperature, etc. The precipitate dissolves in decinormal, centinormal, or millinormal iodine solution, made slightly alkaline by addition of suitable amounts of sodium bicarbonate or phosphate. The readiness with which this solution occurs depends mainly on the amount of stannic acid or of basic stannic chlorides carried down with the precipitate. If the degree of this contamination is considerable, the precipitate must be shaken for several hours with the liquid in order to effect complete solution ; but if the amount be smaller or vanishing, solution takes place in less than a minute. This observation led us to prevent co-precipitation of basic tin compounds by adding tartaric acid to the reaction mixture of hydrochloric acid, stannous chloride and arsenite. There seems to be no inclination for the precipitate to entrain stannous compounds.

Bettendorff found the reaction to be incomplete, even after the lapse of a long time, with hydrochloric acid of 23 per cent HCl, while with such of 25 per cent it was complete "after some minutes." This concentration represents the minimum. It is better to operate with a concentration of nearly 30 per cent, which presents no difficulties when the ordinary reagent acid of 40 per cent is used. That is to say, 25^{cc} of the latter acid should be employed as a minimum to each 10^{cc} of the solution to be examined.* The most obvious cause of errors lies in the possibility of loss by evaporation of the highly volatile arsenious chloride during the reduction process. This we guarded against in our earliest experiments by sealing up the reaction mixture in glass tubes, an effective but inconvenient

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* This rests of course on the assumption that the substance to be examined contains nothing to neutralize the hydrochloric acid. Otherwise a far greater amount of acid may become necessary. Thus when tartar emetic is to be examined for arsenic, the salt is dissolved directly in the 40 per cent acid, and enough of the latter must be taken to furnish 25 to 30 per cent of absolute acid, *after* that consumed in converting the potassium and the antimony into chlorides has been duly allowed for.

expedient, which fortunately proved to be unnecessary, since sufficient protection is afforded by closing the solution in a bottle with a well-ground glass stopper, provided the temperature is not raised higher than 35° or 40°. The latter should not be lower than 25°, since the reaction then becomes undesirably slow.

In the absence of tartaric acid, the arsenic does not usually visibly deposit on the glass walls, but when the precipitation of tin compounds is prevented, a small part of the arsenic sometimes forms an extremely thin film, adherent to the glass. The existence of such a film should be assumed, even when none is visible. Experiment has demonstrated that a minute truly, but titratable amount of arsenic may be present in this way on the seemingly quite clean surface of the vessel in which the reduction has taken place.

The process finally assumed the following form. The material to be examined, if in the form of a solution more bulky than 20^{cc}, is neutralized and boiled down to 10 or 20^{cc} and transferred to a white bottle of 80 to 100^{cc} capacity, provided with a very well-ground stopper. To the liquid is added two and a half times its volume of the tin reagent, prepared by dissolving twenty grams of stannous chloride crystals and forty grams of tartaric acid in one liter of forty per cent hydrochloric acid.* The stopper is inserted and the flask set aside to stand in a warm place till the precipitated arsenic has subsided, leaving the supernatant liquid water-white† and clear. This usually takes about two or three hours, more or less, if the temperature is nearly 40°. An asbestos filter is prepared in the usual manner, either in a Gooch crucible or in a Neuman filter tube. The precipitated arsenic is transferred to the filter with the aid of a small amount of concentrated hydrochloric acid, rigorously chlorine-free. The flask is rinsed repeatedly with small amounts of water which are passed through the filter, which is completely washed by aid of suction without allowing it to be exposed to the air more than necessary, except at the last draining, a precaution which may not be requisite, but which seems indicated. The proper amount of centinormal or of decinormal iodine solution is now measured into the flask by a pipette as indicated by the equation,

$$As + 5I + 7NaHCO_3 = Na_2HAsO_4 + 5NaI + 7CO_2 + 3H_2O,$$

allowing for an excess of ten to one hundred per cent above

---

* This reagent will remain colorless if the constituents are arsenic-free. It should be kept in bottles holding not more than 200^{cc} and closed in such a manner as to give assurance of protection of the contents against oxidation.

† Of course this does not apply when nickel chloride or other colored salts are present.

the theoretical.* The precipitate, with the asbestos filter, is now transferred quantitatively to the flask and shaken with the iodine solution.† Enough of a five per cent solution of sodium bicarbonate or of sodium phosphate should now be added to maintain neutrality throughout the reaction, but not an unduly large excess, and the shaking be continued till the asbestos is thoroughly disseminated through the liquid and till it is certain that every particle of arsenic is dissolved. Fresh starch paste is added and the excess of iodine is titrated back by hundredth or thousandth normal arsenite solution.

For quantities of arsenic smaller than 0·5 mg., thousandth normal solutions may be employed, but it must not be forgotten that in such high dilutions a correction must be employed for the amount of iodine required to produce the end-reaction, if satisfactorily exact results are required. This correction usually amounts to about $0·6^{cc}$ of $N/1000$ for each 50^{cc} of solution, but it should be determined under the actual conditions of the titration. A main factor influencing the sensitiveness (aside from temperature) is the concentration of iodide in the liquid. For larger quantities than 10 mg. of arsenic up to 100 mg. tenth normal iodine solution is preferably employed.

The degree of precision to be expected in the results obtained by this method may be seen from the following test analyses. A hundredth normal arsenic solution (containing 0·375 mg. As per cc.) was made by dissolving 990·0 mg. of As_2O_3 in water to make two liters, and also a fifth normal

TABLE

Arsenic taken Milli-grams	Volume of solution cc.	Vol. of HCl used cc.	Vol. of iodine sol. added	Vol. of As sol. req.	Weight of As found	Error mg.
1	3·75	10	25	$50·02N/100$	$25·02N/100$	3·75	0·00
2	3·75	10	25	41·05	16·03	3·753	+0·003
3‡	3·75	10	50	30·03	5·23	3·72	−0·03
4	7·519	20	60	60·06	10·00	7·510	−0 01
5	0·375	2	10	5·01	2·46	0·382	+0·007
6	71·02	10	30	$51·01N/10$	$35·2N/100$	71·23	+0·21
7‡	75·00	10	50	$55·04N/10$	$49·4N/100$	75·15	+0·15

‡ Note. In analyses Nos. 3 and 7, about 0·1 gram of crystallized copper sulphate was added, without, as may be seen, influencing the results. In another experiment, not recorded in the table, similar to No. 3 except that the copper was omitted, a solution of titanous chloride was substituted for the stannous chloride. In this case there was a negative error of 0·2 mg. in the arsenic. Twenty hours was required for the reaction, which is slower than when stannous chloride is used.

* One cubic centimeter of centinormal iodine solution =0·15 mg. As.
† It is ordinarily easy to see when the reaction is complete. When the amount of arsenic is less than 5 mg., it is practically instantaneous.

solution by dissolving 9·900 grams of the oxide in sodium hydroxide solution, saturating with carbon dioxide and then making up to one liter. The amounts of arsenic which appear in column 1 of the table were obtained by measuring the appropriate volume of one of these solutions.

All volumetric apparatus employed was, of course, carefully standardized. The volumes of the standard solutions, as given in columns 4 and 5, are corrected for temperature and titre.

A somewhat similar process to that described in the present paper has been published by Engel and Bernard.* These authors reduced the arsenic with a mixture of hypophosphorous and hydrochloric acids and titrated the precipitated metal in essentially the same manner as that adopted by us. Their test ·analyses are very good on larger amounts of arsenic. They publish none for quantities less than 54 milligrams.

The reaction is very much slower than it is with stannous chloride. This necessitates allowing the mixture to stand for twelve hours and then boiling, a proceeding which may well result in loss of arsenious chloride.

It is far less easy to obtain hypophosphorous acid free from traces of arsenic than it is stannous chloride. The most important advantage which the use of the tin salt presents is probably to be found in the broad range of its applicability. In almost all of the salts which one ordinarily desires to subject to an arsenic determination, no other operation is required. Even compounds of lead, bismuth or antimony need no preliminary separation. We have found that titanous chloride ($TiCl_3$) may be substituted for the tin salt, but without advantage so far as known. It is probable that the lower chlorides of chromium, molybdenum, or vanadium would answer the same purpose, but they hold out no promise of superiority.

It is extremely likely that for the determination of fainter arsenical mirrors, obtained by the Marsh method, the iodometric titration will be found useful. A mirror of 0·01 mg. can scarcely be weighed satisfactorily, even with the best balance, because the weight of the tube when subjected to the action of the necessary reagents might change by an amount considerably in excess of the weight of the mirror. But it could be dissolved in millinormal iodine or starch iodide† and the excess titrated back by arsenite or thiosulphate of the same normality. For smaller mirrors than this, optical methods of comparison will still have to be used.

* Comptes rendus, cxxii, 390, 1896.
† Compare Zeitschr. f. anorg. Chem., xxvi, 180, 1901.

Art. XXVI.—*Preliminary Report on the Messina Earthquake of December 28, 1908;* by Frank A. Perret, K.I.C., former Honorary Assistant at Royal Vesuvian Observatory.

As special representative of the American Consulate, the writer sailed from Naples on Dec. 30, arriving at the Straits at daybreak of the 31st.* He remained eight days and the scientific observations and photographs were chiefly confined to Messina and its environs, Reggio and Villa San Giovanni having been inspected only from the sea during a visit of the U.S.S. "Scorpion" to the Calabrian coast. The present report must, therefore, be considered as preliminary in its nature and limited by the extraordinary conditions incident to life in destroyed cities under martial law, and in a state of siege.

Before proceeding to a detailed account of the observations, it may be well to present a summary of the principal facts:

For several weeks preceding the earthquake a number of more or less severe shocks were felt in the neighborhood of the Straits, the most important occurring on Nov. 5 and Dec. 10. Exactly twenty-four hours before the great event, i. e. at 5.20 A. M. of Dec. 27th, the seismograph at the Messina Observatory registered an important earth movement.

Etna and Stromboli were unusually active on Dec. 25th, but neither showed sympathetic action at the time of the earthquake nor immediately after.

The earthquake occurred at 5.20 A. M. of Dec. 28, 1908 (cf. fig. 1). The macroseismic duration was about 32 seconds.

The epicentrum was apparently at the northern entrance of the Straits or a little to the E. and N. of this.

The intensity within the megaseismic area was between the 9th and 10th grade of the Mercalli scale, and fell off rapidly with increasing distance from the epicentrum, indicating a centrum at no great depth, possibly 15 kilometers or less.

The destructive area extends to and beyond Palmi on the north and to Ali on the south, say twenty miles in either direction.

The isoseismals will show an elliptical form with the major axis lying N. and S. or, more precisely, from E. of N. to W. of S.

Within the megaseismic area free surface waves were produced, and their forms, preserved in the stone pavement of the Messina embankment, were photographed by the writer.

The event occurred on a steep barometric gradient, the mercury rising 5^{mm} during the night to a maximum at 9.00 A. M. of the 28th and then falling 10^{mm} in the course of the day.

The moon was nearing its quadrature position of the 29th and had just passed its perigee, these conditions producing the

Fig. 1.
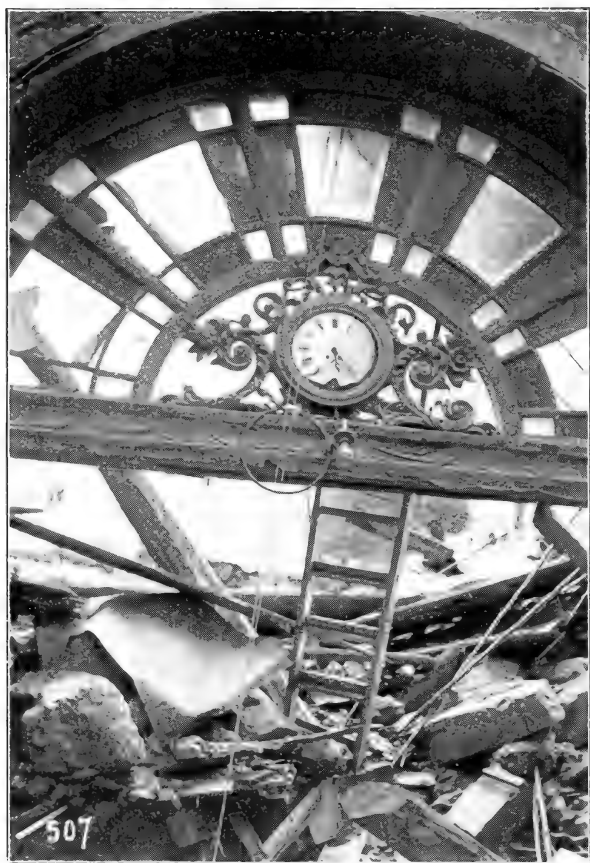
Fig. 1.　Office of the Hotel Trinacria, clock stopped at 5.23.

"Terrestrial Maximum" of Dec. 28th on the writer's astro-seismic curve for 1908.*　This combination was preceded by three very favorable luni-solar positions during the month of December, and this fact had led the writer to expect some

* Science, Aug. 28, 1908.

important volcanic or seismic event before the close of the year.

At the moment of the earthquake the moon was near the nadir and the sun just below the eastern horizon.

The earth movement resulted in a sea wave which arrived at Messina two or three minutes after the shock and at Villa San Giovanni several minutes later. It reached the point of Schisò (Naxos) in 35 minutes and Malta in 115 minutes. It was also registered by the mareograph at Ischia, the greatest rise (22^{cm}) occurring at 2.30 p. m. and the intervals between crests being 12 minutes. The height of the wave at Messina

FIG. 2.
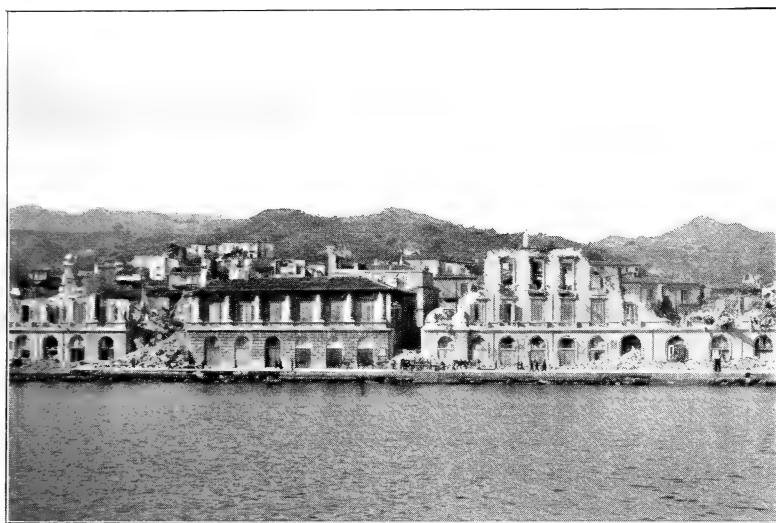
FIG. 2.   View along water-front, showing relative stability of low buildings.

seems not to have exceeded three meters ; at Reggio it was somewhat greater and reached its maximum on the coast below Taormina. In all cases the wave was noteworthy only by its development on reaching shallow water—a small, low free-board ferry-boat with passengers aboard having been in the Straits at the time and suffering no inconvenience beyond the difficulty of landing at the damaged and submerged ferry-slips.

The earthquake is described as having been preceded for a few seconds by a singing sound like a far-away wind storm which rapidly drew nearer and became a rumble and a roar when the earth movement began.

Nearly all the after-shocks observed by the writer were accompanied by sound phenomena.

Observers at Taormina report having seen luminous effects on the horizon in the direction of Messina immediately before the earthquake, but at Messina all was dark. The sea appeared luminous, possibly because of having been converted into foam by the vibrations. There is no doubt of luminous effects having been observed immediately before and during other earthquakes in this region—that of 1905 being accompanied by a strong red glow upon the mountain tops.

Fig. 3.

Fig. 3.   Collapse of the embankment.

The Messina seismograph recorded a part of the movement.

The loss of life and property was enormous owing to the " rubble" construction of the buildings.

As has often been noted, those buildings which presented their diagonal to the direction of the earth movement resisted better than those whose faces paralleled or right angled the motion, and those on loose or sloping ground suffered most.

In Messina the general direction or " throw" of the movement was from N.E. to S.W., and the same was the case at Villa San Giovanni.

There seems to be no evidence of a geological sinking. The sea has advanced in places as much as one hundred meters, but

this is evidently due to the downslip of loose material into deep water. The Messina embankment, built of lava blocks on made ground, has collapsed under the influence of the earth vibration and the sea wave, but the relative insignificance of its fall is shown by the perfectly upright walls of houses not twenty feet away.

Unless subsequent soundings shall demonstrate the contrary, it does not seem that any great physical changes have taken

Fig. 4.

Fig. 4.   Partial collapse of the embankment.

place upon the earth's surface in consequence of the earthquake. That of 1783 resulted in considerable downfalls along mountain ranges, the formation of lakes by the sinking of plains and the production of crevasses. In the present case these latter are limited to insignificant fissures.

The earthquake was lightly felt at Naples and more strongly on the island of Capri.

Properly constructed houses in Calabria withstood the shock.

Entering the Straits at daybreak of the 31st, I observed
that the famous rock of Scylla, which, together with the light-
house (Faro di Messina) on the opposite point and several of
the Lipari Islands, was reported as having disappeared, stood
in its accustomed place.   The lighthouse also was standing,
but the lantern at the top had been slightly displaced toward
the east.   The first view of Messina from the sea did not give

Fig. 5.

Fig. 5.   Free surface wave-forms retained by curb stones of the embankment.

the impression of a complete disaster.   A considerable portion
of the façades of the line of buildings along the quay—the
famous "Palazzata"—remained standing as well as a num-
ber of one or two-storied houses, but a nearer view showed
that there was practically nothing back of the façades and that
these houses were damaged, although still standing (fig. 2).
   On going ashore it was easily seen that the embankment had
collapsed from the sliding down into the deep harbor of its
insecure foundations (figs. 3, 4).   All along the quay a critical
eye could detect signs of the free surface wave, and in one spot
the curb had become detached from the sidewalk and retained
admirably the full wave form into which it had been thrown.
(See fig. 5.)   The average distance from crest to crest of these
waves was two meters and the height from trough to crest

(double amplitude) was 30^{cm}. In other places the wave was of flatter form, i. e., height 16^{cm}, crest to crest 6 м.

The " rubble " construction of the buildings was apparent all along the quay, broken arches of the " Palazzata " revealing the small round stones set in mortar of poor quality (figs. 6, 7).

Fig. 6.

Fig. 6.   Showing rubble construction.

A conspicuous exception was seen in the building occupied by the French Consulate, the walls of which were fairly thick and built of tiling or thin brick, its chief defect being the weakness of the floors and its height of four stories (fig. 8). The relative stability of these walls was shown by a seven-foot pier glass which was not even cracked.   The American Consulate building had collapsed to a compact heap of mortar and stone.

The general direction of the earth movement was well shown by the wreck of the Maurolico monument in the Villa Mazzini (fig. 9). This has fallen due S.W. and, having been symmetrical and standing on a level plain, it gave as fair an index as could be obtained. The same general direction was

FIG. 7.

FIG. 7.   Broken arch of the Palazzata showing rubble construction.

observed just outside the city, where the top of a tall stack had been snapped off and fallen S.S.W. (fig. 10). Two other single column monuments on the hills west of the city had also fallen S.W. At Villa San Giovanni a tall stack was tilted S.W. Although in Japan it is generally found that such objects fall inward or toward the epicentrum, this was not the case here, the most probable explanation being that, owing to the slight depth of the centrum and the nearness of the city to the epi-

centrum, there was a very pronounced vertical component at the beginning of the earth movement which, in combination with the horizontal motion, threw the objects in the direction of the movement instead of tripping their bases and causing them to fall inward. This will be more evident to the reader

Fig. 8.

Fig. 8. Ruin of French Consulate. Walls fairly thick and well built but floors weak and house too high for this type of construction.

from an inspection of the photograph of the Maurolico monument, the dome of which has been thrown to a distance of five meters from the center, which would scarcely have been the case if it had fallen under the impact of horizontal motion. The lantern of the Faro forms a case of displacement toward the epicentrum.

The principal after-shocks observed by the writer were the following:

Jan. 2,— 8.14 A. M.—$\frac{1}{2}$ sec., weak.
　　　　　9.40 P. M.—$\frac{1}{2}$ sec., strong, threw down walls.
　　　　　11.42 P. M.—two weak shocks $\frac{1}{2}$ sec. apart.
Jan. 3,— 3.55 A. M. ⎫
　　　　　4.56 A. M. ⎬ weak, brief duration.
　　　　　7.24 A. M. ⎭
Jan. 5,—12.10 noon—$\frac{3}{4}$ sec., strong ; several weak shocks two to
　　　　　　　　　　three minutes later.
　　　　　5.05 P. M. ⎫
　　　　　9.50 P. M. ⎬ unimportant.
Jan. 6,— 9.00 A. M. ⎫
　　　　　10.00 A. M. ⎬ unimportant.

FIG. 9.
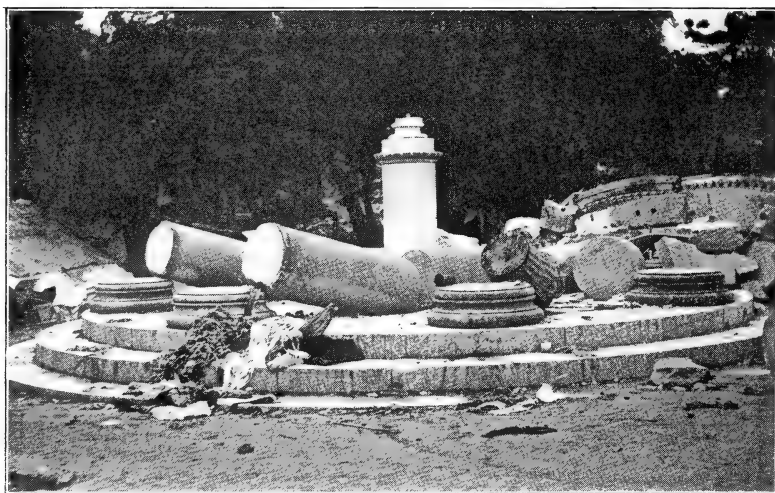
FIG. 9.   The Maurolico Monument in the Villa Mazzini ; this has fallen due S.W.

Jan. 7,— 5.00 A. M.—strong, brief duration.
　　　　　6.28 P. M.—5 sec., strong, threw down walls, followed by
　　　　　　　　　　a replica.
　　　　　Several shocks during the night and the early
　　　　　morning of Jan. 8th.

This should not be taken as a complete record of all shocks occurring during the time nor can the relative intensity be depended upon as accurate, the various observations having been made on shore, on shipboard and in the ruins. The need of a good, portable seismograph was never better illustrated than by this event, as all the instruments in the neighbourhood were destroyed. It would have been possible to take a portable

instrument down to Messina from Naples and to have thus obtained a complete record of all after-shocks.

Of those indicated above three are deserving of special mention. That of Jan. 2, at 9.40 P. M., occurred when the writer was standing on the deck of a steamer moored to the embankment. The impression was that of a submarine explosion—a loud report and a sharp vertical movement. These, however,

FIG. 10.

FIG. 10.   Tall stack ; top snapped off and fallen S.S.W.

were partly due to the iron hull of the ship receiving the impact from the water. In from three to five seconds was heard the crash of falling walls within the city and smouldering fires blazed up anew. This shock is *reported* to have snapped the anchor tips of the British cruiser " Exmouth," which was carried two miles to the southward by a twelve-knot current through the Straits.

At ten minutes past noon of the 5th another strong shock of the same general nature occurred, but this was felt on shore

only as a horizontal wave motion. It was followed by several weaker movements.

At 6.28 P. M. of Jan. 7, a shock lasting fully five seconds formed the most interesting of those observed. The duration was such as to give ample time to study the phenomenon and it was impossible to avoid the conviction that the originating movement at the centrum had a duration not greatly inferior to that of the observed effect. This is contrary to the accepted ideas of the day regarding earthquake generation and a discussion of the subject may be reserved for a future paper, but

FIG. 11.

FIG. 11. Fronts fallen from houses, lying East and West.

the writer feels in duty bound to record the impression in the belief that no honest observation is without value.

This shock was experienced when on board the U. S. S. "Scorpion" and the man on watch reported having "seen" the earthquake pass through the city from N. to S. When interrogated he could give no more definite information, but it is evident that the earth waves had produced a visible undulation of the buildings and walls along the water front. Many walls fell and the shock was followed by another not as strong. A number of shocks occurred during the night and in the early morning of the 8th.

As to the cause of these Calabrian earthquakes, the writer inclines to the opinion of Mercalli, viz.: that they are due to the movements of deep-seated magma and belong, therefore,

to the type which he denominates "inter-volcanic." In their nature they are, of course, tectonic, and I often permit myself to ask if the primal cause of all tectonic earthquakes may not yet be found in magmatic intrusion, the fact of their non-occurrence in the immediate neighborhood of active volcanic vents and of their prevalence in the steeply folded portions of the earth's surface constituting, in my opinion, an argument for, and not against, the hypothesis.

FIG. 12.

FIG. 12.   North end of Quay.

At all events, this portion of the Italian peninsula lying, as it does, between the Tyrrhenian and Ionian deeps and subject to the upheaval revealed by the Quaternary terraces of the Aspromonte, must be considered as one of the most pronouncedly seismic areas of the globe. This being the case, it is idle and harmful to encourage the hope that this region will not be subject in the future, as it has been in the past, to frequent and severe earthquakes. Rather should it be impressed upon both government and people that, sooner or later, these are certain to occur and that the proper construction of houses to withstand their effects is an absolute necessity. Only thus, with the active prosecution of the study of prediction, may we

hope to avoid future repetitions of the recent great disaster, and ample means should, therefore, be provided for putting earth-science on a world-wide basis and bringing it thus to at

Fig. 13

Fig. 13.   Wreck of a tall, poorly constructed building.

least a par with astronomy.   A glance at a list of the volcanic and seismic catastrophes of the last eighteen years will suffice to show that few other lines of scientific investigation can vie with this in importance to the human race.

Vomero, Naples, Italy.

ART. XXVII.—*A New Connecting Link in the Genesis of Fulgur;* by CARLOTTA J. MAURY.

AMONG a quantity of fossils lately collected by Professor G. D. Harris at Montgomery, Louisiana, from the Jackson horizon of the Eocene is a very interesting species which forms a perfect connecting link between *Levifusus* and *Fulgur.* A dozen specimens were found.

The relationship of the two genera was pointed out some years ago by Dr. Dall and Professor Harris. Dr. Dall in 1890 stated that *Fulgur,* which took its rise in the Eocene, was descended from such forms as *Levifusus Blakei* and *trabeatus.* Professor Harris later noted the tendency shown by many *Levifusi* to revert to an ancestral *Pleurotoma*-like form and traced the derivation of *Fulgur* from *Pleurotoma* through *Surcula, Levifusus* (*pagoda*-like forms), *Levifusus* (*suteri*-like forms), *Levifusus* (*trabeatus*-like forms), *Levifusus Branneri* to *Fulgur echinatum.*

But *Levifusus Branneri* Harris in addition to shoulder spines is ornamented by a row of twelve nodules on the center of the body whorl. The Montgomery shell is without the slightest trace of this row, and, as shown in the accompanying figure, presents such a striking resemblance to *Fulgur* that it might almost be taken as one of the many varietal forms of *Fulgur spiniger.* The spire, however, is almost

Levifusus fulguriparens n. s. (Longitude 25^{mm}.)

exactly that of *Levifusus Branneri.* To emphasize the fact that it is the most direct ancestor of *Fulgur* known, the name *fulguriparens* has been given to the Montgomery shell.

Hastings-on-Hudson, N. Y.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *A Method for Calculating the Boiling-points of Metals.*— The view was advanced by F. KRAFFT about four years ago that the essential process of boiling in a vacuum consists in overcoming gravity, and that this, on the surface of the earth, is equivalent to the atmospheric pressure. As a proof of this fact he showed that the elements mercury, cadmium, zinc, potassium, sodium, bismuth and silver require just the same addition of heat to bring them from the point of the commencement of volatilization in a vacuum to the point of boiling in a vacuum, as is required to bring them from the latter point to the point of boiling under atmospheric pressure. In order to obtain further data in regard to this interesting relation, KRAFFT and KNOCKE have determined the data under consideration for arsenic, and have found :

Commencement of evaporation, 0^{mm} _ _ _ _ _ _ _ _ _ _ _ _ _ 96°
Sublimes at 0^{mm} _ 325°
Sublimes at 760^{mm} _ 554°
Difference in each case _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ 229°

They found with thallium :

Commencement of evaporation, 0^{mm} _ _ _ _ _ _ _ _ _ _ _ 174°
Boiling-point at 0^{mm} _ 818°

Since the difference here is 644°, the calculated boiling point at 760^{mm} is 1462°. In this manner, from data furnished by Krafft and his co-workers, Moissan calculated the approximate boiling point of copper as 2240° and of gold as 2530°, and he found by distilling in an electric furnace an alloy consisting of equal parts of copper and gold, that the copper boiled off faster than the gold, thus showing a lower boiling point of the copper, as indicated by the calculation.—*Berichte*, xlii, 202. H. L. W.

2. *Some Properties of the Radium Emanation.*—About two years ago RUTHERFORD observed that the emanations of radium, actinium, and thorium were completely absorbed by cocoanut charcoal at ordinary temperatures. He has recently repeated this experiment with the radium emanation, using much larger quantities, and has found that the actual volume of this emanation capable of absorption at room temperatures is very small. For example, several grams of the charcoal are required to absorb completely the emanation from 200 mg. of radium at ordinary temperature, although the volume of the gas is only one-tenth of a cubic millimeter. As was to be expected, the absorptive power of the charcoal increases rapidly with the lowering of the temperature. It was found that 0·8 g. of charcoal from which

air had been removed by heating absorbed the emanation from 83 mg. of radium (about 0·05 cubic mm.) at −150° C. As the temperature was slowly raised, less than one-tenth of the absorbed emanation could be pumped out at −50° C., as was shown by measurement by the γ-ray method. Above −40° C. the emanation commenced to escape rapidly, and half had been pumped off at 10° C. About 10 per cent remained at 100° C., but practically all was released at the temperature of the softening of glass. The results show that at 10° C. the charcoal absorbs about 0·03 cubic mm. per gram, and at −40° C. about 0·06 cubic mm per gram.— *Chem. News,* xcix, 76.   H. L. W.

3. *Method for Preparing Hydrogen Phosphide.*—MATIGNON and TRANNOY have devised a simplified method for the preparation of the gas PH_3. They mix powdered calcium phosphate which has been previously calcined, in order to remove every trace of moisture with powdered aluminium, in the proportions required by the equation

$$3Ca_3(PO_4)_2 + 8Al_2 = 3Ca_3P_2 + 8Al_2O_3$$
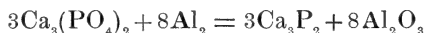
put the mixture in a crucible, heat it to dull redness, and ignite it with an ignition mixture according to the Goldschmidt method. The products of the reduction do not separate, but form a brownish mixture, which after being broken up is suitable for the production of hydrogen phosphide by the action of water, followed by hydrochloric acid towards the end of the operation. The resulting gas was found to contain 2 or 3 per cent. of hydrogen, but otherwise it appeared to be perfectly pure.— *Comptes Rendus,* cxlviii, 167.   H. L. W.

4. *The Theory of Valency,* by J. NEWTON FRIEND. 12mo, pp. 180. London, 1909 (Longmans, Green and Co.).—This work is one of a series of text-books of Physical Chemistry, edited by Sir William Ramsay. Nine of these monographs have already appeared, and five more are announced as in the course of preparation. The book under consideration gives a concise account of the more important theories of chemical combinations which have exercised the minds of scientific men down to the present day. It appears that heretofore there has been no treatise in the English language upon the important subject of valency, while in German there is only one, a not very exhaustive work which was published several years ago. The book will be useful to students of chemical theory, since it covers the ground very thoroughly and gives a very full list of references to the literature.   H. L. W.

5. *Recent Advances in Organic Chemistry,* by A. W. STEWART. 8vo, pp. xv, 296. London, 1908 (Longmans, Green and Co.).—The author has endeavored to give an idea of some of the most recent researches in organic chemistry which have been carried out within the last ten years. The subject has been considered from a synthetic point of view and the work has some commendable features, but is too condensed to be of much value

to one who is familiar with the advances made in recent years. While many important researches unfortunately have not been considered, nevertheless the subject has been treated in such a manner that the book will tend to stimulate the enthusiasm of students of organic chemistry.   T. B. J.

6. *Michelson's Ether Research.*—EMIL KOHL, after a close scrutiny of Michelson's celebrated experiment, concludes that a careful study of the formation of the interference lines which are the essential feature of this experiment is necessary before a conclusion can be reached in regard to the negative results. He calls attention to the importance of the factor of the distance; and discusses the questions which arise if ordinary light is employed instead of monochromatic, and recommends that the experiments should be repeated with attention to these points.—*Ann. der Physik*, No. 2, 1909, pp. 259-307.   J T.

7. *Influence of Pressure upon Thermoelectric Force.*—HEINRICH HÖRIG employed a pressure of 1400 kg/cm^{-2} and found that the thermoelectric force of a platinum mercury combination, which before pressure at $\Delta t = 150°$, gave an electromotive force of 10^{-6} volt per degree increase of temperature. When this thermo-element was submitted under the same conditions of temperature to a pressure—it gave for kg/cm^{-2} a change per degree Δt of $2 \cdot 18 \cdot 10^{-10}$ volt. The current direction of this pressure effect was opposed to the original thermoelectric effect, and up to a pressure of 1400 kg/cm^{-2} no deviation from proportionality with the pressure was observed. Similar results were obtained with a eutectic KNa alloy.—*Ann. der Physik*, No. 2, 1909, pp. 371-412.   J. T.

8. *Aluminum Cell as a Condenser.*—The use of this property of aluminum is attracting much attention in view of its possible practical use with alternating currents. J. DE MODZELEWSKI carried out experiments with a cell having aluminum anodes and Ni cathode in a six per cent ammonium bicarbonate solution and found that slow and gradual increase of voltage was necessary for a high degree of formation. The capacity of the condenser was about 15 mfd. The author indicates the need of preliminary forming at a low voltage. It is said that temperature plays an important part in the formation. The author does not refer to this fact.—*Lumière Electr.*, Aug. 8, 1908, pp. 187–188.   J. T.

9. *Changes in the Spectra of Gases submitted to the Magnetic Field.*—A. DUFOUR has studied the Zeeman effect in a number of rarified gases, and gives photographs of the normal and abnormal effects observed. He believes that the results obtained confirm the theory of the presence of negative and positive electrons. —*Physik. Zeitschrift*, Jan. 15, 1909, pp. 124–138.   J. T.

10. *Die elektrischen Eigenschaften und die Bedeutung des Selens für die Elektrotechnik;* von. CHR. RIES. Pp. 93, 52 figures. Berlin, 1908 (Administration "Der Mechaniker").— This volume of nearly 500 pages gives an interesting account of the properties of selenium, particularly as regards the connection

between the temperature and light and its electrical conductivity. This is a subject to which much attention has been given in the last decade, and numerous applications in the arts have been found, the most important of which are the light telephone and electrical tele-photography. These technical uses of selenium are well described and illustrated.

11. *Physics for Secondary Schools ;* by CHARLES F. ADAMS. Pp. 490. New York, 1908 (American Book Co.). *Elements of Physics ;* by GEORGE A. HOADLEY. Pp. 464. New York, 1908 (American Book Co.).—The above are new text-books, alike in their design to meet the requirements of College Entrance Boards and the various State and Association reports. They are interestingly written, are well illustrated and contain a large number of problems. Each contains an Appendix : that of the former including a discussion of variation and proportion, a table of natural sines and tangents and a table of constants for copper wire ; that of the latter, answers to problems and a summary of the fundamental formulæ.   D. A. K.

II. GEOLOGY AND NATURAL HISTORY.

1. *Iowa Geological Survey, Annual Report for 1907 ;* SAMUEL CALVIN, State Geologist. Vol. xviii, pp. 386, 16 plates, 41 figures. Des Moines, 1908.—The Iowa Survey is continuing its researches in the coal resources of the state and has undertaken investigations of the location, extent, and character of the peat deposits. Arrangements have also been made with the U. S. Geological Survey for coöperation in securing a topographic map for the entire state. In addition to the statistics of mineral production, the report for this year contains an important paper by Charles R. Eastman, on the Devonian Fishes of Iowa, treated under the following heads : Relations of Paleoichthyology to Biology ; Stratigraphy of the Devonian Fish-bearing Beds of Iowa ; Evolutionary History of Fishes ; Systematic account of Devonian Agnatha and Pisces including the subclasses Elasmobranchii, Holocephali, Dipneusti, Teleostomi ; Faunal lists. Three maps by Professor Schuchert showing the Devonian paleogeography are included in the illustrations.   H. E. G.

2. *Oklahoma Geological Survey ;* CHAS. N. GOULD, Director. Bulletin No. 1, Preliminary Report on the Mineral Resources of Oklahoma ; by CHAS. N. GOULD, L. L. HUTCHISON and GAYLORD NELSON. 80 pp., 11 figs. Norman, 1908.—The recently founded Oklahoma Survey is justifying its existence by a timely study of the economic resources of the state. Among other papers, the first volume includes preliminary reports on coal, oil and gas, asphalt, gypsum, salt, lead and zinc, glass sand, and building stones, including clay and Portland cement.   H. E. G.

3. *Glaciation of the Uinta and Wasatch Mountains;* by
WALLACE W. ATWOOD. U. S. Geological Survey, Professional
Paper No. 61. Pp. 93, 15 plates, 24 figures. Washington, 1909.—
"Every large canyon that heads near the crest of the range (Uinta)
has been glaciated," and evidence of at least two epochs of glacia-
tion appears. During the first epoch the lower limits of the ice
were 8,000 feet on the north side of the range and 7,000 feet on
the south; for the later epoch the corresponding figures are
8,400 and 8,000 feet. The maximum extent of glaciation in an
east-west direction was 82 miles, in a north-south direction 42
miles and within this area were one hundred and four glaciers over
a mile in length, eight of which were over 20 miles long, the
longest extending $27\frac{1}{2}$ miles.

In the Wasatch range there were 50 Pleistocene glaciers exceed-
ing a mile in length, extending on the east side of the range to an
altitude as low as 6,000 to 7,000 feet; on the west side 14 glaciers
reached an altitude of less than 6,000 feet and 7 of the 50 larger
glaciers reached the shores of Bonneville and parts of their
moraines are buried by lake deposits. A very interesting feature
of the work is the proof of at least two distinct glacial epochs
in the Wasatch, corresponding with the periods of humidity in
old Lake Bonneville.

Mr. Atwood's paper is an important contribution to glacial
geology and has given a definite quantitative form to the theories
and surmises of the 40th Parallel Survey.   H. E. G.

4. *Glacial Waters in Central New York;* by H. L.
FAIRCHILD. New York State Museum, Bull. 127, 1909. Pp. 61,
42 plates. Albany.— Previous papers by Professor Fairchild
have dealt in great detail with the Pleistocene history of central
New York. The present paper deals with the ice-border drain-
age, particularly with reference to its connection with the present
water bodies of this district. The tracing of the ice work in this
region necessarily involves detailed descriptions of local phe-
nomena, which serve as types of similar occurrences elsewhere.
The glacial lake succession in New York state is well brought
out by a series of maps which trace the water bodies through the
following stages: Local glacial lakes, Lake Newberry, Lake Hall,
Lake Vanuxem, free drainage, Lake Warren, Lake Dana, Lake
Dawson, Lake Iroquois. The maps and illustrations are up to the
high standard set by the New York Survey.   H. E. G.

5. *Ground Waters of the Indio Region, California;* by
WALTER C. MENDENHALL. U. S. Geological Survey, Professional
Paper 225. Pp. 53, 12 plates, 5 figures. Washington, 1909.—
Included in this report on the water resources of part of the
desert region of southern California is a geographic and geologic
sketch of the Colorado desert, a region made known by the
explorations of William P. Blake in 1853, since which time it
has been scarcely at all studied by geologists. Mr. Mendenhall
shows that the desert lowland, including the Gulf of Mexico, is
due to faulting,—part of it since the Tertiary beds were depos-

ited,—and that Santa Rosa ridge has the topographic character-
istics of a faulted block. The structure of the valley floor has
been determined and a study made of the origin and character
of the delta silts, consolidated Tertiary beds, sand dunes and
saline deposits.   H. E. G.

6. *Die Alpen im Eiszeitalter ;* von Dr. ALBRECHT PENCK
und Dr. EDUARD BRÜCKNER. In three vols., 1176 pp., 37 plates,
136 figures, 19 maps. Leipzig (Tauchnitz).—With the publication
of parts 9, 10, and 11, including the continuation of the study of
the glaciation of the southern and eastern Alps, this great work is
brought to its close. The concluding parts on Glacial Physiog-
raphy (pp. 1141–1152) and the chronology of the Ice Age (pp.
1153–1156) by Professor Penck present the prominent results of
glaciation in a clear manner and make it possible to compare the
glacial history of the Alps with that of other regions.

The first instalment of this work was issued in December, 1901,
and the concluding chapter bears the date of December, 1908.
While much of the field work on which it is based had been
previously done, new observations and development of new
theories have made it necessary to enlarge the original scope and
to delay, accordingly, the final completion of the work. As it
stands, it is probably the most important work on glacial geology
ever issued, not only for the detailed description and explanation
of this classic region for glacial study, but also for its contribu-
tions to the general science of glaciology.   H. E. G.

7. *Geological Survey of Western Australia ;* A. GIBB
MAITLAND, Government Geologist, 1908. Perth.—Two bulletins
have recently been issued by this organization, viz. : Bulletin 31,
Part I.—The Bonnievale and Kunanalling Districts, Coolgardie
Goldfield ; by CHAS. G. GIBSON, Assistant Geologist. Pp. 56
with 6 plates, 2 figures, 3 maps. Part II, The Black Range
District, East Murchison Goldfield. Pp. 65–116, 3 plates, 3 maps.
Bulletin No. 34,—Report upon the Auriferous Deposits of
Barrambie and Errolls (Cue District) and Gum Creek (Nannine
District) in the Murchison Goldfield ; also Wiluna (Lawlers
District) in the East Murchison Goldfield ; by CHAS. G. GIBSON.
Pp. 40, 3 plates, 3 maps, 6 photographs.

8. *Die Geologischen Grundlagen der Abstammungslehre;* von
GUSTAV STEINMANN. Pp. viii, 284. Leipzig, 1908 (W. Engelmann).
—The author is in the main reactionary and out of harmony with
the methods and explanation usually given as to the causes for
organic change. Lamarck and Goethe are his standard-bearers.
The book is dedicated to Lamarck and from his work he selects
as his text " All living families subsist in spite of their variation."
The historical method or the appearance of organisms in sequence
of time plus Steinmann are his main principles. Darwin's book,
he states, should not have been called " Origin of Species " but
" Changeability of Organisms." Through paleontology alone is
it possible to understand the changes that have taken place in the
organic world. To ask the object of an organ or an organization

and to attempt to explain the degree of their usefulness is unscientific.

The problems in the development of life are : (1) Disappearance of extensive groups of plants and animals ; (2) sudden and extensive development of new groups ; (3) absence of connecting forms between great groups of plants and animals, and (4) lack of understanding of the entire development of life. The first problem seemingly has its explanation in the inter-changing of sea and land and the resulting climatic variations ; paleontologic biota, on the other hand, are but fragments of former progressive and repressive assemblages. 2. Imperfection of the local and regional paleontologic records is more apparent than real ; present known record not only a fragmentary but very much scattered one ; new invading biota indicate lost records, elsewhere recoverable, therefore no actual sudden appearance of new groups. 3. Phylogenetic material as yet insufficient and too greatly scattered in museums ; of small groups there is much connecting material but none between classes, orders, etc. 4. Present methods of explanation not scientific and according to nature but philosophic.

Steinmann's phylogenetic-historic methods are peculiarly his own. He complains (wrongfully) about systematists basing their classification on single characters, thereby displacing the true relationships of forms. He would take the entire organism into consideration and group them historically. We will test his results along a single line, namely the Brachiopoda. The family Orthidae is said to be extinct since the Permian, but Steinmann would have us believe that descendants of this stock in *Dalmanella* still live in *Megerlea* and *Kraussina*. His progressive series are the orthid *Dalmanella*, the rhynchonellid *Rhynchonellina*, the terebratulids *Megerlea* and *Kraussina*, because all are said to have the same general external expression (homomorphic) while the arm supports are progressive from crura to loops. Testing this sequence in the light of chronology, we see that *Dalmanella* disappears with the Devonian while *Rhynchonella* does not appear until, and is restricted to, the Jurassic, and the other genera do not appear until the Tertiary. No attention is paid to the fact that *Rhynchonellina* is impunctate, while the punctate shell structure of *Megerlea* and *Kraussina* is very different from *Dalmanella*. Then too no orthid has deltidial plates while the development of the loop both ontogenetically and chronogenetically in *Megerlea* and *Kraussina* indicates beyond a doubt that these genera never arose in *Rhynchonellina* and not at all in *Dalmanella*.

The cemented bivalves Rudistidae are said to have the same general organization as the ascidians and the slight differences that exist are thought to be due to reduction in the latter, caused by prolonged (geological) sessility. Since Cretaceous times the Rudistid descendants have lost their shells and are now the ascidians. On the other hand, *Salpa* are shell-less brachiopods

that have originated in *Productus* through *Richthofenia*, a highly modified sessile productid.

Does progress lie along the path blazed by Steinmann ?

C. S.

9. *Mineralien-Sammlungen. Ein Hand- und Hilfsbuch für Anlage und Instandhaltung Mineralogischer Sammlungen;* von WOLFGANG PRENDLER. I Teil. Pp. viii, 220, with 314 figures. Leipzig, 1908 (W. Engelmann).—This is the first part of a work which is planned to aid those who are concerned with the installation of mineral collections. It gives, in connection with some practical instructions in regard to the collection of minerals, a clear and concise summary of the crystallographic and physical characters of crystals. A novel feature is the discussion of the arrangement of the collections, as regards cases, methods of arrangement, labeling, etc., which gives many useful hints not often found in print.

10. *Jadeite from Upper Burma.*—Dr. A. W. G. BLEECK has recently made a careful study of the occurrence of jadeite in the Kachin Hills of Upper Burma, and has presented some important points in regard to the origin of this much discussed mineral. It is found at three places, viz.: Tawmaw, Hwéka and Mamon, of which the first named is the most important and interesting. The jadeite there occurs in a dike of igneous origin which is intrusive in serpentine, the predominant rock of the plateau. Besides the discussion of the properties of the mineral itself, and the species associated with it, the conclusions of the author are presented as follows in regard to the question of its origin : "He concludes that the jadeite is the result of the metamorphism of an albite-nepheline rock originally forming the dike, both minerals being found together with the jadeite at Tawmaw. The change would be represented chemically as follows :

$$NaAlSiO_4 \text{ (Nepheline)} + NaAlSi_3O_8 \text{ (Albite)} =$$
$$2NaAlSi_2O_9 \text{ (2 Jadeite)}.$$
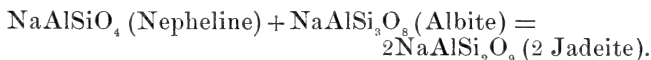
"Under certain conditions of crystallization nepheline-albite rock might form, while, under conditions of high pressure during consolidation or after, jadeite, which has a much lower molecular volume, would be produced, the residual molecule forming albite or nepheline according to which molecule was in excess in the original magma. In the neighborhood of Tawmaw occur various crystalline schists which are intruded into by granite. The granite is traversed by veins of aplite and pegmatite (products probably of the same great eruption) and masses of crystalline limestone are found associated with the granite rocks, containing various minerals characteristic of contact-metamorphism. The relations of the granite to the crystalline limestone in this region are similar to those of Mandalay Hill, Sagyin, and Mogok in the Ruby Mines district, where similar contact minerals, including the different varieties of corundum, are found in the metamorphosed limestone. The crystalline schists include chloritic schists

with well-formed crystals of magnetite, actinolite schists and glaucophane schists. These are all regarded by Dr. Bleeck as the metamorphic products of basic igneous rocks affected by the adjoining granite intrusions. The serpentines form a long narrow ridge, flanked on one or both sides by saussuritic-gabbros, saussuritic glaucophane-schists and chloritic schists. These rocks are traversed by granite and veins of quartz ; all the rocks are regarded as genetically related, and as the results of the differentiation of the same magma, which gave rise successively to the peridotites, gabbros, nepheline-albite (jadeite) rock and the siliceous end-products of granite and quartz."

"Dr. Bleeck finds that the eruptives, including the jadeite, are prominently represented among the bowlders in the Tertiary conglomerate, and thus must have become weathered to contribute to the Tertiary sediments."—*Records Geol. Surv. India,* xxxvi, pp. 254–285, with five plates ; also xxxvii, 16, 1908.

11. *Rubies from Upper Burma.*—Dr. A. W. G. BLEECK has examined the ruby deposits of Naniazeik, Myitkyina district, Upper Burma, which resemble these of Mogok described by J. W. Judd and C. Barrington Brown. The results are stated as follows: "Rubies are found in the soil and alluvial accumulations around the village of Naniazeik as well as in the river-gravels on the eastern slopes of the mountain ranges between Naniazeik and Manwe. This mountain range is composed mainly of granite and crystalline limestone, the latter having obtained its crystalline characters probably as stated before, through the intrusion of the granite. The limestone contains various minerals as the result of contact-metamorphism—garnet, spinel, chondrodite, graphite, forsterite, and other accessories, besides the valuable rubies and sapphires. The contact of granite and marble, exposed on the road from Sikaw to Naniazeik, shows the granite to assume a pressure structure near the margin, and to contain large quantities of phlogopite, which is a prominent mineral also on the marble side of the contact. The marbles, when freshly broken, have the characteristic evil smell of many limestones charged with nitrogenous organic matter. The marble is thus probably the result of the metamorphism of an ordinary sedimentary limestone of chemico-organic origin, but no data are obtainable to determine its age."—*Records Geol. Surv. India,* xxxvi, pt. 3, xxxvii, pt. 1, p. 18.

12. *New Group of Manganates.*—L. LEIGH FERMOR, following Laspeyres, concludes, from a study of psilomelane and related compounds, that there is a special family of manganates, corresponding to the acid H_4MnO_6. This includes *psilomelane,* the lead manganate *coronadite* of Lindgren and Hillebrand and the barium-iron maganate *hollandite,* from Kajlidongri and elsewhere in Central India.—*Records Geol. Surv. India,* xxxvi, 295, xxxvii, 16.

13. *Die Blütenpflanzen Afrikas : eine Anleitung zum Bestimmen der Gattungen der afrikanischen Siphonogamen ;* by FRANZ THONNER. Pp. xvi, 672, with 150 plates and a map of Africa,

showing the floral regions according to Engler. Berlin, 1908 (R. Friedländer & Sohn).—Although the flora of Africa has received a great deal of attention from systematic botanists, especially in Europe, there has been lacking a comprehensive work dealing with the plants of the entire continent. The present volume supplies this want, and is intended more particularly for the use of travelers and colonists, giving them the means whereby they may ascertain the names and relationships of the plants they meet with. For this reason it includes not only indigenous plants but also many that have been introduced, especially those that have become naturalized or are cultivated on a large scale. The work first gives a series of keys for the determination of the natural families. This is followed by a full characterization of the families, under which further keys are given leading to the determination of the genera. The families are arranged according to the widely adopted Engler-Prantl system, and under each family the number of genera and species· represented in Africa is noted. Although many of the generic characters are indicated in the keys, the genera themselves are not formally described, and no attempt is made to enumerate the peculiarities of the species. It is only in the case of economic plants, in fact, that the names of the species are given. In the numerous plates at the close of the volume a characteristic species from each of the more important families is represented. In an interesting summary the author estimates the number of phanerogams for the whole world at 136,000, of which no fewer than 39,000 are accredited to Africa.

A. W. E.

14. *Schwendeners Vorlesungen über mechanische Probleme der Botanik, gehalten an der Universität Berlin ;* by Dr. CARL HOLTERMANN. Pp. vi, 134, with portrait of Schwendener and 90 text figures. Leipzig, 1909 (W. Engelmann).—Professor Schwendener's lectures on the mechanical problems of botany give in a condensed form the results of his important investigations in a field of botanical science which he has made peculiarly his own. These lectures have been edited by his former pupil, Professor Holtermann, and are now made accessible to a wider circle of botanists through the publication of the present work. Among the topics treated, the following are perhaps the most important :— the mechanical system (skeleton) of plants, the theory of leaf arrangement, the upward flow of sap, the stomata, the twining of plants. Wherever possible the mechanical properties of the structures discussed are expressed by mathematical formulas.

A. W. E.

15. *Plant Study, with Directions for Laboratory and Field Work ;* by W. H. D. MEIER, Superintendent City Schools, Havana, Illinois. Boston, 1909 (Ginn & Company).—A series of loose sheets, held together in a binder ; 36 of the sheets give directions for laboratory exercises, abundant space being left for notes. The exercises are apparently designed to prepare the student for the analysis of plants, the last part of the series including a number of blanks for plant descriptions, spaces being left for the specimens themselves.

A. W. E.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The Carnegie Foundation for the Advancement of Teaching. Third Annual Report of the President,* HENRY S. PRITCHETT, *and Treasurer,* THOMAS M. CARNEGIE. Pp. 211. New York City, 1908.—The total capital of the Carnegie Foundation at the end of the year closing on September 30, 1908, was nearly $11,000,000, a million dollars having been added by successive accumulations since the original gift. The income of the year amounted to $530,300, of which $287,000 were expended, leaving the balance of $243,200 to be added to the capital. Of the amount paid for retiring allowances, $246,600, some two-thirds, went to professors, officers and widows in accepted institutions, and one-third was paid to those in institutions not on the regular list. Seven institutions have been added during the past year, making the total now sixty-two. A discussion of the cost of maintaining this retiring allowance system brings out the fact that the sum now paid is 5 per cent. of the active pay of all the professors in service in the sixty-two institutions; it is suggested that this amount is likely to increase somewhat in the future, but even in that case it seems small in view of the importance of the results obtained. The most important change introduced during the past year has been the admission of state universities, colleges and technical schools to the Foundation, Mr. Carnegie having added a sum of $5,000,000 to the original gift. There are some eighty-three institutions included in the list given of tax-supported institutions in this country and Canada. It is to be noted, however, that in order that an institution should get the benefit of the endowment it must be of the requisite academic grade and, further, it is necessary that the application made should be approved by the Governor and by a special vote of the legislature of the state.

An interesting work undertaken in connection with the Foundation is the exchange of teachers between Prussia and the United States. This plan involves the sending of a number of college or high school teachers from this country to Prussia, and the coming of a like number of gymnasium teachers to the United States. The instruction is intended to be supplementary to that ordinarily given, including the informal teaching of the language of the country from which the teacher comes, as also of its ideals and customs, school regulations, etc. The teacher himself is expected to gain much in experience and breadth of view from his life in the foreign country. The amount of money involved is small : for example, Prussian teachers receive leave of absence from their government, with pay and traveling expenses, receiving, also, from the college or high school in America where they are stationed, some $200 or $400, according as the length of service is a half year or an entire year. A list of seven Prussian teachers is given, who have already been assigned to different American schools, and of eight American teachers who have been

accredited to Prussian schools. The next assignment of teachers to Prussia will be made in June 1909, for the semester beginning with October 1.

In addition to the interesting detailed statements in regard to the special work of administering the Carnegie Foundation, Dr. Pritchett contributes also a series of chapters on various university and college questions, which are most suggestive, and which should be carefully considered by those engaged in such work. Some of the topics discussed are the following : Progress toward unity in college requirements for admission ; the admission of conditioned and of special students ; class room and laboratory instruction by teachers ; the support and organization of higher education ; the standards of professional education in the United States. An account is also given of the various denominational boards engaged in regulating education.

Great as is the value of the work accomplished by the Carnegie Foundation for our higher educational institutions in granting retiring allowances to teachers, it is obvious that, under Dr. Pritchett's wise and enlightened administration, its usefulness is extending out into a much broader sphere, and will bring about higher standards and more uniformity in ideals and methods.

2. *Carnegie Institution of Washington.*—Recent publications of the Carnegie Institution are given in the following list (continued from vol. xxvi, pp. 519).

Year Book No. 7, 1908. Pp. vii, 240, with twelve plates. February, 1909.—Noticed on p. 267.

No. 85. Index of Economic Material in Documents of the United States, California, 1849–1904. Prepared for the Department of Economics and Sociology of the Carnegie Institution of Washington ; by ADELAIDE R. HASSE. Pp. 316, 4to.

No. 90. Guide to the Manuscript Materials for the History of the United States to 1783, in the British Museum, in minor London Archives and in the Libraries of Oxford and Cambridge ; by CHARLES M. ANDREWS and FRANCES G. DAVENPORT. Pp. xiv, 499.

No. 93. The Rotation Period of the Sun, as determined from the motions of the Calcium Flocculi ; by GEORGE E. HALE and PHILIP FOX. Pp. 54, with 2 plates, 4 figures.—The investigation of calcium flocculi has led to the conclusion that the rotation periods for different latitudes show the existence of an equatorial acceleration similar to that previously observed in the case of sun-spots, faculæ and the reversing layer. This acceleration, approximately stated, varies uniformly with the latitude. No definite conclusions can be drawn as to the relative velocities of the different phenomena named.

No. 96. Condensation of Vapor as induced by Nuclei and Ions. Third Report ; by CARL BARUS. Pp. vi, 139. With 49 text figures.

No. 97. Supplementary Investigations of Infra-red Spectra : Part V, Infra-red Reflection Spectra ; Part VI, Infra-red Trans-

mission Spectra; Part VII, Infra-red Emission Spectra; by WILLIAM W. COBLENTZ. Pp. 183, with 107 figures.

No. 98. The Topography of the Chlorophyll Apparatus in Desert Plants; by WILLIAM AUSTIN CANNON. Pp. 42, 15 figures and 5 plates. The Induction, Development, and Heritability of Fasciations; by ALICE ADELAIDE KNOX. Pp. 20, 1 figure and 5 plates.

Nos. 102, 103. Papers from the Tortugas Laboratory, Department of Marine Biology of the Carnegie Institution of Washington, ALFRED G. MAYER, Director. In two volumes, Vol. I, pp. 190; Vol. II, pp. 325.—These volumes contain nineteen papers by H. E. Jordan, W. K. Brooks, A. G. Mayer and others.

No. 106. The Gases in Rocks; by ROLLIN THOMAS CHAMBERLIN. Pp. 80, with 2 text figures. Noticed on p. 190.

3. *Report of the Superintendent of the Coast and Geodetic Survey*, O. H. TITTMANN, *showing the Progress of the Work from July 1, 1907, to June 30, 1908.* Pp. 169, 4to, with 9 illustrations in pocket. Washington, 1908.—This Report gives a summary of the work of the Survey during the last year. The most important feature of this is the completion of the reconnaissance for the extension of the primary triangulation from the 98th meridian in Central Texas across Mexico and California, to the triangulation of the same class which extends along the Pacific coast across California, Oregon and Washington. This reconnaissance extends along the arc of the parallel for a distance of about 1200 miles. The completion of the triangulation along the 98th meridian is also an interesting completion of the year's work extending across the country from Canada to Mexico; this arc has been also extended into Mexico. It is further stated that Canada has begun a geodetic survey, so that the work of the International Geodetic Association for the study of the earth and other related problems is being steadily pushed forward. Much progress has also been made during the year on the boundary line between the United States and Canada, and on the Alaska-Canada boundary. Appendix 3 (pp. 69–165), by R. L. Faris, gives the results of the magnetic observations of the year.

4. *Principal Facts of the Earth's Magnetism and Methods of Determining the true Meridian and the Magnetic Declination.* Pp. 96 with 28 figures. Washington, 1908.—The edition of the paper issued by the U. S. Coast and Geodetic Survey on the Declination Tables for 1902 having been exhausted, the publication has now been issued in revised form with such corrections as were necessary. The scope of the work makes it of great general interest, since it is, in fact, a full and readable presentation of the principles of the magnetism of the earth, giving a digest of the subject, with many illustrations, from the earliest historic times. It is not surprising that so interesting a summary of this important subject should have found many readers.

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THE

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AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

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Art. XXVIII.— *Weathering and Erosion as Time Measures ;* [*]
by Frank Leverett.

The writer presented a paper, under the above title, at the Baltimore meeting of the Geological Society of America, which set forth the advantages of estimates of weathering and erosion in making correlations between the drift sheets of Europe and America. Since the correlation of European with American drifts is to be presented as a special paper in the international glacial magazine, Zeitschrift für Gletscherkunde, the present paper will aim only to set forth the value of weathering and erosion in making correlations, and will be restricted mainly to our American deposits. The topographic sheets now published embrace each of the drift formations to a sufficient extent to enable the student to use them in comparing glacial formations of different age. They will thus serve a valuable purpose in the class room. The present paper will fulfill its mission if it helps to a proper understanding of topographic sheets illustrating each of the glacial drifts.

There are certain situations in which the student is able to determine, by erosion alone, the relative ages of the different drift sheets. This can be done where the surface of the drift was left in a flat or featureless condition so that the present reliefs are almost wholly the result of stream action, and it is especially valuable where the streams have been working under sufficiently high gradient to admit of the cutting of well-defined channels. There are places where stream gradients are so low that little or no deepening of the drainage lines has occurred. In such situations and in situations where the drift topography is of a ridged or complicated character, weathering naturally is made a leading criterion for judging of relative

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

ages of the drift sheets under comparison. The rapidity of weathering is especially great in fragmental formations, such as the glacial and fluvial deposits, since a multitude of faces are exposed for attack. It is thus possible to distinguish lesser differences in age than would be detectible in the solid formations. Weathering of glacial material or of fluvial material will reach depths to be measured in feet and meters, while that in rock formations may reach only a few inches or centimeters.

There are certain complications in these studies resulting from differences in climatic conditions and differences in the constitution of the drift which have to be properly considered in forming the estimates. Leaching goes on so much more rapidly under humid conditions than under semi-arid that one may easily be misled if he depends entirely upon the depth to which the leaching extends. In the same way erosion studies are liable to be misleading if one does not take into account differences of rainfall, in stream gradient, and in the texture of the deposits. It is necessary also, in glaciated regions, to ascertain the work accomplished by the drainage from the ice sheet, in order to properly compare the work done by the present streams on drift sheets of different age.

In the glaciated portions of North America there are, fortunately, extensive plains of Kansan, Illinoian, and Wisconsin drift and of glacial lake beds, whose conditions of rainfall, stream gradient and texture of deposits, are sufficiently alike to afford excellent subjects for time estimates based on weathering and erosion. It is not claimed that these studies will give time measures definitely expressible in thousands of years, at least not in the present state of our knowledge; but it is thought that a sufficiently reliable measure of relative age is afforded to form a basis for wide correlations, such as those between the American and European drift sheets.

The table here presented gives the names applied to the several members of the glacial series in each prominent field of Pleistocene glaciation. Some of the lesser fields, west of the Rocky Mountains, may have a similar complexity, but this has not been so fully established. The Skandinavian field has had a great variety of interpretations and stills awaits a satisfactory nomenclature. It will, perhaps, serve our purpose best to make use of the terms employed by the German geologists, though here it must be understood that the earlier literature is not fully in harmony with the later. The order of arrangement in the table is from younger to older in each field.

Table of drift sheets.

Keewatin	Labrador	Skandinavian	Alpine
Wisconsin	Wisconsin	Upper Diluvium	Würm
Iowan ?			
Illinoian ?	Illinoian	Middle Diluvium	Riss
Kansan	Kansan ?	Lower Diluvium	Mindel
Pre-Kansan*	Jerseyan		Gunz

Wisconsin Drift.

In the first attempts by Chamberlin and others to show the complexity of the glacial deposits but two drift sheets were recognized, the earlier and the later, and of these the later embraces what is now known as Wisconsin drift. Its aspect is everywhere much fresher or younger than that of the outlying and underlying drift sheets, so that it can easily be distinguished from them. With the progress of the study it became evident that considerable complexity of ice movement was involved in producing the many moraines of this later drift. The moraines do not form throughout a concentric series, such as one would expect to find had the ice made a simple retreat from its field, with halts at places where moraines occur. Instead, there are groups of concentric moraines which have a trend out of harmony with other groups, resulting in a partial overriding of the earlier by the later. From this it is inferred that the ice made shiftings in its directions of movement, such as call perhaps for some change in its center of accumulation.

The earliest group of these moraines of later drift has been termed the Earlier Wisconsin, while the remainder of the moraines are thrown together under the name Later Wisconsin. The principal exposure of the Earlier Wisconsin is in Illinois, but it has a slight extent beyond the Later Wisconsin in Indiana and Ohio and possibly also in Wisconsin. Whether it is exposed in states farther west has not been determined. The amount of weathering and erosion which the Earlier Wisconsin has undergone differs so little from that experienced by the Later Wisconsin that we may feel sure that no interval of great length separates them. The knolls and basins along the moraines of the Earlier Wisconsin are toned down by erosion and filling so that only the larger ones are well-defined, whereas in the Later Wisconsin the small hummocks and basins still preserve their sharpness of contour. But in the Earlier Wisconsin as in the Later there are wide areas not yet invaded by drainage lines, as may be seen by reference to the Danville, the Urbana, and the Mahomet,

* The Pre-Kansan is sometimes termed Sub-Aftonian.

Illinois, topographic maps.   If one should place these maps besides those of quadrangles inside the Later Wisconsin, as for example the Marion, Sycamore, Upper Sandusky and Arlington sheets in northwestern Ohio, it would be difficult to discover any difference in the character of drainage.   The amount of weathering, however, is perceptibly greater in the Earlier

Fig. 1.
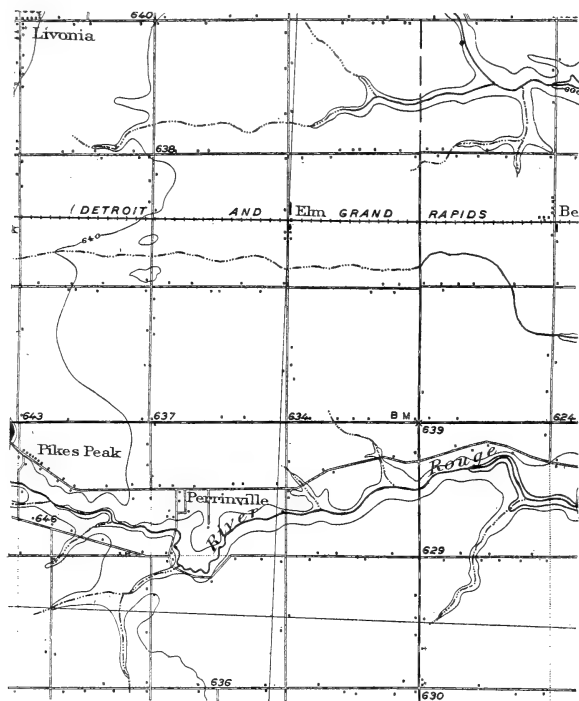
Fig. 1.   Part of the Wayne, Michigan, topographic sheet, illustrating the slight amount of erosion characterizing the beds of the great glacial lakes. Scale, 1 : 90000.   Contour interval, 20 feet.

than in the Later Wisconsin, it being rare to find unleached till on the plains of the Earlier Wisconsin at a depth of less than a meter, whereas on the Later Wisconsin it is frequently found at ½ meter or less, and the average depth of leaching in the Later Wisconsin scarcely reaches a meter.   It is, therefore, chiefly by the weathering and by toning down of the slight inequalities that the Earlier Wisconsin is distinguished from the Later.

The erosion of the Later Wisconsin drift, compared with that of the beds of the large glacial lakes which occupied its surface during the recession of the ice from the St. Lawrence basin, is sufficiently more advanced to be perceptible on many of the topographic maps. The sections of the two maps here introduced serve to bring out this difference (see figs. 1

Fig. 2.
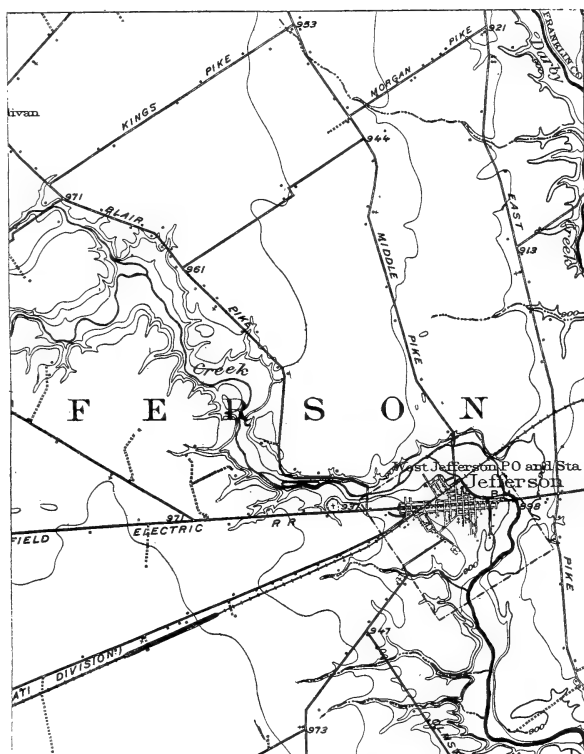
Fig. 2. Part of London, Ohio, topographic sheet, illustrating the amount of erosion ordinarily found on a plain of Wisconsin drift where the slope is sufficient to favor a somewhat rapid development of drainage lines. The incipient stage of development testifies to the recency of the Wisconsin glaciation. Scale, 1 : 93700. Contour interval, 20 feet.

and 2). Fig. 1, which represents a portion of the lake plain in southeastern Michigan, shows the drainage lines to have developed very few tributaries as well as to have cut only insignificant valleys. Fig. 2, which represents the Wisconsin drift in the western portion of Scioto basin in Ohio, shows a slightly deeper valley cutting and the beginning of numerous

tributary valleys.   The tributaries, however, are in a very incipient state of development.   This map near West Jefferson, Ohio, serves to indicate that fully nine-tenths of the drift plain still stands at its original level, and this is true over a large part of the surface of the Wisconsin drift.   In fact there are considerable areas in which less than one-tenth of the surface has been lowered or reduced in any way by drainage lines.

Areas in which the topography of the Wisconsin drift and the Post-Wisconsin erosion may be studied without much complication with rock topography have already been mapped in nearly every state from Massachusetts to North Dakota. Thus a considerable part of southeastern Massachusetts, including the islands of Marthas Vineyard and Nantucket, much of Long Island in New York, as well as the greater part of the plain east and south of Lake Ontario, nearly all the northwest one-fourth of Ohio, the quadrangles mapped in southeastern Michigan, northeastern Illinois and southeastern Wisconsin (except the Broadhead, Janesville and Shoppiere sheets in Wisconsin), the area around Minneapolis and St. Paul, Minnesota, the area north and west of Des Moines, Iowa, certain sheets in the James River valley in South Dakota, and those in the eastern part of North Dakota, may be drawn upon for illustrations.   It will be observed that the morainic areas of southeastern Michigan, southeastern Wisconsin, and in the vicinity of St. Paul, Minnesota, embrace much poorly drained land represented as swamp, whereas such swamp areas are of small extent in northwestern Ohio, northeastern Illinois, and in the region bordering Lake Ontario.   This should not be interpreted to indicate that the less swampy areas owe their condition to greater age.   It results instead from a more favorable original condition for shedding the water or from a different ground-water condition.

There are extensive areas in New England, as also in New York and in Ohio, where rock ridges are prominent, in which the Wisconsin glaciation has served to produce what has been termed by Salisbury superimposed youth.*   In these areas the drainage lines are often as poorly developed as in areas of the Wisconsin drift, where the rock irregularities are completely buried, and they indicate to the physiographer a similar youthfulness.   Such areas, however, are not so satisfactory as the smooth areas of heavy drift for determining the relative age of the different drift sheets.

The character of the glacial drainage of the Earlier Wisconsin appears to have been different from that of the Later Wisconsin, there being no extensive outwash gravel plains associated with the Earlier Wisconsin moraines such as charac-

* Journal of Geology, vol. xii, pp. 711-713, 1904.

terize portions of the Later Wisconsin moraines of the same general region. This fact, and the fact that the outer portion of the Earlier Wisconsin drift in Illinois carries a thin coating of loess, is thought to indicate that a certain degree of aridity prevailed during the culmination and the withdrawal of the ice of this early part of the Wisconsin stage of glaciation. The relatively arid conditions may account to some degree for the poor development of drainage lines, which otherwise seem rather inconsistent with the amount of toning down of knolls and filling of basins which took place on the Earlier Wisconsin moraines. The filling of basins would be accomplished rapidly under conditions of aridity, as is exemplified in our arid western region. It is well, therefore, to keep this climatic factor in mind when making a comparison of the amount of erosion of the Earlier Wisconsin drift with the somewhat younger Later Wisconsin drift.

As may be seen from the above table (p. 351), the Wisconsin drift is the only one of the series named in the Labrador and Keewatin fields which is correlated with certainty. There is a continuous belt of moraines connecting the Labrador and Keewatin fields, but these moraines are of Later Wisconsin age, and it yet remains to be determined whether the Earlier Wisconsin drift is exposed outside the Later Wisconsin in the Keewatin field.

Probable European Correlatives of the Wisconsin Drift.

In the European fields, Skandinavian and Alpine, and also in Great Britain, there is a drift sheet which corresponds closely in the amount of weathering with our Later Wisconsin drift, while certain of the outer moraines of the north German lowland and of Great Britain seem to correspond with our Earlier Wisconsin. The complexity of the last stage of glaciation seems, therefore, about as great in northwestern Europe as in North America. In the Alps the Würm drift has a freshness of contour very similar to that of the Later Wisconsin moraines, while the " Verwaschene Würm," which lies outside the Würm proper at a few points in northern Switzerland, and also at a few points on the southern side of the Alps, has a similar toning down to that displayed by our Earlier Wisconsin moraines, of which it may prove to be the correlative.

The Upper Diluvium of the North German Lowland is much more extensive than the limits assigned by Geikie to the fourth or Mecklenburgian drift. The great Baltic ridge seems, as has been interpreted by several German geologists, to lie well within the limits of the last glaciation, though it certainly

marks a very important position of the ice border, whether a mere halt or a readvance is not yet clear. The results of my own studies are in full accord with those of the German students in placing the limits of the last glaciation far enough south to embrace the prominent moraines along the south border of the region characterized by lakes.

Illinoian Drift.

The Illinoian drift of the Labrador icefield is exposed outside the limits of the Wisconsin drift in Illinois, Indiana, and Ohio, and at its farthest extent reached slightly into Iowa.* The entire outlying portion of this drift is covered by loess except a small district in northwestern Illinois and southern Wisconsin, where the loess is of rather patchy distribution. Beneath the loess there are widespread occurrences of a black soil and muck known as the Sangamon soil, which rests upon the leached surface of the Illinoian drift. It thus appears that the Post-Illinoian history is somewhat complex. The occurrence of the black soil and muck is suggestive of cool, damp conditions, while the overlying loess suggests conditions of aridity. The loess is found to pass beneath the outermost moraines of the Earlier Wisconsin drift and hence antedates the Wisconsin ice invasion.†

The leaching which the Illinoian drift has experienced appears to have been largely accomplished prior to the deposition of the loess, for the loess is sufficiently thick over much of the Illinoian area to preserve an unleached basal portion. Yet in spite of this cessation of the leaching at the time of the loess deposition it had reached a depth, and weathering had gone to a degree, far in advance of the leaching and weathering thus far experienced by the Wisconsin drift. The removal of calcareous constituents, pebbles as well as fine material, was nearly complete to a depth of 4 to 6 feet, while weathering often extended to two or three times these depths. Indeed pipes and weathered seams extend far down into the unleached portion, as is not found to be the case in the Wisconsin drift. One cannot well escape the conclusion that the time involved in this leaching was at least two or three times as great as that of the Wisconsin, and it may considerably exceed this amount. In addition to the weathering and leaching there is a general induration of the entire deposit, produced probably by a partial cementation, a feature which is very sparingly exhibited by the Wisconsin drift.

Turning now to the amount of erosion which the Illinoian

* See The Illinois Glacial Lobe, Monograph xxxviii, U. S. Geological Survey, 1899, pp. 24–130. Also Monograph xli, 1902, pp. 253–294.
† See Monograph xxxviii, pp. 128–129 and plate xi.

drift displays, we find that where drainage gradients are good it far exceeds that displayed by the Wisconsin drift. An excellent topographic sheet for comparing the erosion of the Illinoian with the Earlier Wisconsin is that of the Peoria, Illinois, quadrangle, the western portion of which shows Post-Illinoian erosion, while the eastern portion shows Post-Wisconsin erosion. In studying this sheet, however, it should be borne in mind that the Wisconsin drift area is morainic and more elevated than the Illinoian, and thus has a great advantage in the rapidity of shedding its water; but in spite of this advantage the extent of the erosion is far less than in the Illinoian drift.

Topographic sheets that lie entirely within the Illinoian drift area are the Springfield, Eldorado and Belleville, Illinois, sheets. The Belleville topographic sheet is of especial interest since it exhibits the contrast in the work of streams under different gradients. The western portion, a section of which is here reproduced in fig. 3, illustrates the appearance of the drainage when under a good gradient, while fig. 4, taken from the southeast part of the same quadrangle, illustrates drainage under a low gradient. It will be observed that Silver Creek (in fig. 4) has a broad valley in which abandoned courses of the stream testify to the sluggishness of the drainage and suggest that aggradation rather than channeling is now in progress. The entire Eldorado topographic sheet is in a region of low drainage gradient, while the Springfield sheet represents a region of more rapid drainage gradient. The series is, therefore, very instructive in setting forth the amount of variation that may be found on a drift formation of a given age.

To properly compare the Illinoian erosion with the Wisconsin one must select areas in which drainage conditions are similar, and also where no inequalities of drift surface, such as moraines, etc., come in to give complexity. Figs. 2 and 3 represent fairly well the development of drainage under similar conditions of slope. The conditions are perhaps more favorable in the area represented by fig. 2 for the rapid development of drainage than in fig. 3, yet the stage of drainage development in fig. 3 is advanced far beyond that in fig. 2. The writer has estimated that in the portion of the Illinoian drift in western Illinois and southeastern Iowa, where the conditions for development of drainage are the best, that approximately one-half the surface has been reduced below the original level as a result of the drainage, while in the Wisconsin drift, as already indicated, scarcely one-tenth of the surface has been thus reduced. It is evident that the time required for developing the drainage found on the Illinoian is much greater than that on the Wisconsin on the assumption that the climatic

conditions have been uniform and similar to the present conditions. It is probable, however, that a period of aridity came in at the time of the loess deposition, and this would lengthen materially the time required for the development of the drainage lines in the Illinoian drift.

The presence of a drift sheet of Illinoian age in the Keewatin field is still open to question. The only deposits sus-

Fig. 3.
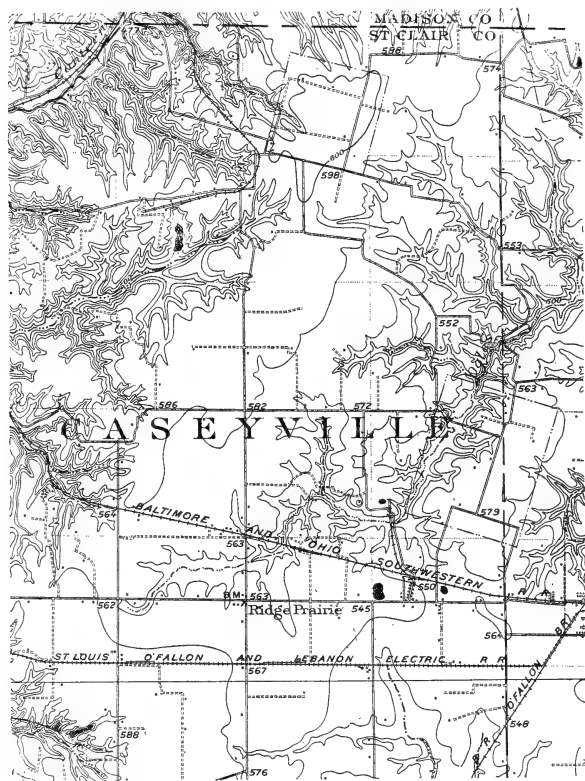
Fig. 3.   Part of the Belleville, Illinois, quadrangle, showing Post-Illinoian drainage under a fair stream gradient.   Scale, 1 : 93700.   Contour interval, 20 feet.

pected to be of Illinoian age, so far as yet noted, are found in southeastern Minnesota and neighboring parts of Wisconsin, just outside the limits of the Wisconsin drift, and these have not as yet been given sufficiently close study to clear up their relations to the broad sheet of Illinoian drift of the Labrador field.

European Correlatives? of the Illinoian Drift.

From their position in the series one would naturally expect to find correlatives of the Illinoian drift in the Middle Diluvium of north German lowland and the Riss drift of the Alpine region. But neither the Riss nor the Middle Diluvium was found to bear a close resemblance to our Illinoian drift. These European drifts are commonly weathered to a depth of

FIG. 4.
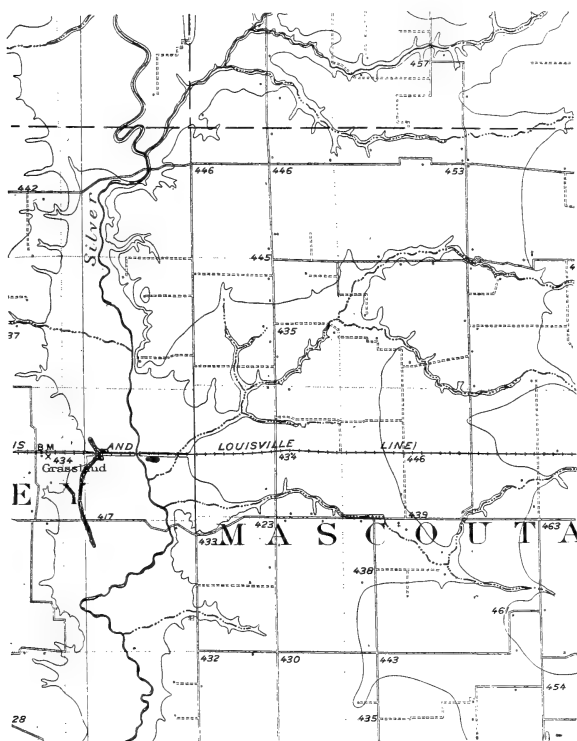
FIG. 4.   Part of the Belleville, Illinois, quadrangle, showing Post-Illinoian drainage under a very low stream gradient.   Compare the small amount of dissection of the drift plain with that in fig. 3.   Scale, 1 : 93700.   Contour interval, 20 feet.

only 3 or 4 feet and there is a very abrupt change to fresh-looking drift at the base of the weathered portion. Were the upper part to the depth of a meter stripped off from these drifts one would find difficulty in distinguishing the Riss from the Würm, or the Middle Diluvium from the Upper Diluvium. The induration of the deeper portion, so generally found in

the Illinoian, is not seen in the Riss and the Middle Diluvium, nor is there the deep penetration of weathered pipes and seams into the unweathered portion. The Riss moraines have not the sharp hummocks that characterize the Würm moraines, but the contrast is not much more striking than is found between our Earlier and Later Wisconsin moraines. The impression one obtains is that the Riss and the Middle Diluvium have reached a condition of weathering intermediate between our Earlier Wisconsin and our Illinoian drifts. Further study into climatic conditions in the several fields and into the constitution of the drift deposits may serve to remove some of the difficulties of correlation. Portions of the area of the Middle Diluvium lying east of the Harz Mountains have at present a very light rainfall, which seems to produce less leaching than is accomplished in more humid districts to the west. Possibly long continued aridity will account for the lack of deep penetration of weathered pipes and seams. At present waters charged with calcareous constituents rise into the soil by capillary action and tend to keep it well supplied with calcareous material. Prof. Keilhack reports that the calcareous material is in the form of a coating on the grains of silica, feldspar, etc., and not in the form of grains or coarse particles of limestone. In other words, the present calcareous content is secondary.

So far as inferences can be drawn from relative amounts of erosion these European drifts differ but little from the Illinoian in the places where erosion conditions are similar as to gradient and texture of deposit. The erosion of the high terraces (Hochterrassen), which connect with the Riss moraines of the Alpine region, seems to be about as great as the ordinary erosion of the Illinoian drift under good stream gradients. The erosion of the Middle Diluvium has been sufficient to remove nearly all traces of the deposit along the borders of the main drainage lines, which compares favorably with the amount of erosion in our Illinoian drift.

Kansan Drift.

The Kansan drift, which is the most extensive sheet of the Keewatin field, is widely exposed in northern Missouri, southern and western Iowa, and neighboring parts of Kansas and Nebraska. Its northern portion is concealed by the Wisconsin drift. The greater part of this drift, like the Illinoian, is covered by loess. Some of this deposit may be older than the Illinoian drift, at least loess has been found between the Kansan and the Illinoian in the district along the Mississippi where the Illinoian overlaps the Kansan drift. A large part of the loess, however, seems to be of the same age as that which

covers the Illinoian drift, and seems to have been deposited after the Kansan drift had been very greatly eroded, for it covers the valley terraces and valley slopes as well as the uplands, and appears deep down in the valleys in positions that can scarcely have been reached by a secondary deposition or by a creep of the deposit. Beneath the loess on the remnants of the old drift plain, preserved between the valleys, one finds a black soil and muck similar to that at the junction of the loess and the Illinoian drift. The region seems, therefore, to have had alternations of wet and dry climates which will complicate to some extent the estimates of erosion. So far as the time element is concerned the periods of aridity will render the length of the Post-Kansan time greater than that required for the mere cutting of the valleys under present conditions of precipitation. The presence of two sheets of loess would seem to call for two periods of aridity.

The topographic maps of northeastern Missouri, from which figs. 5 and 6 are taken, represent a region where the erosion is almost entirely in glacial deposits, the rock surface being deeply buried. It will be observed that a large part of the original Kansan drift plain has been destroyed, the plain being preserved only in narrow tabular divides, such as that on which the towns of Atlanta and Memphis stand. The valley slopes as well as valley bottoms are very broad. The slopes are so toned down as to be generally below an angle of 5° and not uncommonly are reduced to 3° or even less. By reference to figs. 5 and 6 it will be seen that the 20-foot contours are generally broadly spaced, so that four contours, or 80 feet elevation, occupy a breadth of one-fourth to one-half mile on a valley slope. On streams of comparatively small drainage area the valley bottoms frequently exceed a mile in breadth. In the region covered by these maps and in much of northern Missouri and southern Iowa narrow tabular remnants of the original drift surface are preserved. But as one passes from the tributaries of the Mississippi westward to the tributaries of the Missouri these tabular remnants gradually dwindle and in the vicinity of the Missouri valley entirely disappear. The tributaries of the Missouri have some advantage in directness of drainage, which probably partially accounts for the more advanced state of drainage erosion. There may also have been a flatter surface in the vicinity of the Mississippi, since the underlying limestone there was left with broad tabular surfaces at the oncoming of glaciation, while the sandstone areas to the west were broken up into ridges and hills. The tabular divides in the drift surface, however, do not coincide with preglacial divides in the limestone surface, nor are they restricted to the limestone area, but extend westward some distance into the

sandstone area.   The average amount of removal of drift in Post-Kansan time is estimated to be somewhat more than 50 feet, at least it would take more than that amount to bring the valleys up to a level with the tabular divides.   This is apparent from the sections of maps here presented, and was carefully worked out in the field in a neighboring county of Iowa by Dr. C. H. Gordon, while connected with the Iowa

FIG. 5.
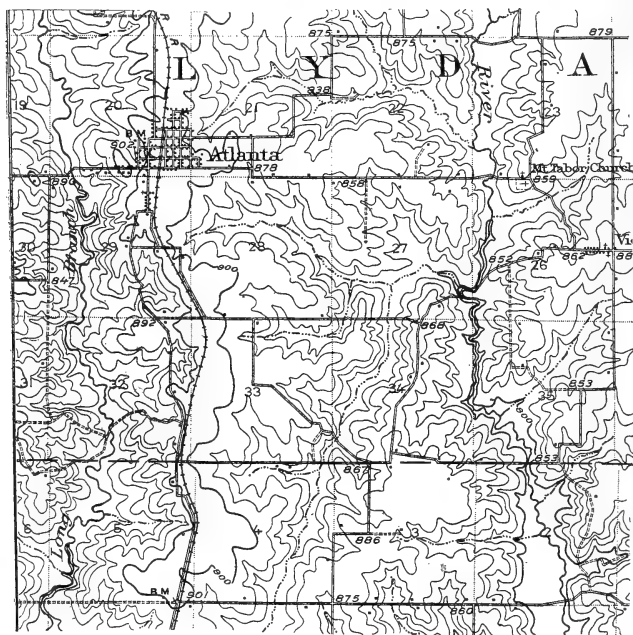
FIG. 5.   Part of the Atlanta, Missouri, topographic sheet showing Post-Kansan drainage.   Scale, 1 : 86500.   Contour interval, 20 feet.

Geological Survey.   To the question whether the streams may have begun their work in depressions somewhat below the level of the tabular divides, it is remarked that the lack of correspondence between the tabular drift divides and the preglacial rock divides, together with the consistent fitting in of each tabular divide with its neighbors to form a plain sloping in the direction of drainage, as well as the evidence to be gathered from the lateral drainage, gives a strong presumption that the surface was brought up very nearly to a plain of the kind preserved in the tabular remnants.

The Kansan drift, in places where erosion has been at a minimum, as on the tabular divides, has a weathering to a depth of several meters. There is more or less complete removal of limestone pebbles as well as of finer calcareous material to an average depth of $1\frac{1}{2}$ to 2 meters. Apparently the deposit originally was as calcareous at its surface as in its unleached portion. It lies in a region where limestone formations have extensive outcrops and there are numerous calcareous

Fig. 6.
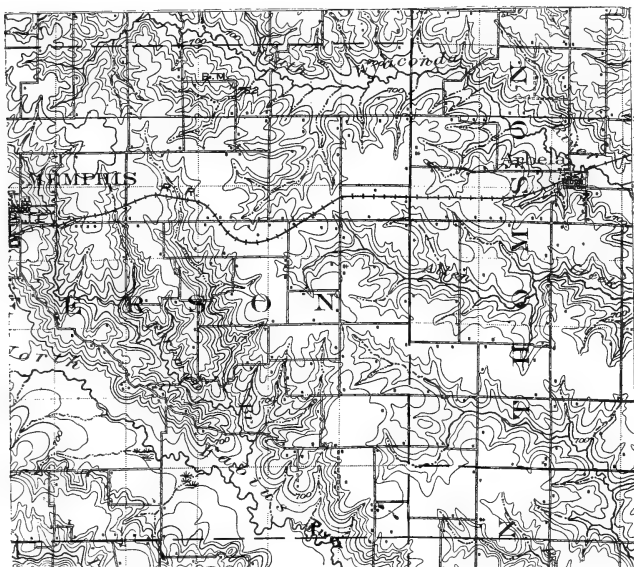
FIG. 6. Part of Edina, Missouri, topographic sheet showing Post-Kansan erosion. Scale, 1 : 173000. Contour interval, 20 feet. The map on this scale is introduced for purposes af comparison with that of the so-called Iowan, fig. 7, which has the same scale.

nodules at the base of the leached part testifying to a contribution of lime from it. The uppermost half meter of the leached portion is often of a decidedly red tinge, below which is a transition through brown to yellow and finally to gray or blue in a space of 4 to 6 meters or more. The statements just made represent conditions in the humid Mississippi valley where there is an average rainfall of about 40 inches. But as one passes westward into the semi-arid districts along and west of the Missouri River, the amount of leaching in this drift sheet is found to become markedly less, and that too where erosion has been fully as great as in the Mississippi valley.

The best sheets to illustrate the Post-Kansan erosion are the Atlanta, Edina, and Kahoka, Missouri, quadrangles, not only because the drift there is sufficiently thick to dominate the topography but also because the maps are better executed than older contour maps of eastern Iowa and eastern Nebraska. The DesMoines, Iowa, and Waukee, Iowa, topographic sheets are, however, recent and of a high standard, and they serve to exhibit the contrast between the erosion of the Kansan and the Wisconsin, the southern edges of the maps being within the limits of the Kansan drift, while the remaining, much less eroded portion is in the Wisconsin drift.

As to the length of the Post-Kansan period of weathering and erosion compared with that of the Post-Wisconsin, only a rough approximation is likely to be reached by measurements of the changes effected in the two drifts. Dr. H. F. Bain has made a computation of the relative size of valleys in the Kansan and in the Wisconsin drift in the vicinity of Des Moines, Iowa, and ascertained the capacity of the Post-Kansan valleys to be about seventeen times that of the Post-Wisconsin.[*] While a considerable time must necessarily be allowed for a drainage system to get well started and thus correspondingly lengthen the Post-Wisconsin time and reduce the difference in the age of the Wisconsin and the Kansan drift, the periods of aridity through which the Kansan drift has passed prior to the Wisconsin stage of glaciation may fully offset this lengthening of the Post-Wisconsin time.

The question of a correlative of the Kansan drift in the Labrador field is considered below in connection with the discussion of the Pre-Kansan drift.

European Equivalents of the Kansas Drift.

In each of the glaciated districts of Europe a drift sheet is found in which the weathering is strikingly similar to that of the Kansan drift. In the Alpine region the apparent correlative is the Mindel drift; in north Germany it is the Lower Diluvium, the drift formed at the maximum extent of the Skandinavian ice field, when it reached the recesses of the mountainous districts of Silesia and Saxony ; in Great Britain it is the chalky bowlder clay of the southeastern counties. Not only is there a similar depth of leaching but also a similar degree of oxidation, and a deep penetration of weathered pipes and seams. In the Cromer sections on the east coast of England the weathered seams are conspicuous to depths of 10 to 15 meters, and the leaching of the chalky bowlder clay is generally thorough to a depth of about 2 meters. The reddish tinge of the upper part of the weathered drift in these supposed Euro-

[*] Geology of Polk County, Iowa Geological Survey, vol. vi.

pean correlatives is also as conspicuous as in our Kansan. If we consider that since the time when the Kansan drift and its correlatives were deposited there have been repeated climatic changes from cold to warm and probably also from humid to arid, it may seem remarkable that weathering should have been so similar in amount in these widely separated glaciated districts. It is at least suggestive of worldwide influences in the control of the climatic conditions that produced glaciation.

Pre-Kansan Drift.

The Pre-Kansan drift of the Keewatin field, so far as yet known, lies entirely within the limits of the Kansan drift and has exposures only beneath the Kansan. It is from these exposures alone that one may learn the degree of weathering, and they are inadequate to throw much light upon its erosion. Recent studies in western Iowa, under the Iowa Geological Survey, indicate that herbivorous animals had taken possession of that region in the interval of ice recession between the Pre-Kansan and the Kansan, so it is inferred that there was plant growth such as comes only with a genial climate. Data bearing directly upon the amount of leaching of the gravelly surface portion of this drift were obtained by my assistant, R. T. Chamberlin, in 1907, at exposures near Afton Junction, Iowa, the type locality of the interglacial Aftonian exposures. Four classifications of pebbles from near the surface of the deposit show percentages of limestone pebbles ranging from 14 to 20 per cent, while two classifications of pebbles from underlying till, not affected by leaching, show 38 and 52 per cent of limestone pebbles. In other respects the pebbles of the gravel and of the underlying till are strikingly similar. It thus appears probable that the limestone content of the gravel was originally about the same as that of the till, and that nearly two-thirds of the limestone had been removed from the surface portion of the Pre-Kansan drift before it was buried under the Kansan. The limestone pebbles remaining in this surface portion are in an etched and deeply weathered condition, so that had there been but a moderate extension of the interglacial stage the limestone might have been completely removed. In places gravelly portions of the Pre-Kansan drift had become firmly cemented in this interglacial stage, so that masses were gathered up by the ice of the Kansan stage and incorporated as bowlders in the Kansan till. The change which the Pre-Kansan drift experienced probably approaches if it does not equal that which the Illinoian has experienced, and appears to be greater than that which has affected the Wisconsin drift. It may therefore properly be referred to a distinct glacial stage.

Equivalents of Kansan or Pre-Kansan in the Labrador Field.

The writer has never had opportunity to study, or even to travel across, the area in New Jersey and northeastern Pennsylvania occupied by the sheet of old drift of the Labrador field to which Chamberlin and Salisbury have applied the term Jerseyan. The patchy distribution and weathered appearance

Fig. 7.

Fig. 7.   Part of Oelwein, Iowa, topographic sheet showing topography of a so-called Iowan drift plain. The amount of erosion here displayed should be compared with that in the Illinoian, figs. 3 and 4, and Kansan drift, figs. 5 and 6.   Scale, 1 : 173000.   Contour interval, 20 feet.

reported by those who have studied it, seem to indicate an age as great as that of any drift sheet in the Keewatin field. It is, therefore, considered by these students a probable correlative of the Pre-Kansan or Sub-Aftonian drift of the Keewatin field. The old drift of northwestern Pennsylvania, which has been examined by the present writer, is thought from the weather-

ing and erosion to be at least as old as the Kansan drift, and possibly the correlative of the Pre-Kansan drift. Its aspect is decidedly older than the Illinoian drift exposed in the western part of the field covered by the Labrador ice sheet. The topography of the quadrangles within the limits of the Jerseyan drift and of the old drift of northwestern Pennsylvania is controlled to so slight an extent by glacial deposits that the topographic sheets are not likely to have much value in setting forth the amount of Post-Jerseyan erosion, and hence are not drawn upon for illustrations.

European Equivalents of the Pre-Kansan.

Upon turning to the European fields conditions somewhat similar to that of the Kansan and Pre-Kansan have been brought to notice. Thus in the Alpine region the oldest drift, known as the Gunz, is almost completely overridden by another old drift, the Mindel. In that region, as in the American, just discussed, it is difficult to determine the difference in age because of the meager exposure of the Gunz drift. The studies of Penck and Brückner, however, have shown that there was an advanced state of weathering of the surface of the Gunz drift before the Mindel glaciation buried it. The Mindel and Gunz drifts are thought by Penck to be separated by a shorter interval than that between the Riss and Mindel.* In the Skandinavian field observations by Nathorst and others indicate that in southern Sweden a set of striæ out of harmony with the ice movement which carried the lower bowlder clay of Germany is likely to have preceded that movement. While the earlier movement may not have been sufficiently distinct from the later to constitute a separate stage of glaciation, Geikie has suggested applying to it a distinct name, Scanian, from the district in Sweden where it was brought to light.

Iowan drift?

Since it is through a study of weathering and erosion that the presence of the so-called Iowan drift has come to be questioned, it seems fitting that this discussion should include a brief statement concerning the leading features in the region that drift has been supposed to cover. The region lies in northeastern Iowa immediately east of the area covered by the Des Moines lobe of Wisconsin drift. The topographic maps which lie wholly or partly within its limits are the Decorah, Oelwein, Elkader, Winthrop, Farley, Stanwood and Rock Island. Fig. 7, which represents part of the Oelwein quad-

* Die Alpen im Eiszeitalter, p. 1168.

rangle, illustrates well the topography of the part of this region where the valleys are excavated entirely in the drift. Farther east the drift becomes so thin that rock ridges dominate the topography.   It will be observed that the surface presents broad slopes, as in the Kansan drift, but the valley bottoms are less well defined, the slopes on either side extending nearly to the streams.   Tabular divides are also wanting and considerable inequality is found along the lines of water parting. This region differs also from neighboring parts of the Kansan in being nearly free from loess.

The inspection of such a map as that given in fig. 7 naturally raises the question whether the departures which it exhibits from the typical Post-Kansan erosion, shown in figs. 5 and 6, may be interpreted as a superimposed youth, such as might result from a fresh invasion of the ice into a much eroded region of older drift.   A study in the field would naturally be directed to the solution of the question of the existence of a drift sheet too fresh to be consistent with the interpretation that the valleys were entirely formed after its deposition, and a special search should be made to discover whether a fresh drift is so situated in the valleys as to indicate clearly that it was deposited after the valleys were excavated.   Upon visiting the field in 1906 and again in 1907, and spending about two months in careful examination of the exposures on uplands, slopes, and valley bottoms, the writer was unable to discover any trace of fresh drift.   The valleys were found to be filled with a concentrate of the more resistant constituents of the drift, the soluble constituents having apparently been removed just as in the weathered portion of the Kansan drift.   The valleys are shallower than in the Kansan drift of southern Iowa and northeastern Missouri, and run out at their heads in so-called sloughs.   But so far as discovered this shallowness is not occasioned by the deposition of a fresh sheet of drift, but rather seems due to a filling by slope wash.   The ramification of the valleys into the uplands is not strikingly different from that found in the Kansan drift and seems to call for a maturity of stream work of a similar rank.   In view of the fact that my own studies have not been exhaustive and that the Iowan invasion is still held by the Director of the Iowa Geological Survey, who has had a longer acquaintance with the region, I still consider the question of an Iowan invasion an open one.

Ann Arbor, Michigan, February 22, 1909.

Art. XXIX.—*The Chalk Formations of Northeast Texas ;*[*]
by C. H. Gordon.

It has long been known that deposits of chalk occur in northeast Texas, but writers are not in accord as to the relations of these formations. In a paper read before the Geological Society of America by Mr. R. T. Hill in 1893,[†] which was the successor to a number of papers on the Cretaceous of the Arkansas-Texas region by this author during the preceding six or seven years, mention was made of the occurrence of chalk in the southern part of Lamar county, and its identity with the chalk of the White Cliffs of Arkansas was asserted. This chalk, which Mr. Hill states is " called the Anona[‡] chalk in Texas," is regarded by him as distinct from the Austin chalk of central Texas and as belonging to a higher horizon. He says: " It is not known what has become of the Austin chalk in this section, but my hypothesis, backed by some evidence, is that to the southward it has been faulted down. The Anona (White Cliffs) chalk is an entirely distinct and higher bed, for it is underlain by the Taylor (Exogyra ponderosa) marls which overlie the Austin chalk." It is stated that the Austin chalk reappears in its normal position to the eastward, at Rocky Comfort in Little River county, Arkansas, on the north side of the Red River.

In a paper on the chalks of southwestern Arkansas, published in the 22d Annual Report of the U. S. Geological Survey (p. 698), Mr. J. C. Taff refers to the Texas deposits and says: " The white chalk is exposed from Austin northward to Sherman, Texas, through a distance of nearly 250 miles, without appreciable change in its thickness of nearly 600 feet, and with very slight variation in texture, color, and nature of material. * * * In the vicinity of Sherman, a few miles south of Red River, the chalk formation turns eastward and continues down the south side of the valley through Grayson, Fannin, Lamar, and Red River counties, and into the northwestern part of Bowie county. From the last locality the chalk passes beneath the bottom land of the Red River to Rocky Comfort, Arkansas. Farther east it comes to the surface at White Cliffs, on Little

[*] Read before the Geological Society of America at the Baltimore meeting, 1908. Published by permission of the Director of the United States Geological Survey. During a part of the time devoted to field study in northeast Texas, the author was assisted by Mr. L. F. Russ of the University of Texas.

[†] Bulletin Geological Society of America, vol. v, pp. 297–338, 1893.

[‡] Hill's spelling of " Anona " was corrected by Veatch to Annona. See Professional Paper No. 46, U. S. Geological Survey, p. 25 (footnote).

River, and Saline Landing on the West Saline River.   In the Arkansas region, it is known as the White Cliffs formation."

In a recent paper[*] Veatch follows Hill in assigning the Annona chalk to a higher horizon than the Austin.   The statement is made[†] that the Austin is not found east of Paris, Texas.   In his table of correlations, the upper part of the Bingen sand is regarded as the equivalent of the Austin chalk. He says: "The Bingen, which is the lithological counterpart of the Woodbine, apparently contains littoral equivalents of the Austin and Eagle Ford."

The formations underlying northeast Texas consist chiefly of Upper Cretaceous and lower Tertiary rocks.   The Woodbine sands, which constitute the base of the Upper Cretaceous, appear along the south side of Red River, in the northern part of Lamar county.   The strata have a general dip of about 50 to 60 feet per mile toward the south by southeast.   As a result of this, in passing from north to south, higher formations appear in successive belts except where interrupted by coverings of more recent deposits.   The classification of the Upper Cretaceous of northeast Texas as adopted in a forthcoming report on the underground waters of the region is as follows:

Navarro and Taylor.

6. Dark laminated clays and blue sandy shales ; limited exposures in the north part of Hopkins county.

5. Glauconitic sands in the south part of Delta county.

4. Sandy marls and clays with lime concretions filled with fossils.   Underlies most of Delta county.

3. Impure sandy chalk forty to fifty feet thick grading into marls above and the sandy beds below.   Exposed in the north part of Delta county near Enloe and extends in a narrow belt southwestward somewhat to the south of Ladonia and between Fairlie and Wolf City in Hunt county.

2. Fine yellow glauconitic sand with thin lenses of fossiliferous limestone.   Grades upward into the chalk and downward into clay.   Thickness about 40 to 60 feet.

1. Blue clay marls forming a deep black soil similar to that of the marls above.   One hundred to one hundred and fifty feet.

Austin Formation.

Annona Chalk.—Bluish and creamy-white chalk.   Thickness fifty to one hundred feet.

Brownstown Marls.—Blue marly clay, slightly glauconitic.   Four hundred to five hundred feet thick.

[*] Professional Paper, No. 46, U. S. Geological Survey, 1906.
[†] Ibid, p. 19.   See also p. 24.

Eagle Ford Formation.

Blossom Sands.—Glauconitic sands interlaminated with and grading into clay. Sands appear decidedly brown and red at the surface from oxidation of the contained iron. Eighty to one hundred feet thick. Constitute a narrow sandy belt extending from east to west through Red River and Lamar counties. Named from the village of Blossom in the eastern part of Lamar county, which is located upon their outcrop. Dark blue and black laminated clays with thinly bedded clay limestone and nodular septaria of blue limestone. These septaria are highly fossiliferous and often weather out in bowlders of various sizes. These clays grade downward into the Woodbine sands and upward into the Blossom sands. Their thickness is from five hundred to six hundred feet.

Woodbine Formation.

Ferruginous and argillaceous sands, in places glauconitic and lignitiferous. Thickness estimated to be five hundred to eight hundred feet.

STRATIGRAPHIC RELATIONS OF THE ANNONA CHALK.

The chalk to which Hill gave the name Annona makes its appearance on the south side of Red River in the northern part of Red River county and extends in a belt 2 to 4 miles wide to the south of west across Red River and Lamar counties, and westward. Owing to the hardness and greater resistance to erosion, this belt appears usually as a low ridge, covered to a slight depth only by soil through which the white chalk frequently appears, and in which ribbons of white mark the courses of wet-weather streams. The chalk contains a varying proportion of sand.

In composition, the chalk corresponds closely with that of the Austin, as shown by the following analyses :

	1	2	3	4
Calcium carbonate	84·14	82·51	84·48	70·21
Silica and insolubles	10·14	11·45	9·77	23·55
Ferric oxide and alumina	4·04	3·61	1·15	1·50
Magnesia (and H_2O)	1·68	1·19	trace	0·58

1. Annona chalk, 7 miles south of Paris, Texas. Analysis furnished by Mr. J. A. Porter, Paris, Texas.
2. Texas chalk, locality unknown. 21st Annual Report, U. S. Geological Survey, Pt. VII, 1899–1900, p. 329.
3. Rocky Comfort, Arkansas, Ibid.
4. Average rock from quarry, Texas Portland Cement Works, 3 miles west of Dallas, Texas, Ibid., p. 737.

Upon the outcrop of the chalk are located the towns of Clarksville, Atlas, Roxton, Honey Grove, etc. Annona, the town in Red River county from which the formation received its name, lies several miles south of the outcrop of the beds.

About three miles west of Clarksville, the exposures of chalk and accompanying marls are interrupted by a covering of Quaternary deposits, partly filling a broad shallow valley excavated in the formation now occupied by the headwater branches of Cuthand Creek.

At Clarksville several wells have been extended through chalk and underlying marls to the Blossom sands. No distinction is made in the well records between the marl and the chalk, both being included under " white rock," which is said to be about 600 feet thick.

The outcrop of the blue chalk marls, called the Brownstown marls, which underlie the Annona chalk, constitutes a belt of black land, several miles wide, along the north side of the chalk and bounded on the north by a strip of sands (Blossom sands) representing the top of the Eagleford formation. The thickness of the Brownstown in Red River and Lamar counties is estimated at 400 to 500 feet. It thins toward the west, with a corresponding diminution in the width of outcrop, as shown in Fannin county. Accompanying this change in the thickness of the marls, there is an increase in thickness of the chalks, the north boundary of which passes to the northward of Honey Grove and thence to Sherman.

The chalk beds occurring in the vicinity of Sherman have generally been recognized as Austin. It is evident therefore that the Annona chalk and the underlying Brownstown marls are stratigraphically the equivalents of the Austin chalk. The meager collections of fossils thus far obtained from these formations in northeastern Texas offer little in the way of faunal evidence bearing on the classification of these beds. The collections thus far made indicate a wide range of the species represented and no satisfactory conclusion can be drawn from them.

One hundred to two hundred feet above the Annona chalk is another bed of chalk having a thickness of fifty to one hundred feet. This chalk outcrops along the south side of North Fork in the northern part of Delta county from the vicinity of Enloe to the western boundary of the county. The position of this chalk suggests its correlation with the Saratoga chalk in Arkansas, which occupies a similar position with respect to the Annona (White Cliffs) in that region. There are no intervening exposures of chalk, however, and the data from well borings seems to indicate that these upper

chalk formations occur in lenses rather than as persistent formations.

Conclusions.

1. The stratigraphic relations of the Annona chalk shows conclusively that it is the equivalent of the upper part of the Austin chalk formation of central Texas.

2. That the Brownstown marl, which underlies the Annona in northeast Texas and western Arkansas, is the stratigraphical equivalent of the lower portion of the Austin.

3. That the term Austin should be used for the formation as a whole, while the names Annona and Brownstown may be used to designate the chalk and marl members respectively.

4. For the sands at the top of the Eagle Ford formation, which are of importance in certain areas as a source of water, the name Blossom is here proposed. The Clarksville wells draw their supply of water from these beds, in view of which, in the absence of knowledge of the outcrop of the formation, Veatch called them the Sub-Clarksville Sands.

Knoxville, Tenn.

Art. XXX.—*The Devonian of Central Missouri;* by
Darling K. Greger.

The Devonian of central Missouri is a two-fold formation of
somewhat variable thickness and in the region of its greatest
development it consists of more or less heavy-bedded, blue,
gray and reddish-brown limestones, and of coarse, blue and gray
shales and shaly limestones, the latter weathering to a light
yellow, highly siliceous clay.

The occurrence of Devonian strata in the central Missouri
region was known to Owen (1) in the early fifties, and he out-
lined its area with some degree of accuracy as follows: "In
Missouri this formation (Devonian) was traced, reappearing
for a very limited space in the valley of the Auxvasses in
Calloway county; skirting for a short distance one of the south-
ern promontories of the Iowa and Missouri coal-field, in close
proximity to the great uplift of magnesian limestone, of Silu-
rian date, in the same vicinity. It has, probably, a consider-
ably greater range in this locality than here ascertained and
laid down by me."

Numerous exposures of the strata here considered occur in
Warren, Montgomery, Callaway, Boone, Cole, Moniteau and
Cooper counties, with their maximum development in central
Callaway county. While the Devonian of this region is readily
separable into two divisions upon both faunal and lithologic
grounds, the lower member only bears a distinctive name, and
this even is ill-defined as it appears in the literature.

C. R. Keyes (2), in a discussion of the geological formations
of Missouri, defines the Callaway limestone or lower member
in the following manner: "In southeastern Missouri, rocks
containing the typical fauna of the Western Hamilton are
sparingly represented in Perry and Cape Girardeau counties,
in connection with the limestones above mentioned (Grand
Tower limestone). In this region the limestones belonging to
this group are dark colored shaly rocks, quite different from
the associated strata.

"North of the Ozark uplift the Devonian rocks referred to
the Hamilton extend westward along the Missouri river as far
as Jefferson City, having their most typical development in
Callaway county. In several places abundant fossils of this
formation have been obtained from strata having lithological
characters not very unlike the beds of the eastern Ozark region
referred to the same age."

The two paragraphs above quoted are somewhat misleading,
since if the writer means to apply the name Callaway lime-

stone to the strata "having their most typical development in Callaway county" he would likewise include beds in Perry and Cape Girardeau counties, which to our knowledge contain an entirely distinct assemblage of fossils, a fauna in fact intimately related to the southern Illinois Devonian, which has been shown by Weller (3), Schuchert (4), and Savage (5), to belong to the eastern or Mississippian Province.

While we regret that the name Callaway limestone has assumed a place in our literature through a somewhat illegitimate course, its retention should be insisted upon since the formation has its greatest development both in area and thickness in Callaway county.

To the upper member of the central Missouri Devonian we would apply the name Craghead Creek shale since the typical exposure of this division is found on Craghead Creek (6), a small tributary of Middle River, south of Fulton about six miles, on the old Snyder farm. At this place about 35 feet of shale is exposed and the contact with the Mississippian above and the Callaway limestone below are both visible. The discovery of these shales dates back to 1858 and it is quite possible that Dr. S. S. Laws, then president of Westminster College, was the first collector to visit the locality, since it was through him that Prof. Swallow became acquainted with its rich fauna.

A number of small outcrops of the Craghead Creek shale occur in Callaway county, but it is nowhere so fully exposed as on the Snyder farm, where within a distance of one mile the following section is exhibited: Lower Coal-measures, Upper Burlington, Lower Burlington, Kinderhook, Craghead Creek shale, Callaway limestone, first Magnesian limestone, Saccharoidal sandstone.

Structurally the Craghead Creek shale is readily divisible into three members: the lower portion made up of dark blue and drab shale, with interbedded bands of shaly limestone, highly fossiliferous; the middle member consisting of a light drab, argillaceous limestone with few fossils, mostly remains of Crinoidea; the upper member consisting of a light gray, siliceous shale, this like the lower member being highly fossiliferous.

With the exception of the Brachiopoda and Crinoidea the fossils of the Craghead Creek shale have received only a cursory study, hence the following notes on the fauna are almost exclusively confined to these forms.

The faunal lists here presented are based on collections made in the following localities. Callaway limestone: Bellama Springs, southeast of Fulton, Auxvasse Church, east of McCredie, and Sampson's Ford, east of Fulton. The Craghead

Creek shale list is that of the type locality. The names preceded by an asterisk are species common to the Lime Creek shale or the Cedar Valley limestone of Iowa.

(A) = abundant, (C) = common, (R) = rare and (VR) = very rare.

Fauna of the Craghead Creek Shale.

Anthozoa.

Acervularia profunda Hall.   (R)
Aulopora sp. ?   (C)
Aulopora sp. ?   (C)
  Heliophyllum? sp. ?   (C)

Bryozoa.

Leioclema occidens White and Whitfield.   (A)

Crinoidea.

Aristocrinus concavus Rowley.   (VR)
Melocrinus gregeri Rowley.   (R)
Melocrinus lylii Rowley.   (R)
Melocrinus tersus Rowley.   (R)

The four species of Crinoidea described by Prof. Rowley seem to be confined to the limestone constituting the middle member of the shale and have not been found outside of Callaway county.

Brachiopoda.

Athyris minima Swallow.   (C)
Atrypa gregeri Rowley.   (C)
Atrypa hystrix occidentalis Hall.   (R)
Atrypa reticularis Linnæus.   (A)
Camarotoechia sp. nov.   (R)
  Cranaena morsii Greger.   (R)
Cyrtina triquetra Hall.   (C)
Dielasma calvini Hall and Whitfield.   (C)
  Dielasma sp. nov.   (R)
Gypidula comis Owen.   (R)
  Hypothyris sp. nov.   (R)
  Leiorhynchus sp. nov.   (R)
Philhedra famelica Hall and Whitfield.   (C)
  Philhedra crenistria Hall.   (R)
  Productella callawayensis Swallow.   (C)
  Productella marquessi Rowley.   (C)
Pugnax altus Calvin.   (R)
Schizophoria iowensis Hall.   (C)

Schizophoria macfarlani Meek. (A)
Schuchertella pandora Billings. (R)
Spirifer amarus Swallow. (A)
*Spirifer asper Hall. (R)
*Spirifer euryteines Owen. (R)
Stropheodonta sp. ? (A)†
Strophonella crassa Rowley. (VR)

PELECYPODA.

Six species of this class are recognized in the fauna, but all are preserved only as casts of the interior and their relationship has not been determined.

GASTROPODA.

The Gastropods, like the Pelecypods, are poorly preserved casts and their affinities are unknown.

CEPHALOPODA.

Nautilus lawsi Swallow. (R)
Orthoceras sp. ? (C)

FAUNA OF THE CALLAWAY LIMESTONE.

PORIFERA.

*Stromotopora sp. ? (A)

ANTHOZOA.

*Acervularia davidsoni Edwards and Haime. (A)
Aulopora sp. ? (R)
*Favosites alpenensis Winchell. (A)
*Pachyphyllum woodmani White. (R)
Zaphrentis, two indet. sp. (A)

CRINOIDEA.

Megistocrinus cf. *latus* Hall. (R)
Melocrinus cf. *nodosus* Hall. (R)

BRACHIOPODA.

*Athyris fultonensis Swallow. (A)
*Atrypa reticularis Linnaeus. (A)
*Cranaena iowensis Calvin. (C)

†Prof. Swallow in 1860 described in the St. Louis Academy of Science Transactions ten species of Stropheodonta from the Callaway limestone and Craghead Creek shale, without illustrations. The types were lost at the time the State University burned and from the descriptions specific identification is impossible.

Cyrtia occidentalis Swallow.   (R)
Cyrtina missouriensis Swallow.   (A)
Hypothyris sp. nov.   (R)
**Pentamerella dubia* Hall.   (R)
**Philhedra famelica* Hall and Whitfield.   (R)
Spirifer annae Swallow.   (A)
**Spirifer iowaensis* Owen.   (R)
**Stropheodonta costata* Owen.   (C)
Stropheodonta sp. indet.   (A)

PELECYPODA.

Conocardium sp. nov.   (A)

GASTROPODA.

Callonema? sp. ?   (R)
Euomphalus sp. ?   (A)
Loxonema? sp. ?   (C)
Pleurotomaria providensis Broadhead.   (R)

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(2) Keyes, C. R., Geological Survey of Missouri, 1894, vol. iv, page 43.
(3) Weller, S., Jour. Geol., vol. v, no. 6, 1897.
(4) Schuchert, Charles, Amer. Geol., vol. xxxii, 1903.
(5) Savage, T. E., this Journal, vol. xxv, 1908.
(6) U. S. Top. Atlas, Fulton Sheet, edition of 1890.

Fulton, Missouri.

Art. XXXI.—*The Volumetric and Gravimetric Estimation of Thallium in Alkaline Solution by Means of Potassium Ferricyanide;* by Philip E. Browning and Howard E. Palmer.

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

In a former paper from this laboratory* it was shown that reactions involving oxidation by ferricyanide in alkaline solution and reoxidation by permanganate of the resulting ferrocyanide in acid solution might be applied to the determination of cerium in the presence of the other rare earth compounds.

In the work to be described the same reactions were applied to the volumetric estimation of thallium. A solution of thallium nitrate was made up by dissolving 10 grms. of pure thallous nitrate in water and making up to a liter. This solution was standardized by precipitating definite portions with potassium bichromate in alkaline solution, filtering, and weighing the thallous chromate,† and also by evaporating measured portions of the solution with an excess of sulphuric acid and weighing as the neutral sulphate ;‡ the mean of closely agreeing results by both methods was taken as the standard.

Volumetric.—The procedure was as follows: Measured portions of the solution of thallous nitrate were drawn from a burette, water was added to about 100^{cm^3} a sufficient quantity of a solution of potassium ferricyanide to give an excess, and potassium hydroxide to complete precipitation of the brown thallic hydroxide. The precipitate was filtered off on asbestos, generally without settling, and washed thoroughly. The filtrate was acidified with sulphuric acid and titrated with standard permanganate. From the following equations, representing the reactions, the amount of thallium present may be readily calculated:

$$Tl_2O + 4K_3FeC_6N_6 + 4KOH = Tl_2O_3 + 4K_4FeC_6N_6 + 2H_2O$$
$$5K_4FeC_6N_6 + KMnO_4 + 4H_2SO_4 =$$
$$5K_3FeC_6N_6 + 3K_2SO_4 + MnSO_4 + 4H_2O$$
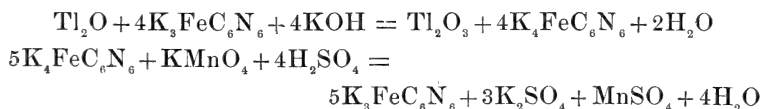
It was found necessary to apply a correction for the amount of permanganate used to give the first tinge of pink color to the amounts of ferricyanide used in the determinations. This seldom exceeded ·1 of 1^{cm^3} of the permanganate.

The following table shows the results obtained with different amounts of the thallium salt:

* Browning and Palmer, this Journal (4), xxvi, 83.
† This Journal (4), viii, 460.   ‡ This Journal (4), ix, 137.

	Tl$_2$O taken as the nitrate grm.	Tl$_2$O found grm.	Error grm.
(1)	0·0809	0·0809	+ 0·0000
(2)	0·0809	0·0808	− 0·0001
(3)	0·0809	0·0809	± 0·0000
(4)	0·1213	0·1212	− 0·0001
(5)	0·1213	0·1216	+ 0·0003
(6)	0·1213	0·1218	+ 0·0005
(7)	0·1213	0·1218	+ 0·0005
(8)	0·1213	0·1212	− 0·0001
(9)	0·1213	0·1207	− 0·0006
(10)	0·1618	0·1614	− 0·0004
(11)	0·1618	0·1613	− 0·0005
(12)	0·1618	0·1616	− 0·0002

Gravimetric.—The satisfactory character of the precipitate of thallic hydroxide obtained by this process suggested the possibility of applying it to a gravimetric estimation of thallium. Several precipitations were made according to the method described and the precipitate contained in a perforated platinum crucible upon an asbestos felt was dried over a low flame at about 200° C. to constant weight. The results follow in the table :

	Tl$_2$O$_3$ taken as the nitrate grm.	Tl$_2$O$_3$ found grm.	Error grm.
(1)	0·1305	0:1309	0·0004 +
(2)	0·1305	0·1314	0·0009 +
(3)	0·1305	0·1308	0·0003 +
(4)	0·0870	0·0872	0·0002 +
(5)	0·1740	0·1741	0·0001 +
(6)	0·1740	0·1739	0·0001 −
(7)	0·1740	0·1742	0·0002 +
(8)	0·1305	0·1307	0·0002 +
(9)	0·1305	0·1309	0·0004 +
(10)	0·1305	0·1308	0·0003 +
(11)	0·0870	0·0872	0·0002 +
(12)	0·0870	0·0874	0·0004 +

In experiments (5) to (12) the precipitated thallic hydroxide was washed with hot water, a procedure to be recommended when large amounts are present.

Art. XXXII.—*Descriptions of Tertiary Insects*, VI; by
T. D. A. Cockerell.

A Peculiar Neuropteroid Insect from Colorado.

Eomerope gen. nov. (Meropidæ.)

Rather stout-bodied, with the end of the abdomen formed
somewhat as in *Bittacus*, or nearer, perhaps, to the type of
certain Trichoptera; legs with many very strong spines; wings
shaped much as in *Merope*, but more elongate, and at the same
time with the costal region more strongly arched, and includ-
ing (between the costa and subcosta) four longitudinal series
of cells.

Eomerope tortriciformis sp. n.

♂. General aspect that of a tortricid moth; length 13^{mm};
head small; width of thorax about 4^{mm}, of abdomen about 3½,
both no doubt somewhat widened by crushing; color of body,
as preserved, pale ferruginous, the apex of the abdomen darker,
and a dark chitinous plate (? ventral) in the region of the basal
half of the first abdominal segment (fig. 3); end of abdomen
not elongated, but bearing a pair of thumb-shaped obtuse
harpes, directed obliquely upwards (fig. 2); the uncus or corre-
sponding structure short and apparently obtuse, without an
upturned point; legs with short femora (hind femur about 3^{mm}),
but rather long and slender tibiæ and tarsi; (hind tibia about
5^{mm}), the tibiæ (at least) with delicate appressed hair$_2$ and
numerous very large spines (fig. 1) which are finely striated
longitudinally (fig. 1a). The structure of the tarsi, the antennæ,
mouth-parts, etc., cannot be seen.

Wings as preserved pale reddish, nearly the color of the
shale, faintly striated by the slightly darker veins but without
spots or bands; anterior wing 15½^{mm} long, and about 4 broad
(the exact breadth difficult to determine), with the basal part of
the costa strongly arched, but the apical two-thirds nearly
straight (the costal outline much as in *Apochrysa*); apex
rounded. Hind wings about 13^{mm} long and 3 broad, more
slender than the anterior.

Venation of anterior wings.—Subcosta remote from the
costal margin, leaving a large space in which there are for a
considerable distance four longitudinal rows of cells. The first
upward branch bounds basally two large cells only, but the
second branch curves forward and runs parallel with the main
stem of the subcosta, and between it and the costal margin are
three rows of cells, the second and third of the middle row
being hexagonal (this is shown, better than it can be described,
in fig. 5); toward the apex of the wing the symmetry is some-

what lost and the cells become reduced, as shown in fig. 7. The cells of the second row from costa, after the third, become longer and lose their hexagonal form, having the lower side straight ; after the eighth cell the middle row is lost, there being two large cells in place of three, but there is a

FIGS. 1—5.
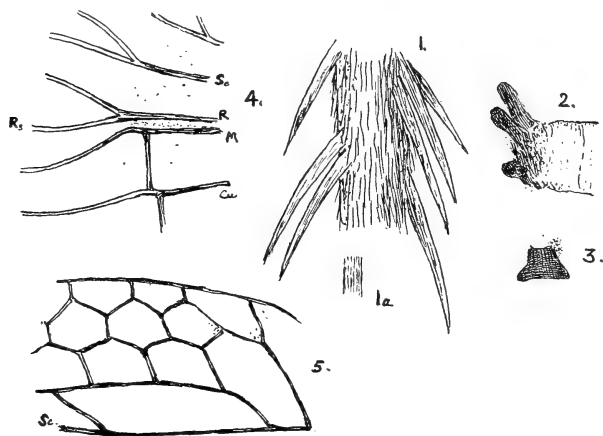
Eomerope torticiformis Ckll.

FIG. 1. Part of anterior tibia, showing the fine hairs and large spines. 1a. part of spine magnified, showing the finely striated surface.
FIG. 2. Apex of abdomen.
FIG. 3. Chitinous plate in region of first abdominal segment.
FIG. 4. Venation of anterior wing, showing relationship of radius, media, etc.
FIG. 5. Venation of costal region of anterior wing near base.

small middle cell immediately after, as shown in fig. 7. The area between the subcosta and its upper branch (they ultimately unite again as shown in fig. 7) is divided into three very long cells, the cross-veins being opposite the fourth of the second series of cells (shown in fig. 5) and the basal part of the seventh of the same series. From the subcosta to the radius are four cross-veins, placed at wide intervals, the fourth being shown in fig. 7 (*Panorpa* has usually two such cross-veins). The radius and media at first run side by side, so that upon superficial examination they look like one very stout vein ; at the point where the radius branches the media bends downwards, as shown in fig. 4 (this differs from *Panorpa* in the earlier branching of the radius). The radial sector forks, and the lower branch forks again ; the upper branch of the latter fork again branches, and its upper branch is connected by a cross-vein with the upper main branch of the sector, so that there is enclosed an elongated cell, very acute basally, obliquely

truncate apically, and with its lower side divided into three sections. The media and cubitus appear to be formed much as in *Panorpa*, and are connected by cross-veins, as shown in fig. 4. Their distal parts are obscured. There are two very strong but short curved anal veins, running downwards to the lower margin (much as in *Merope*, but shorter and more curved).

FIGS. 6—7.
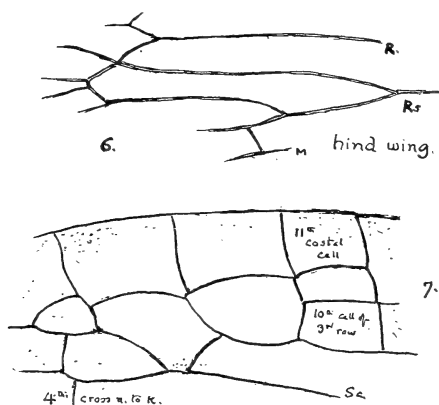
Eomerope tortriciformis Ckll.

FIG. 6. Venation of hind wing, showing branches of radia. sector.
FIG. 7. Venation of costal region of anterior wing toward apex.

Venation of hind wings.—This cannot be wholly made out, but fig. 6 shows the discal region. The branches of the radial sector enclose a long cell much as in the anterior wing.

Hab.—Miocene shales of Florissant, 1907 ; doubtless from Station 14, but the specimen is not marked with any number or collector's initial. Holotype in Yale University Museum.

This is one of the most puzzling fossil insects I have had occasion to describe, but I believe it is correctly assigned to the Mecaptera. The form of the wing, with the strongly convex costa and numerous costal cells, is very different from that of *Panorpa*, *Bittacus*, etc., but the isolated and peculiar *Merope*, of the eastern United States, shows an approach to this condition, the costal area being broad, and some of the cells divided into two. On the other hand, the apical structures of the abdomen in *Eomerope* do not resemble those of *Merope*, but are even more simple than *Bittacus*, showing resemblance to the doubtless more primitive condition found in the Trichoptera. There is no particular resemblance to the Mesozoic Orthophlebidæ.

Handlirsch divides the modern Mecaptera or Panorpatæ into four families : Bittacusidæ, Panorpidæ, Meropidæ, Boreidæ.

If this is admitted, apparently Meropidæ may be divided into Meropinæ, for *Merope*, and Eomeropinæ, n. subf., for *Eomerope*, the latter being separated on the structure of the abdomen and the venation of the anterior wings. It may be supposed that these insects represent an American type, once prevalent, but now reduced to a single genus and species, *Merope tuber*, Newman.

A New Type of Mecaptera, approaching the Nemopteridæ.

Eobanksia bittaciformis gen. et sp. nov.

Wings long and narrow, hyaline, with the apical half of the costa fuscous; anterior wing about 16^{mm} long and 3 wide; hind wing about 12^{mm} long and 2 wide.

Fig. 8.
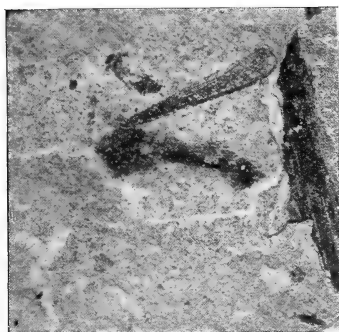
Fig. 8.   *Eobanksia bittaciformis* Ckll.

Anterior wing. — Costal margin of basal half of wing heavy, faintly arched, with several straight or very slightly oblique cross-nervures to subcosta. On the apical half of the wing the narrow area between the radius and costa is wholly fuscous, and no cells are visible. Subcosta straight, running parallel with and close to the radius, its exact termination not visible on account of the darkening. Radius *perfectly straight*, even toward the base of the wing only half a millimeter from costal margin, and terminating on costa a short distance before the obtuse apex of wing. Radial sector leaving radius about 6^{mm} from base of wing, and branching after a course of about 3^{mm}, running practically as in *Bittacus ;* the lower branch simple ; the upper running near the radius, and forked after a course of 4^{mm} ; in another specimen the lower branch of this fork is again forked. Media appressed to radius at base, and after 3^{mm} leaving it at a very acute angle, and having a straight unbranched course, practically parallel with the stem and lower branch of the radial sector. Cubitus small and weak, running close to lower margin, and bending abruptly downwards to end upon it, after about 4^{mm}. Cross-nervures irregular and variable, but more numerous than the *Bittacus*, especially in the basal half of the wing. No anal visible, nor indeed is there room for one.

Posterior wing.—Narrow, with two strong parallel closely adjacent straight veins running its entire length, about two-

fifths of the wing above, and three-fifths below them ; media represented by a straight rather weak vein in the lower field ; cross-nervures oblique, their more distal ends on the margin.

The type consists of a pair of wings ; another specimen (Station 13 B, *Miss Gertrude Darling*) shows the thorax and

FIG. 9.
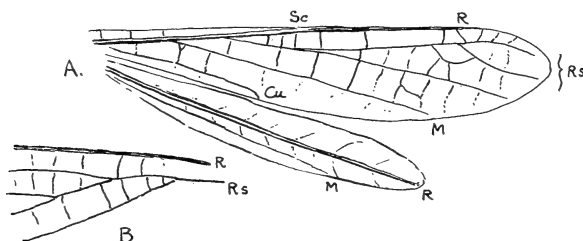
FIG. 9. *Eobanksia bittaciformis* Ckll.
A. Diagram of wing of type.
B. Branching of radial sector in another specimen.

abdomen ; the head is missing. The thorax is about 6^{mm} long, the abdomen about 13, the latter curved, and apparently formed exactly as in *Bittacus*, although no details can be seen. When the wings are folded backwards, the costa is downward.

Hab.—Miocene shales of Florissant, Colorado. A cotype in Yale Museum. This remarkable insect seems to form a new family (Eobanksiidæ) of Mecaptera. The anterior wing is very like that of the Panorpids in many respects ; the hind wing closely resembles that of the Nemopteridæ, though not so elongated, and without an apical expansion. (Some Nemopteridæ have no expansion.) Mr. N. Banks, to whom I sent a sketch of the venation, agrees that there is a distinct approximation to *Nemoptera*. Formerly it used to be maintained that the Panorpids (Mecaptera) and Nemopterids were allied ; the insect now described appears to lend support to this opinion. The genus is dedicated to Mr. N. Banks, in recognition of his labors on the Neuroptera.

Trichoptera from Florissant.

Phenacopsyche vexans gen. et sp. nov.

Anterior wing.—Length about 19^{mm} (16½ visible, the base hidden), outer margin about 10^{mm}, lower margin about 14. Costa with basal half straight, apical slightly arched ; apex obtuse, outer margin regularly convex. Wing brownish, from a rather dense scaling or pubescence, the apical part of the costal region and the broad (3^{mm}) outer margin darker than the rest (possibly less denuded) ; veins dark brown.

The wing has an extraordinarily Lepidopterous appearance, being very much as in the broader-winged Noctuids, and even more like some of the Hesperiids, especially in the distinct anal angle. Regarding it as Lepidopterous, the visible portion of the venation nearly agrees with that of *Adoneta*, except for the

Fig. 10.   Fig. 11.
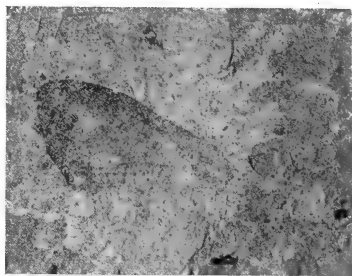
Figs. 10 and 11.   *Phedacopsyche vexans* Ckll.

insuperable difficulty of two extra veins between the supposed media and cubitus. Treated as Trichopterous, this difficulty disappears, the supposed median cell being the discoidal, in the forks of the radial sector.

The generic characters ascertained are as follows :—

Discoidal cell present, elongate triangular ; no median cell ; radius (R_1) joined to first branch of radial sector (R_3) by a cross-nervure, about 1^{mm} (on R_2) beyond discoidal cell : at this cross-nervure (which is regularly present in *Panorpa*, and also occurs in various Trichoptera, as *Rhyacophila*, *Odontocerum*, and *Namamyia*) the radius is bent a little upwards, as shown in the figure. The five branches of the radius, and four of the media, are all present, and consequently the apical cellules 1 to 7, none being either absent or stalked. R_2 and R_3 leave the discoidal cell close together near its apex, and R_5 leaves its lower corner, being in a line with its lower side. M_3 and M_4 are stronger than M_1 and M_2, and appear to form the principal branches of the media, M_1 and M_2 leaving from an evanescent vein passing up from the media to the radius. Mr. N. Banks, to whom I sent a sketch of the venation, remarks on the apparent absence of the anterior main branch of the media, which should go to M_1 and M_2. I have carefully examined the specimen, and although the main stem of the media is strong and dark, I find no sign of this branch. It seems as if it had migrated forwards, to form the vein leaving M_3 for the bases of M_1 and M_2, the latter being connected at the base also (by a cross-vein) with the radial sector.

Apparently the genus must be referred to the Odontoceridæ, but Mr. Banks intimates that this is hardly a natural family, but "a sort of waste-basket" for things hardly fitting into Seri-

FIG. 12.
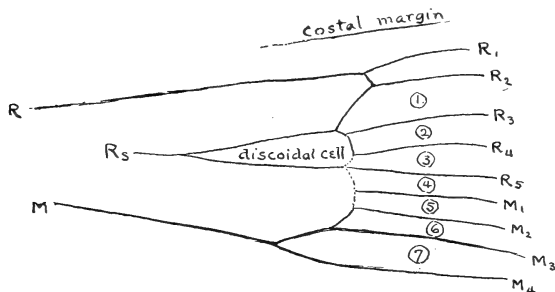
FIG. 12. *Phenacopsyche vexans* Ckll. Diagram of venation.

costomatidæ, and without the necessary characters of Leptoceridæ, Rhyacophilidæ, or Hydropsychidæ.

Hab.—Miocene shales of Florissant, 1908 (Station 13 B, *Geo. N. Rohwer*).

Hydropsyche scudderi sp. nov.

Larva in general similar to that of *Hydropsyche* sp., figured in Bull. 47, New York State Museum (1901), plate 15, f. 3, but much longer (length about 31^{mm}), though not broader (width of thorax about 3^{mm}), and with the thoracic plates much more nearly equal in size, being, in lateral view, about as deep as long. Head and thoracic plates strongly chitinized, of the usual rather dark reddish brown color; head 3^{mm} long and 2 deep, apparently quite normal; abdomen visible only as a faintly darker shade, of about the same width as the thorax, having slight indications of dark transverse and longitudinal markings. On one specimen indications of the branched gills, yellowish in color, can be seen on the first three segments. The caudal end is slender and produced, the caudal legs provided with the usual spreading bunches of hair. No indication of any case.

There are two good specimens before me, one showing the dorsal, the other the lateral aspect. Many others have been found; those in which the abdomen cannot be clearly seen are curiously similar to Scudder's *Planocephalus aselloïdes.*

Hab.—Miocene shales of Florissant.

Scudder is no doubt correct in assuming that the Hydropsychidæ of Lake Florissant did not breed in the lake, but in the small streams running into it. During the volcanic eruptions these streams may have been so heated that the larvæ were killed and then washed into the lake.

University of Colorado, Dec. 2, 1908.

ART. XXXIII.—*Divided Lakes in Western Minnesota ;* by
ROBERT F. GRIGGS.

No feature of the physiography of western Minnesota is
more notable to the casual observer than the large number of
twin lakes. Throughout Becker and Ottertail counties and
presumably over a much larger area a very large proportion of
the lakes are partially or completely divided by narrow necks
stretched across from shore to shore. This feature is very
striking to the traveler in the region, because these narrow
ridges cutting the lakes in two are almost always traversed by
the main roads, which thus connect the country lying on oppo-
site sides of the lake, the importance of the road depending on
the size of the lake and the consequent amount of country
benefited by the short cut. These dividing ridges are ice-
pushed ramparts, features which, on lake margins, are well
known and have been fully described by others. But no one,
so far as the writer has found, has shown the possibilities of ice-
shove in building new shore lines and cutting up the lakes in
which it works.

The mechanism of ice action and its effects in building ram-
parts of sand and bowlders along the shore have been most fully
described by Bulkley ('00) and Gilbert ('90, '08). Briefly it
is this : If the ice covering a lake is subjected to further
declines in temperature after freezing, it contracts and is broken
up by cracks running in every direction ; water from below now
seeps into these cracks and freezes. Thus the shrinkage in
volume is taken up by new ice, so that when the temperature
rises and the ice expands the whole sheet must enlarge. This
enlargement causes the ice, carrying with it whatever bowlders
or other material it may grip, to shove up onto the shore if it
be low, or if it be a resistant cliff, to pile up against it, or if the
lake be long and narrow, to buckle up in the open water where
the major cracks due to lateral friction and other causes create
zones of weakness. The shove may be very slight in the begin-
ning but as it is repeated with every change of the weather
until the ice is broken up, its cumulative effects are so great as
to push up large ramparts of bowlders or to cause considerable
destruction along the shore.

A typical example of an arm of a lake cut off from the main
body by an ice-pushed rampart occurs near the northeastern
angle of Lake Pelican (fig. 1), where a small pond is separated
from the lake by such a barrier. This rampart, though very
narrow, stands quite high above the water and supports a row
of trees. Its back side slopes somewhat gently into the swampy

bottom of the pond. But its front slope (fig. 2) exhibits the typical features of an ice rampart. It is built of gravel with occasional bowlders of large size. It is very steep and in places the ice has shoved up over the bowlder front and cut into the turf of the top.

Detroit Lake on the line of the Northern Pacific Railway is the most accessible example of a large lake with such barriers. In this case the process of division is not complete and the two ramparts form a pair of slender points stretching out from the opposite shores. A view of the southern point is shown in

Fig. 1.

Fig. 1. A dividing rampart, Lake Pelican.

figure 3. It is remarkable in its extreme narrowness. Though nearly a mile long, it is hardly more than one hundred feet wide at the widest point and the tip is so sharp that the extremity is hardly wide enough for the feet of the observer. The opposite point reaching out from the northern shore is very similar but is not so long. The two are connected by a submerged bar over which the water is so shallow that boats can cross only in a narrow passage in the center. But there is no channel across and the passage is simply the lowest point in the continuous ridge. In character this point is very different from such ramparts as that shown in figure 1. It is built of sand and gravel from which bowlders are almost absent. It is nowhere high or steep-sided like the bowlder rampart, but rises scarcely three feet above water level.

In many respects this point resembles sand spits formed by water work. The fine materials of which it is built and its

extremely sharp point both resemble such spits.   Its structure
and position show plainly, however, that water can have had
practically no part in its construction.   There is nothing of the
V-shaped ridging characteristic of cusps built out directly from
the shoreline, nor are there any hooks such as are often built
by long shore currents.   Moreover this lake has no currents or
waves competent to build such a spit.   Its longest diameter is
less than three miles and there are no currents along its shores
except those due to local winds.   Such waves as are raised by
the prevailing westerly winds are directly opposed to the

Fig. 2.
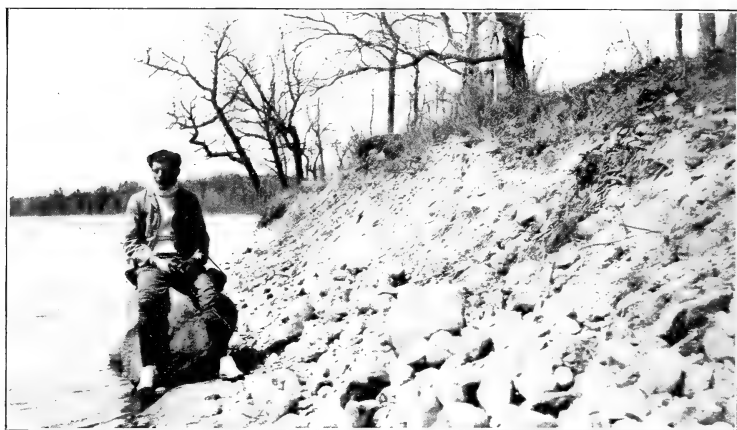
Fig. 2.   Front slope of rampart shown in fig. 1.

building up of such north and south spits and, especially at
their extremities, tend to destroy them and scatter the materials
of the sharp ridge.

That water currents can have no part in the formation of
these spits is shown very clearly by another small lake some
miles west of Detroit.   This lake (fig. 4) is completely divided
by one barrier while two others project from its shores.   It is
so small that water work of any magnitude is impossible.
Indeed it is so small as to raise the question whether ice-push
could become sufficiently great to heap up the ramparts
observed.   Such action is undoubtedly greatly favored in this
lake by the very slight depth which would enable the ice to
seize abundant materials for its work.   It is known that ice-
shove is entirely absent from deep lakes, but to just what degree
extreme shallowness would favor the contraction and expansion
needs to be determined by careful field studies.

Even a superficial examination is sufficient to show that ice is the only agent now at work in the formation of these dividing barriers. It is easy to see that the effects of ice action on such submerged ridges as that described in Lake Detroit would accentuate the ridge and pile up the rampart till it emerged from the water and formed a complete barrier across the lake. It is not difficult to see how such a ridge would be formed on any shoal which the ice could reach and grapple, especially if it happened to be located, as is very often the case, along lines

Fig. 3.

Fig. 3.   Partially completed dividing rampart.   Lake Detroit.

of the major cracks in the ice which tend to run from headland to headland because of the strains set up by the independent expansion and contraction of the separate bays of the lake. But it is difficult to understand how ramparts could be built out from the shore even along the major cracks where the ice buckles up and forms high ice ridges, unless there were a shallow place in the beginning. But though these lakes are shallow as lakes go, areas shallow enough to be reached even by the very thick ice of the Minnesota winter are by no means abundant. Though it be demonstrated that ice is responsible for accentuating and extending these ridges after they reach a certain point in their history, it is a question how much of their formation may be assigned to this agency and how much must be attributed to the original irregularities of the lakes, such as lines of moraine crossing them. This question can only be answered by extended field study in the region conducted during the winter, when the ice may be seen at work and its actual effects determined.

But while it may be difficult to explain the division of large lakes completely by ice action, it is evident that the cutting off of small ponds and swamps from the main body of the lake is

entirely explicable on this basis. Though such cases are less striking than the larger ramparts such as that in Lake Detroit, they are very much more numerous. Almost every large lake in the region has several sloughs cut off by ice ramparts.

The effect of the formation of ice barriers across the bays of a lake is very marked on the later history of the lake. The primary effect is to dredge out the shallows to clean out the

Fig. 4.

Fig. 4.   Small lake with three ramparts.

advancing marsh vegetation and to pile up steep banks, thus enlarging the lake and counteracting the most potent agencies tending to fill it up. But when the barriers are thrown across so as to divide the lake into small parts, secondary effects appear which reverse the primary. As the reaches of water over which the wind sweeps are reduced, the consequent erosive action of waves on the shores is lessened and transportation by long shore currents is checked. This greatly accelerates the filling up of the lake by favoring the growth of vegetation in its shallow water. This is so marked that it is difficult to find such a bay which is not already far along toward extinction. Most of them are so choked with vegetation that though their character is plainly evident on inspection it cannot be made to appear in a photograph such as figure 1. It is obvious that in regions where its action is well developed ice-shove is to be reckoned as an indirect aggradational factor of first importance.

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Columbus, Ohio, Feb., 1909.

ART. XXXIV.—*The Heat of Formation of Titanium Dioxide, and third paper on the Heat of Combination of Acidic Oxides with Sodium Oxide ;* by W. G. MIXTER.

[Contributions from the Sheffield Chemical Laboratory of Yale University]

THE thermochemistry of titanium is limited to that of the reaction $TiCl_4 + Aq = 57,870^c$ (Thomsen). As the heat of formation of the tetrachloride is not known, that of the oxide or acid can not be calculated. Good results might be obtained by burning titanium in oxygen if it could be ground to a fine powder. A coarse powder burns well in sodium peroxide, and hence this method was used.*

The metal used in the investigation was made by Dr. M. A. Hunter in the laboratory of the General Electric Company. The specimen was in irregular nuggets, was malleable when hot and brittle when cold. The density of a bright piece of the metal was found to be 4·51 and that of the pulverized portion 4·49 at 18°. Moissan† states that the density of titanium is 4·87. But the purest he made in the electric furnace contained two per cent of carbon.

For use in the combustions the metal was pulverized in diamond mortar and then ground in an agate one which it did not scratch. It was impossible to grind it to a fine powder, as some particles were flattened and others rounded. It was assumed that the impurities adhering to the nuggets were converted into dust by the grinding and also that the steel from the mortar was dust. Accordingly the dust was floated off in water and only the coarser portion retained. A qualitative analysis revealed no impurities in the metal. For a determination of titanium 0·5662 gram was dissolved in molten potassium pyrosulphate, the fusion was dissolved in cold water and the titanic acid was precipitated by boiling. The titanium dioxide obtained weighed 0·9453 gram, equivalent to 0·5676 gram of titanium or 100·2^c per cent. The following are the thermal data :

	1	2
Titanium	2·000 grams	2·001 grams
Sulphur	1·000 "	1·000 "
Sodium peroxide	20 "	20 "
Water equivalent of system	3,003 "	2,979 "
Temperature interval	4·958°	4·958°

* The details of the sodium-peroxide method are given in the first paper, on the Heat of Combination of Acidic Oxides with Sodium Oxide, in this Journal, xxvi, 125.
† C. R., cxx, 290.

Heat effect _____	14,889^c	14,770^c
" of oxidation of sulphur_	−5,271^c	−5,271^c
" " " " iron ____	6−48^c	6−48^c
" " oxygen absorbed ___	−71^c	−70^c
	9,499^c	9,381^c
For 1 gram of titanium_____	4,749^c	4,693^c

The mean is 4,721^c and for 48·1 grams of titanium it is 227,100^c. The temperature of the fusion was above the melting point of silver and no metallic titanium remained. The fusion, when treated with water, left a white residue which dissolved on addition of an excess of hydrochloric acid and the solution had the red color of pertitanic acid.

Titanic Oxide.

Titanic oxide was prepared as follows: The hydroxide, purchased for the pure compound, was fused with potassium pyrosulphate, the fusion was dissolved in cold water and the titanic acid was precipitated by boiling. It was washed with hot water, digested with hot ammonia and washed again and finally heated to redness for an hour. It contained no iron, alumina or zirconia. The following are the experimental data:

	3	4	5
Titanic oxide _____	3·302 gr.	4·001 gr.	3·970 gr.
" " in residue ___	0·057 "	0·074 "	0·103 "
" " combined ___	3·245 "	3·927 "	3·867 "
Sulphur _____	1·000 "	1·000 "	1·000 "
Sodium peroxide _____	16 "	18 "	19 "
Water equivalent of system	3,081 "	2,956 "	3,022 "
Temperature interval_____	2·417°	2·580°	2·536°
Heat effect_____	7,446^c	7,626^c	7,664^c
" of oxidation of sulph'r	−5,271^c	−5,271^c	−5,277^c
" " " " iron__	−48^c	−48^c	−48^c
" " oxygen evolved___	____	+78^c	+72^c
	2,127^c	2,385^c	2,417^c
For 1 gram of titanic oxide	655^c	607^c	625^c

The mean is 629^c and for 80 grams of titanic oxide it is 50,300^c. The solutions of the fusions in hydrochloric acid had the red color of pertitanic acid.

Since a pertitanate is formed when titanium or its dioxide is fused with an excess of sodium peroxide, it is probable that the

same compound results in both cases. Moreover, it makes no difference in the heat effect of $Ti+2O$ derived whether we assume the formation of $Na_2O_2.TiO_3$ obtained by Mellikoff and Pessarjewsky* or $Na_2O.TiO_3$. Taking the latter compound, the calculations are as follows:

$$3Na_2O_2 + Ti = Na_2O.TiO_3 + 2Na_2O + \text{-----} \quad 227,100^c$$
$$3Na_2O + 3O = 3Na_2O_2 + \text{----------------} \quad 58,200^c$$
$$\overline{ 285,300^c}$$
$$Na_2O + TiO_2 + O = Na_2O.TiO_3 \text{ ----------} \quad 69,700^c$$

$$Ti + 2O = TiO_2 \text{ (amorphous)} + \text{-----------} \quad 215,600^c$$

$$Na_2O_2 + TiO_2 = Na_2O.TiO_3 + \text{-------------} \quad 50,300^c$$
$$Na_2O + O = Na_2O_2 + \text{--------------------} \quad 19,400^c$$
$$\overline{ }$$
$$Na_2O + TiO_2 + O = Na_2O.TiO_3 + \text{--------} \quad 69,700^c$$

The large heat of formation of titanium dioxide was to be expected because of the difficulty of reducing the oxide to the metal. The heat of combination of TiO_2 or TiO_3 with Na_2O cannot be calculated from the experimental results, but it is less than that of silicon dioxide.

Lead.

Lead, in a finely divided form for the work, was obtained by scraping a revolving cylinder of the metal with a thin tool. The experimental data were as follows:

Lead -------------------------	20	grams
" unburned ---------------------	0·94	"
" burned ----------------------	19·06	"
Sulphur------------------------	1	"
Sodium peroxide-----------------	20	"
Water equivalent of system -------	3,982	"
Temperature interval-------------	2·822°	

Heat observed -------------------	11,237^c
" of oxidation of sulphur------	—5,271^c
" " " " iron---------	—48^c
" " oxygen absorbed ---------	—62^c
	5,856^c

For 1 gram of lead--------------	307^c
" 206·9 grams ----------------	63,500^c

*Ber. d. deutsch. chem. Gesell., xxxi, 953.

The fusion was yellow and it yielded to hot water a little sodium plumbate. The insoluble yellowish brown powder left by the water liberated chlorine from hydrochloric acid—a proof of the presence of peroxide.

The heat of $Pb.O = 50\cdot3$ is Thomsen's. Tscheltzow* found for $PbO.O = 12\cdot1$, hence $Pb.2O = 62\cdot4$, which is used in the following calculation:

$$2Na_2O_2 + Pb = Na_2PbO_3 + Na_2O + \text{\_\_\_\_} \quad 63,500^c$$
$$2Na_2O + 2O = 2Na_2O_2 + \text{\_\_\_\_} \text{_____} \quad 38,800^c$$
$$2Na_2O + 2O + Pb = Na_2PbO_3 + \text{_____} \quad 102,300^c$$
$$Pb + 2O = PbO_2 + \text{_____} \quad 62,400^c$$

$$2Na_2O + PbO_2 = Na_2PbO_3 + \text{_____} \quad 39,900^c$$
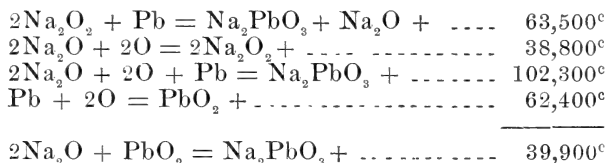
As the fusion in the foregoing experiment yielded a mixture of lead oxides, it seemed best to use lead dioxide in place of the metal. For this purpose the dioxide was made by acting on lead acetate with a hypochlorite and also by treating red lead with nitric acid, but the products were not pure enough for the purpose. Accordingly dioxide was prepared by electrolyzing a saturated solution of lead nitrate in dilute nitric acid. It was washed, dried, pulverized, and washed again to remove adhering nitrate. Finally the lead dioxide was heated to 280° until the weight was constant, and as it still retained water the temperature was raised until some red lead formed on the bottom of the beaker containing it. The composition of the product was as follows: PbO_2, $93\cdot7$; PbO, $6\cdot0$; H_2O, $0\cdot3$ per cent. The correction for lead oxide and water would be small and was not made in the following experiments:

	2		3	
Lead dioxide	20.	grams	20.	grams
Sulphur	2·	"	1·5	"
Sodium peroxide	25	"	15	"
Water equivalent of system	4,018	"	4,090	"
Temperature interval	3·418°		2·658°	
Heat observed	13,733^c		10,871^c	
" of oxidation of sulphur	−10,542^c		−7,906^c	
" " " " iron	−48^c		−48^c	
" " oxygen evolved	+151^c		+260^c	
	3,294^c		3,177^c	
For 1 gram of lead dioxide	165^c		159^c	

The mean is 162^c for 1 gram of lead dioxide and for $238\cdot9$ grams it is 38,700^c, which agrees well with the result of experi-

* C. R., c, 1458.

ment 1. The fusion of 2 when treated with hot water left lead oxide and but little dioxide, while in 3, where less sodium peroxide was used, considerable lead dioxide remained. These facts indicate that the lead dioxide which separates on the hydrolysis of sodium plumbate is reduced to oxide by sodium peroxide in the presence of water. The following results support this view : a mixture of the two oxides was placed in cold water and the whole was heated. The solution contained lead, but gave no chlorine after adding hydrochloric acid and warming. A fusion of equal parts of lead and sodium peroxide left, after exhausting with water, lead dioxide, while when two parts sodium peroxide were taken the insoluble residue was brownish yellow and contained but little lead dioxide.

The heat of hydrolysis of sodium plumbate is derived as follows :

$$Na_2O.PbO_2 + Aq = 2(Na.O.H.Aq) + PbO_2 - Na_2.O.PbO_2 - H_2O$$
$$15,500^c = \quad 223,600 \qquad\qquad - 139,700 \quad -68,400$$
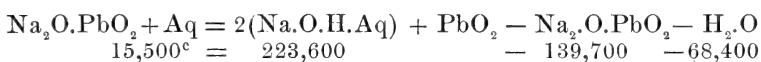
Since the PbO_2 is in the solid state before and after the hydrolysis of the plumbate, it makes no difference in the thermal result if it first combines with water and is finally dehydrated. The hydrolysis as given above is only complete in a large volume of water, since sodium plumbate is soluble as such in a concentrated solution of sodium hydroxide.

Zirconium Dioxide.

Two experiments were made with mixtures of zirconium dioxide, sodium peroxide, and sulphur. The fusions were not good, and the residues remaining after treatment with hot water set free chlorine from hydrochloric acid, indicating the presence of a peroxide. The results were 251^c and 268^c for 1 gram of zirconium dioxide, mean 258^c and for 122.7 grams $31,700^c$. If the dioxide was all oxidized to trioxide $19,400^c$ are to be added, giving $51,100^c$. The only interpretation to be given to the result is that the heat of ZrO_2 or $ZrO_3 + Na_2O$ is small.

Ceric Oxide.

But one experiment was made with ceric oxide with the result of 94.6^c for 1 gram and $16,300^c$ for 172 grams. The fusion was placed in cold water and after gas ceased to come off the solution was decanted. When the insoluble residue was treated with hot water much gas was evolved—an indication of the presence of a peroxide of cerium. If $2CeO_2$ is oxidized by sodium peroxide to Ce_2O_5 $9,700^c$ are to be added for the heat of the oxygen taken from sodium peroxide. The thermal result does not indicate combination of sodium oxide with an oxide of cerium.

ART. XXXV.—*Note on Crystal Form of Benitoite;* by C. PALACHE.

THE symmetry class to which the crystals of the interesting new mineral benitoite belong could not be definitely established by the forms hitherto observed upon them. Rogers[*] assigns it to one of two classes, the trigonal-bipyramidal (Class 19 of Groth) or the ditrigonal-bipyramidal (Class 22 of Groth) with probabilities favoring the latter. Neither of these classes has hitherto had a representative among crystals.

Crystals of benitoite recently acquired by the Harvard Mineral Cabinet present a new form which establishes the correctness of Rogers' assumption of its ditrigonal-bipyramidal symmetry. The form is the second order pyramid $(22\bar{4}1)$; it occurs on all the crystals on the specimen with distinct but small faces which uniformly present a dull luster in striking contrast to that of the trigonal pyramids. The lateral edge between these second order pyramid faces is in most cases truncated by the second order prism with similarly dull faces. These two forms, characteristic for class 22, would appear as trigonal forms in class 19; the fact that when a face of either occurs, others are present of like quality and with six-fold repetition, seems to determine the type positively. Although dull the new faces gave distinct reflections on the goniometer. The average of six excellent readings, 0001 to $22\bar{4}1$, was 71° 15′.

The average of ten excellent readings, 0001 to $10\bar{1}1$, was 40° 12′, a value just half way between those obtained by Rogers (40° 10′) and Lauderbach (40° 14′). Calculated from this value $a : c = 1 : 0.7319$ and $p_0 = .4879$. Calculated from this axial ratio the angle 0001 to $22\bar{4}1$ is 71° 10′. The list of forms for benitoite is then as follows:

Prisms: m $(10\bar{1}0)$, μ $(01\bar{1}0)$, a $(11\bar{2}0)$.

Pinacoid : c (0001).

Trigonal pyramids: $p(10\bar{1}1)$, π $(01\bar{1}1)$, e $(01\bar{1}2)$.

Second order pyramid : x $(22\bar{4}1)$.

The figure shows a typical combination.
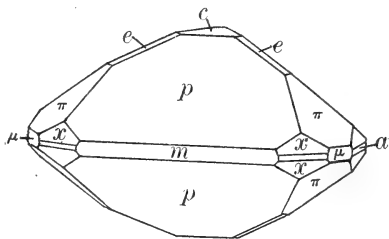
Octahedrite, a mineral not before recorded from the benitoite locality, was observed on part of the specimen from which natrolite had been wholly removed by solution in hydrochloric acid. It appears in groups of pale brown crystals, combinations of unit pyramid and base; the crystals are small and present facetted and curved faces so that they could not be measured but chemical tests showed the presence of titanic oxide alone.

Harvard Mineralogical Laboratory, March, 1909.

* Science, xxviii, 616, 1908.

ART. XXXVI.—*Alamosite, a new Lead Silicate from Mexico ;* by C. PALACHE and H. E. MERWIN.

IN this paper is presented the description of a monoclinic lead metasilicate showing in form, habit, and composition close analogies with wollastonite, with which it is regarded as isomorphous. This mineral was sent to the Harvard Mineralogical Laboratory for identification by the Foote Mineral Co. of Philadelphia, who generously placed at our disposal their whole supply of the material. According to their meager data regarding its occurrence it is found in an undeveloped gold and copper prospect situated near Alamos, Sonora, Mexico. The minerals making up the ore in hand are, however, with trifling exceptions all compounds of lead.

The gangue is in part massive white quartz, in part a compact gray, brown or black material shown by analysis to contain quartz, the new lead silicate and either limonite or hematite, in varying admixtures. Interspersed through this massive material are occasional vugs lined with quartz crystals and irregular bunches of the lead compounds. Of these the most abundant is cerussite in snowwhite aggregates and rare crystals. Minute flakes of pale green leadhillite were identified by cleavage, optical character and chemical reactions. Wulfenite is also found, partly in orange-colored crystals, more abundantly as a bright yellow stain in all the other minerals of the ore, particularly in the lead silicate.

FIG. 1.

The lead silicate is in radiated fibrous aggregates of more or less pronounced spheroidal form, irregularly interspersed among the minerals already mentioned. It is snow-white in the mass, transparent and colorless in the rare cases where tiny fibers had been free to develop singly in open spaces between the spheroids. There is a perfect cleavage transverse to the fibers yielding a curved concentric fracture surface of pearly luster which extends almost uninterruptedly through all the individuals of a spheroid. The few developed crystals that could be secured for study were minute—not more than $0\cdot5^{mm}$ in diameter—and the best of them were but poorly adapted to measurement, several fibers being generally adherent in subparallel groups so that it was difficult to secure readings
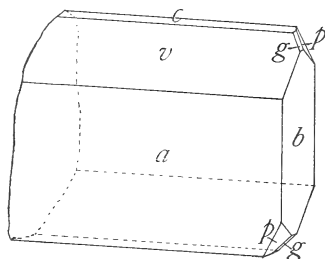
from individual crystals. The high luster of the mineral, however, made it possible to obtain readings from the most minute faces and fairly consistent measurements were finally obtained from six crystals.

Alamosite is monoclinic, the fibers elongated parallel to the axis of symmetry (crystallographic axis b). This habit and the minute size of the crystals made it necessary to mount them on the two-circle goniometer with 010 as pole and the orthodome zone as prism ; the measurements and calculated angles of the table are, therefore, given for that position, but the symbols and axial ratio are for the normal position. The position was chosen so as to bring out as well as might be, the relation in form to wollastonite.

The crystals are simple showing the forms c(001), a(100), b(010), m(110), v(101), g(011) $p(\bar{1}2\bar{1})$, and r(121). The figure shows a typical combination in which the forms named, except m and r, are represented in about their normal development. The relations to wollastonite are shown by the following angles :

		Alamosite	Wollastonite
Axial Ratio	$a\ :\ b\ :\ c$	$1{\cdot}375\ :\ 1\ :\ 0{\cdot}924$	$1{\cdot}053\ :\ 1\ :\ 0{\cdot}967$
Angle 001 to 100$=\beta$		$84°10'$	$84°30'$
" 001 to 101		32 02	40 03
" 001 to 011		42 36	43 55
" 100 to 110		53 50	46 21

Table of calculated and observed angles of alamosite, with 010 as pole and 100 as first meridian.

Elements for this position : $p_0=1{\cdot}088$; $q_0=0{\cdot}731$; $\mu=84°10'$
Elements for normal position : $p_0=0{\cdot}672$; $q_0=0{\cdot}919$; $\mu=84\ 10$

		Calculated		Measured (mean)		No. of faces
		ϕ	ρ	ϕ	ρ	
c	001	$84°10'$	$90°00'$	$84°10'$	$90°00'$	8
a	100	00 00	90 00	00 00	90 00	6
b	010	00 00	00 00	00 00	00 00	6
m	110	00 00	36 10	00 00	36 00	1
v	101	52 08	90 00	51 53	90 00	3
g	011	84 10	47 24	84 10	47 29	6
p	$\bar{1}21$	$-60\ 11$	31 57	$-60\ 12$	31 58	9
r	121	52 03	34 25	52 10	34 18	2

Physical Properties:—Cleavage perfect parallel to 010, therefore across the fibers. Specific gravity $6{\cdot}488\ \pm{\cdot}003$, determined in the pycnometer on $\cdot6^{cc}$ of mineral (Merwin). Hardness $4{\cdot}5$. Luster adamantine. Plane of the optic axes

parallel to plane of symmetry. Refraction and double refraction high but not determined.

Chemical Composition :—A small amount of the mineral was picked out under the microscope as free as possible from adhering quartz and other substances contained in the ore. The absence of cerussite was proved by lack of effervescence in nitric acid. The mineral fuses at 3 to a greenish yellow bead, colorless when cold ; it is easily reduced on charcoal to a lead button and is soluble in nitric acid with strong gelatinization.

The analysis by H. E. Merwin gave the following result :

	Per cent	Mol. Ratio	Per cent for PbSiO₃
SiO₂	21·11	·348	21·32
PbO	78·13	·351	78·68
CaO	trace	----	----
FeO	·09	----	----
Residue* from PbO	·53	----	----
Insol. residue, quartz	·08	----	----
	99·94		100·00

* This residue was lost after weighing and was therefore not determined.

The molecular ratio of PbO to SiO₂ is almost exactly 1 : 1, indicating for the mineral the formula PbSiO₃.

There seems little doubt after considering its characteristics that alamosite should be classified with wollastonite. That it is to be regarded as isomorphous with that mineral is, however, open to question. In favor of this interpretation are (1) similarity of chemical type and behavior with acids ; (2) identity of crystal system and habit ; (3) close approximation in the values of the angle β and in the lengths of the *c*-axes ; (4) similarity of optical orientation. Opposed to the assumption of isomorphism are (1) difference in lengths of the *a*-axes ; (2) difference of cleavage.

The case is analogous to the relation of anglesite and anhydrite where, however, isomorphism is less strongly indicated than in the present pair of minerals.

Alamosite is very similar in appearance to barysilite but may be readily distinguished from it by its optical characters.

Harvard University, March, 1909.

Art. XXXVII.—*Absence of Polarization in Artificial Fogs ;* by C. Barus.

The astonishing feature of Tyndall's experiment, made in the usual way with motes of mastic suspended in water, is the completeness of the polarization of the light reflected or scattered at right angles to the impinging beam. This is particularly well shown with the double image prism, in which, for horizontal beams of light with vertical and horizontal vibration beams and line of sight horizontally at right angles to each other, only one of the beams (that for which vibration is vertical) is visible in the turbid water. The other is quite extinguished while lying in a vertical plane either above or below the visible beam.

In making the same experiment with dense fogs, I was surprised to find an almost entire absence of this discriminating character. Both beams are always in view and about equally intense. These fogs were produced in the fog chamber with phosphorus nuclei and were intensely luminous, with several millions of water particles per cubic centimeter of an average size less than $\cdot0001^{cm}$. Even for fogs so dense and therefore so fine that the light penetrates scarcely 30^{cm}, both beams were about equally brilliant. On examining the two beams with a Nicol, however, they are found to be almost completely polarized at right angles to each other ; whence it follows that the vibration, which is horizontal *outside*, has been turned about 90 degrees in a horizontal plane after entering. In other words, whereas it vibrates in a horizontal plane normal to the observer on the outside of the fog chamber, it vibrates in a horizontal plane parallel to the observer in the inside of the fog chamber ; or, while the plane of the two vibrations is normal to the primary beam on the outside, it is parallel to the two beams on the inside of the fog chamber. The beam with vertical vibrations naturally remains unchanged. Finally, if coronas are produced from a polarized source, they are found to be polarized throughout all their colors and quite extinguished between crossed Nicols.

As the motes do not produce coronas and will not subside, it is difficult to specify their size. But the marked occurrence of scattering is sufficient evidence for the absence of regular reflection. Virtually at least, the particles are very small. With regard to the fogs, however, even in the case of the very finest particles, the light is still regularly reflected and refracted, and not scattered, as in the first instance, to an appreciable extent. Hence, for a line of vision normal to the primary beam, the direction of vibration may be turned 90 degrees parallel to the plane of the beam and vision, and now vibrates normal to the line of vision, seeing that light is not completely polarized on reflection from a surface of water.

Brown University, Providence, R. I.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Prussian Blue and Turnbull's Blue.*—Many investigators have studied the well-known blue precipitates produced on the one hand by mixing solutions of ferric salts with solutions of ferrocyanides, and on the other hand by mixing solutions of ferrous salts with solutions of ferricyanides, but the compositions of the precipitates thus produced under varying conditions have not been perfectly established. Müller and Stanisch have now undertaken an investigation of this subject by the use of what appears to be a more satisfactory method than has been previously employed. Instead of attempting to isolate and analyze the precipitates themselves, they have determined their compositions indirectly by mixing known volumes of solutions of known strength, and after analyzing measured volumes of the clear liquids standing above the precipitates, calculating the composition of the latter. All of the substances were determined volumetrically by means of permanganate solution—the ferrous iron and the ferrocyanide directly, the ferric iron after reduction with zinc, and the ferricyanide after reduction with a ferrous salt in alkaline solution. Several series of experiments with systematically varying proportions of the reagents gave satisfactory and concordant results leading to the following conclusions: The blue precipitates are all ferrocyanides, whether produced from ferrocyanide or ferricyanide; the precipitate $Fe'''_4[Fe''(CN)_6]_3$ is produced by mixing solutions of ferric chloride and potassium ferrocyanide in molecular proportions $> 4 : 3$; the precipitate $KFe''Fe'''_3[Fe''(CN)_6]_3$ is formed from ferrous chloride and potassium ferricyanide in molecular proportions $> 4 : 3$; the precipitate $KFe'''[Fe''(CN)_6 + K_2Fe''[Fe''(CN)_6]$ is produced from ferric chloride and potassium ferrocyanide in molecular proportions $< 1 : 1$; the precipitate $KFe'''[Fe''(CN)_6]$ is produced from solutions of ferrous chloride and potassium ferricyanide in molecular proportions $< 1 : 1$. It is proposed to study in the future such proportions as have not been included here, and also to control the results by the determination of potassium.—*Jour. prakt. Chem.*, lxxix, 81.   H. L. W.

2. *The Chemistry of the Radio-active Elements.*—The chemical characters of most of the radio-active elements are only imperfectly known. It has been found that some of them accompany certain well-known elements in precipitations, while others volatilize at high temperatures. Whether the volatilized substances are the uncombined elements, their oxides, or other compounds is unknown, while in the case of precipitations the phenomenon of adsorption may play an important part in such exceedingly low concentrations as exist in these cases, so that conclusions in

regard to chemical relations must be drawn with caution. In view of these circumstances, STRÖMHOLM and SVEDBERG have undertaken a study of the subject by the use of isomorphism. As an example of the behavior of normal elements, the following experiments were made : To equal portions of a warm saturated solution of barium nitrate, equal amounts of dilute solutions of silver, mercuric, lead and bismuth nitrates were added, and after cooling it was found that the crystallized barium nitrate contained neither silver, mercury nor bismuth, but it had taken up much lead in solid solution. From a similar series of experiments with potassium nitrate none of the above mentioned metals showed a solubility in the solid phrase, while in the case of sodium nitrate a considerable amount of silver and a little lead were found in the crystals. The authors applied this method to a solution of Rutherford's thorium-X, and found that this element is iso-morphous with barium and lead, that it follows barium in its pre-cipitations, and therefore belongs to the alkali-earth group of metals. Similar experiments with thorium nitrate solutions gave less definite results on account of the numerous radio-active bodies present in such solutions, but it is the purpose of the authors to extend their studies by this method to other series of radio-active elements.—*Zeitschr. anorgan. Chem.*, lxi, 338.   H. L. W.

3. *The Hydrogen Silicides.*—LEBEAU, in a preliminary account of his researches on the subject, shows that the hydrogen silicides, produced by the action of hydrochloric acid upon magnesium silicide, are more numerous than heretofore supposed. Besides the two gaseous compounds SiH_4 and Si_2H_6 already known, it is evident that a liquid silicide exists, and probably also one which is solid at ordinary temperatures. Lebeau condensed a large volume of the silicides by means of liquid air, then by allowing the solid thus produced to attain ordinary temperature a com-paratively small amount of hydrogen silicide, SiH_4, free from hydrogen, was given off, while a colorless liquid remained behind. Upon fractioning this liquid there was obtained practically pure Si_2H_6, which was found to boil at about $-7°$ C. The liquid silicide was obtained only in small quantity and was not satisfac-torily analyzed, but it appears to be silicoethylene, Si_2H_4. This unsaturated compound is spontaneously inflammable with explo-sive violence when exposed to the air, and it is probably the vapor of this substance which gives spontaneous inflammability to the two gaseous silicides when they are not perfectly pure. The solid substance was observed as a small residue which becomes brown upon exposure to the air and thus yields silicon. —*Bulletin*, IV, v, 89.   H. L. W.

4. *Determination of Boron.*—COPAUX and BOITEAU have studied several methods for the determination of this element, including the extraction of boracic acid by means of ether, its volatilization by means of methyl alcohol and its volumetric determination by acidimetry in the presence of glycerine. They find the latter method very satisfactory and particularly well

adapted to the analysis of borotungstates. Precise details of the method of operation are given, together with numerous test-analyses which show remarkably good results.—*Bulletin*, IV, v, 217. H. L. W.

5. *Canal Rays.*—J. STARK and W. STEUBING continue the studies of J. Stark upon the Doppler effect in these rays, with apparatus affording a large dispersion (a Rowland plane grating with a ruled surface of 8×16^{cm} and 15,000 lines to the inch). The observations are given in full tables, which give the fall of potential of the dark space and velocity of rays. The fall of potential at the cathode varied from 390 volts to 9600 ; the velocity of the canal rays varied over this range from $1 \cdot 299 \cdot 10^7$ to $1 \cdot 760 \cdot 10^7$. Much space is given to the discussion of the cause of the variation observed in the Doppler effect, especially the maxima and minima. The article closes with a discussion of the observed reflected canal rays, which give a Doppler effect, with a cathode fall of 2500 volts. The reflection of the positive charge of the canal rays amounts to 50 per cent.—*Ann. der Physik*, No. 5, 1909, pp. 974–998. J. T.

6. *Zeeman Effect of Mercury Lines.*—P. GMELIN has studied this effect with the lines of rare lengths 5790, 5769, 4916, 4358, and shows how the strength of a magnetic field can be measured by a determination of the Zeeman effect. The article closes with the following table :

Classen (cathode rays) $\qquad \dfrac{\epsilon}{\mu} = 1 \cdot 776 \times 10^7$

Bacherer (Becquerel rays) $\quad \dfrac{\epsilon}{\mu} = 1 \cdot 730 \times 10^7$

Gmelin (Zeeman effect) $\qquad \dfrac{\epsilon}{\mu} = 1 \cdot 771 \times 10^7 .$

—*Ann. der Physik*, No. 5, 1909. J. T.

7. *Presence of Rays of High Penetrability in the Atmosphere.*— The extension of our knowledge of radio-activity has led to much study of the presence of γ-rays in the earth and in the earth's atmosphere. TH. WULF describes an improved and portable electrometer which is well adapted for the study of radio-activity and he applies it to a study of the γ-rays in the atmosphere, finding a winter type without the midday depression which characterizes the summer type.— *Physik. Zeitschrift*, No. 5, March 1, 1909, pp. 152–157. J. T.

8. *Use of Radiometer for Observing Small Pressures.*—J. DESSAR states that if the residual gas in a radiometer is helium, pulverized carbon cooled by hydrogen is incapable of lowering the pressure so that the vanes will not turn, when the light of the voltaic arc is concentrated upon them. On the contrary, when the residual gas is hydrogen the absorption of the gas by the carbon is sufficient to cause all movement to cease. He believes that a radiometer filled with helium will prove a useful apparatus for the study of radio-activity.—*Proc. Roy. Soc.*, London, Series A, vol. lxxix, 1907. J. T.

9. *Wireless Telegraphy and Telephony Popularly Explained;* by WALTER W. MASSIE and CHARLES R. UNDERHILL. Pp. 76. New York, 1908 (D. Van Nostrand Co.).—This book is intended to be a simple, elementary exposition of the inception and development of wireless telegraphy and telephony. The space devoted to the latter subject is less than four pages. There are a number of simple diagrams and some excellent half-tone plates showing elaborate apparatus. The book closes with a highly speculative "interview" by Nikola Testa, in which a few of the wonders to be wrought within the near future by the application of wireless transmission are briefly outlined.   B. B. B.

10. *An Introduction to the Science of Radio-activity;* by CHARLES W. RAFFETY. Pp. xii, 208. New York, 1909 (Longmans, Green & Co.).—The author has "endeavoured to give a concise and popular account of the properties of the radio-active elements and the theoretical conceptions which are introduced by the study of radio-active phenomena. This work, as its title indicates, does not claim to be more than an introduction to the subject, and no attempt has been made at an exhaustive treatment." The attempt appears to have been distinctly successful, however, and the book is in many respects superior to others of the same class which have previously appeared. The method in which the subject is treated follows very closely along the lines originally laid down in Rutherford's familiar treatise, and is frequently suggestive of the author's familiarity with collected works of this sort rather than with the original papers in the literature. A notable and unfortunate exception is to be found in the somewhat detailed discussion of the very questionable results recently obtained by Ramsay in experiments with the radium emanation.   B. B. B.

II. GEOLOGY AND NATURAL HISTORY.

1. *Publications of the U. S. Geological Survey,* GEORGE OTIS SMITH, Director.—Recent publications of the U. S. Geological Survey are noted in the following list (continued from p. 86) :

TOPOGRAPHIC ATLAS.—Thirty-seven sheets.

FOLIOS.—No. 160. Accident-Grantsville Folio, Maryland-Pennsylvania-West Virginia. Description of the Accident and Grantsville Quadrangle ; by G. C. MARTIN. Prepared under the supervision of WILLIAM BULLOCK CLARK, coöperating geologist. Pp. 14, with 8 maps, columnar sections.

No. 162. Philadelphia Folio. Norristown, Germantown, Chester and Philadelphia Quadrangles, Pennsylvania–New Jersey–Delaware ; by F. BASCOM, W. B. CLARK, N. H. DARTON, H. B. KÜMMEL, R. D. SALISBURY, B. L. MILLER and G. N. KNAPP. Pp. 23 ; 2 topographic maps; 3 colored geologic maps; columnar sections and 21 figures.

No. 163. Santa Cruz Folio, California. Description of the Santa Cruz Quadrangle; by J. C. BRANNER, J. F. NEWSOM and RALPH ARNOLD. Pp. 11 ; columnar sections, 3 maps, II plates.

PROFESSIONAL PAPERS.—No. 58. The Guadalupian Fauna ; by GEORGE H. GIRTY. Pp. 651, 31 plates. See p. 413.

No. 59. Contributions to the Tertiary Paleontology of the Pacific Coast. I. The Miocene of Astoria and Coos Bay, Oregon; by WILLIAM HEALEY DALL. Pp. 278, 33 plates, 14 figures.

No. 60. The Interpretation of Topographic Maps ; by ROLLIN D. SALISBURY and WALLACE W. ATWOOD. Pp. 84, 170 plates, 34 figures. See p. 265.

No. 61. Glaciation of the Uinta and Wasatch Mountains ; by WALLACE W. ATWOOD. Pp. 96, 15 plates, 24 figures. See p. 340.

No. 63. Economic Geology of the Georgetown Quadrangle (together with the Empire District), Colorado ; by JOSIAH E. SPURR and GEORGE H. GARREY ; with General Geology by SYDNEY H. BALL. Pp. 422, lxxxvii plates, 155 figures. See p. 408.

BULLETINS.—No. 353. Geology of the Taylorsville Region, California ; by J. S. DILLER. Pp. 128, 5 plates, 12 figures. See p. 412.

No. 354. The chief Commercial Granites of Massachusetts, New Hampshire, and Rhode Island; by T. NELSON DALE. Pp. 228, 9 plates, 27 figures.

No. 356. Geology of the Great Falls Coal Field, Montana ; by CASSIUS A. FISHER. Pp. 85, 12 plates, 2 figures.

No. 358. Geology of the Seward Peninsula Tin Deposits, Alaska; by ADOLPH KNOPF. Pp. 769, 20 plates, 7 figures.

No. 359. Magnetite Deposits of the Cornwall Type in Pennsylvania; by ARTHUR C. SPENCER. Pp. 102, 20 plates, 21 figures.

No. 361. Cenozoic Mammal Horizons of Western North America ; by HENRY FAIRFIELD OSBORN, with Faunal Lists of the Tertiary Mammalia of the West; by WILLIAM DILLER MATTHEW. Pp. 138, 3 plates, 15 figures.

No. 363. Comparative Tests of Run-of-Mine and Briquetted Coal on Locomotives, including Torpedo-Boat Tests and some foreign specifications for briquetted fuel ; by W. F. M. GOSS. Pp. 57, 4 plates, 35 figures.

No. 365. The Fractionation of Crude Petroleum by Capillary Diffusion ; by J. ELLIOTT GILPIN and MARSHALL P. CRAM, under supervision of DAVID T. DAY. Pp. 33, 3 figures.

No. 366. Tests of Coal and Briquets as Fuel for House-Heating Boilers ; by D. T. RANDALL. Pp. 44, 3 plates, 2 figures.

No. 367. The Significence of Drafts in Steam-Boiler Practice ; by WALTER T. RAY and HENRY KREISINGER. Pp. 60, 26 figures.

No. 368. Washing and Coking Tests of Coal at the Fuel-testing Plant, Denver, Colo., July 1, 1907, to June 30, 1908. By A. W. BELDEN, G. R. DELAMATER and J. W. GROVES. Pp. 53, 2 plates, 3 figures.

No. 371. Reconnoisance of the Book Cliffs Coal Field between Grand River, Colorado and Sunnyside, Utah; G. B. RICHARDSON. Pp. 54, 10 plates, 1 figure.

No. 372. Bibliography of North American Geology for 1906 and 1907, with Subject Index; by F. B. WEEKS and J. M. NICKLES. Pp. 317.

No. 376. Peat Deposits of Maine; by EDSON S. BASTIN and CHARLES A. DAVIS. Prepared in coöperation with the Maine State Survey Commission. Pp. 127, 3 plates, 20 figures.

No. 378. Results of Purchasing Coal under Government Specifications; by JOHN SHOBER BURROWS. With a paper on burning the small sizes of anthracite for heat and power purposes; by DWIGHT T. RANDALL. Pp. 44.

WATER SUPPLY PAPERS.—No. 221. Geology and Water Resources of the Great Falls Region, Montana; by CASSIUS A. FISHER. Pp. 89, 7 plates.

No. 225. Ground Waters of the Indio Region, California, with a sketch of the Colorado Desert; by WALTER C. MENDENHALL. Pp. 56, 12 plates, 5 figures.

No. 226. The Pollution of Streams by Sulphite Pulp Waste. A Study of Possible Remedies; by EARLE BERNARD PHELPS. Pp. 36.

MINERAL RESOURCES of the United States: 1907. In two parts. Part I. Metallic Products. Pp. 743, 1 plate, 1 figure. Part II. Nonmetallic Products. Pp. 897, 1 plate, 6 figures. Washington, 1908. The several chapters of this important work have already been issued, in advance, in separate forms.

2. *Economic Geology of the Georgetown Quadrangle, Colorado;* by J. E. SPURR and G. H. GARREY; with *General Geology* by S. H. BALL. 4°, pp. 422, 87 pls., 155 figs.; Prof. Paper 63, U. S. Geol. Survey. Washington, 1908.—While this important work contains an extremely complete study of all the different phases of the geology of the area mentioned in the title, and a very full account of the mineral veins, ores and mines for which the district is noted, and thus presents a great mass of material which it would be impossible to adequately review in a brief notice, probably that feature of the work which is of most importance and general interest concerns the conclusions regarding the genesis of the ore bodies to which the authors have been led as the result of their studies.

Besides the sedimentary formations in the area which have been metamorphosed into gneisses and schists, the great bulk of the rocks are of igneous origin, intrusive in occurrence and due to successive upthrusts of different magmas mostly in pre-Cambrian, but some in Tertiary, times. The older these rocks are the more gneissoid is the structure which they exhibit. They vary from granites through monzonites to diorites. They are cut by aplites and pegmatites and by later dikes and masses of porphyry, bostonite, syenite, etc. In general, later than the intrusion of these porphyries, etc., occurred the formation of veins by deposition along fault fissures, which were also later in

origin than the porphyries. The mineral veins lie in distinct areas or belts. The greatest contrast in them is offered by those which are chiefly silver-bearing as compared with those which are predominantly gold-bearing.

As a result of the investigation of the gold, silver and lead deposits of Colorado two chief natural groups appear, those following injections of a monzonite magma including a large part of the mineral zone with northeast trend across the state, and those which followed isolated local outbursts of magma of an alkalic character. Both periods of ore deposit are of Tertiary age. The ores of the Georgetown district belong in the former northeast belt of which they are a portion. The gold ores are pyritic; the silver ores are galena-blende. Areas covered by the veins coincide with those injected by porphyry dikes and the ore formation is believed to have immediately followed the intrusions. The gold ores depend definitely upon magmas producing one family of igneous rocks, the silver ores upon a distinctly different magmatic family.

Further study of the deposits leads to the belief that the ores have been formed in the case of the pyritiferous gold veins by magmatic waters given off during the pneumatolytic stages of consolidation of certain dikes, due to the intrusion of alkaline magma, while the deposition of the silver-lead ores has followed in a similar way from monzonitic magmas. Since the latter deposits, however, are the older they have suffered much erosion, and in their present status represent the action of a secondary period of concentration and enrichment from descending surface waters.

In connection with this the waters of certain hot-springs have been studied and, from their composition and the mineral reactions which they produce, it is concluded that they are of magmatic origin. Many of the minerals which they form are due to reactions with the wall rocks with which they come in contact and thus wall rocks of differing composition have produced different sets of minerals. The general conclusion is drawn from the study that the greater portion of the gold, silver and lead ores of Colorado are of magmatic origin and this mode of ore formation, that is their being due to emanations from igneous magmas, is one of first importance, in comparison with which all other modes of formation, save in the case of the most common metals, shrinks into insignificance. L. V. P.

3. *Geology of the Gold Fields of British Guiana;* by J. B. HARRISON. 8°, pp. 320, 33 pls. London, 1908 (Dulau & Co.).— While this volume is ostensibly devoted to a description of the occurrences of gold ores in the colony, it is for the most part made up of a report on the results of reconnaissance work following explorations along several important rivers; it contains in addition a considerable amount of careful, thorough and excellent petrographical research made upon the rock types collected. Especially to be commended are the very complete and accurate analyses which have been carried out on a considerable number

of rock types. It would be impossible in a brief notice to give any account of the large amount of information contained in this volume, mostly of a detailed local character, but those interested in petrography on the one hand, and those who are concerned with the ecomonic features, such as the gold deposits, on the other, will find in it much that is of general importance.   L. V. P.

4. *Essai sur la Constitution géologique de la Cuyane hollandaise (district occidental);* par H. VAN CAPPELLE. *Etude pétrographique;* par E. H. M. BEEKMAN. 8°, pp. 177 and map. Paris, 1907.—This work contains an account of geological observations made during voyages of exploration along the south bank of the Corantyn (Corentyne) River and along the Nickerie River and one of its branches. The observations are necessarily confined to a narrow strip along the route traversed. Metamorphic rocks consisting of various gneisses, quartzites and schists were observed, frequently cut by igneous masses, granites, diorites and gabbros being most prominent, although other types of rocks also occur. The author discusses the alteration of these rocks and also the character of the soil formed, especially that of laterite. He describes the distribution of gold and its relation to the rock formations. The petrographic study consists of a description of the mineral composition of the large number of rock specimens collected, as seen in thin section under the microscope.

While the work was in the nature of a rapid reconnaissance, it adds considerably to our knowledge of a little known region.

L. V. P.

5. *The Eruption of Vesuvius in April, 1906;* by H. J. JOHNSTON-LAVIS, Sci. Trans. Roy. Dublin Soc., Vol IX, Pt. 8, Jan. 1909. 4°, pp. 139-200, pls. iii–xxiii.—The author, who has long been known for his studies of Italian volcanic phenomena and especially of Vesuvius, gives in this paper a general account of this eruption with special details upon certain phases. Outside of these latter, which deal chiefly with a discussion of the petrography of the products of the eruption and of certain views concerning volcanic action which the author has developed as a result of his studies, the memoir furnishes an excellent general description of the eruption and its attendant phenomena; this is made graphically interesting by a series of plates reproducing excellent photographs. In addition two maps add greatly to its value.   L. V. P.

6. *Text-Book of Petrology;* by F. H. HATCH. 12°; pp. 404; 5th ed., 1909. London (Sonnenschein & Co.).—This little volume, which contains a short account of the general principles of petrology, has been rewritten and given a general redressing by the author. Since such subjects as the rock minerals and their characters under the microscope, the physical characters of rocks, their modes of occurrence and classification, rock textures and a variety of others are dealt with in the first 150 pages, these subjects are necessarily handled in a very brief and elementary way. The following 125 pages are devoted to a general description of igneous rocks, these being divided into the plutonic, hypabyssal

and volcanic groups, and again subdivided according to the plan whose outline is shown in the succeeding notice. The remainder of the work is composed of a description of the distribution of igneous rocks in the British Isles. While the volume is intended especially for British students, who may desire to attain a knowledge of the elements of petrography, there are doubtless many teachers of the subject in this country who will desire to acquaint themselves with the author's methods and ideas of this subject.

L. V. P.

7. *Classification of the Plutonic Rocks;* by F. H. HATCH; Science Progress No. 10, 1908, pp. 1–21, reprint.—The writer believes that the physical differences between the abyssal granular rocks and the glassy or porphyritic ones is so great that any scheme of classification which presumes to be of a natural, as opposed to an artificial, character must recognize this. Assuming then that the plutonic group is a natural one, he proposes a subdivision of it on chemical grounds, according to the silica content, these groups being again subdivided according to the alkali and calc-alkali contents. In this the "ultra basic" rocks (peridotites, etc.), are not included. This gives rise to the following grouping, which sufficiently illustrates the scheme proposed :

	Alkali Series			Monzonite Series	Calc-alkali Series
	Fels-pathoid Series	Soda Series	Potash Series		
Acid Group $SiO_2 > 66\%$		Soda-Granite Sub-Family	Potash Granite Sub-Family	Adamellite Sub-Family	Granodiorite Sub-Family
			GRANITE FAMILY		
Intermediate Group SiO_2 52–66%	Nephelite Syenite Sub-Family	Soda-Syenite Sub-Family	Potash-Syenite (Plauenite) Sub-Family	MONZONITE FAMILY	DIORITE FAMILY
	SYENITE FAMILY				
Basic Group $SiO_2 < 52\%$	Nephelite-gabbro Sub-Family	Essexite Sub-Family	Shonkinite Sub-Family	Kentallenite Sub-Family	GABBRO FAMILY
	ALKALI-GABBRO FAMILY				

L. V. P.

8. *Elements of Optical Mineralogy;* by N. H. and A. N. WINCHELL. 8°, 502 pp., many figs. and col. plates. New York, 1909 (Van Nostrand Co.).—The authors state in the preface that this work had its inception under the impulse of a conviction that English students and independent workers in petrography needed a clear and systematic description of the apparatus used and the methods employed in this science. They feel that the principles, methods and data of optical mineralogy have not yet been presented concisely and clearly in any single publication and it is their aim to supply this deficiency.

In accordance with this view the first chapter is devoted to an explanation of the nature of light and such of its phenomena as are of importance in this connection ; the second deals with the elements of crystallography ; the third describes the general phenomena of optical mineralogy and the apparatus used in investigating them from the petrographic standpoint. These three chapters contain 100 pages, and of necessity, since they cover so wide a field, the material is greatly condensed. It is illustrated, however, by many figures which serve to explain the text.

The remaining portion of the volume is devoted to a description of all minerals which are important as rock constituents, or which are sufficiently transparent to have optical properties, especial emphasis in all cases being laid upon the latter in the description. Numerous figures in the text help to convey the optical characters in succinct form.

Whether the teacher or student of petrography decides to use this, or one of the several other excellent works we now have, as his main reliance in gaining a mastery of the principles of this subject, he will at all events find this volume a most serviceable handbook of reference with respect to the optical properties of minerals. As such it will prove a great convenience in the library of every working mineralogist and petrographer.

L. V. P.

9. *Geology of the Taylorsville Region, California;* by J. S. DILLER. *United States Geological Survey. Bulletin 353.* Pp. 121, with 5 plates and 12 figures. Washington, 1908.—Little has been published regarding the district in California between Honey Lake and Lassen Peak, a region which has much of geological interest. Dr. Diller's report shows that the " sedimentary rocks of the Taylorsville region contain a more nearly complete record of the geological history of the Sierra Nevada than has yet been recorded in any portion of the range." Eighteen sedimentary formations are represented : Silurian 1, Devonian 1, Carboniferous 4, Triassic 2, Jurassic 7, Tertiary 1, and Quaternary 2 ; the Carboniferous, Jurassic, and Triassic being the richest in fossil remains. In place of the single fault bounding the Sierra Nevada farther south, there are in this district at least three more or less parallel fault zones. The easternmost one,— the Honey Lake,—presents an escarpment 2,000 feet high, composed of quartz diorite overlain by auriferous gravel and breccia.

During Cretaceous time, a peneplain was developed by erosion of the Jurassic mountain masses.   H. E. G.

10. *Explorations in Turkestan. Prehistoric Civilizations of Anau.* Edited by RAPHAEL PUMPELLY, Director of the Expedition. In two volumes, 494 pages, 97 plates, figures 548. Carnegie Institution, Washington, 1908.—The results of the expedition of 1904 fully justify the expense and the time required for preparation of results; the two volumes, in fact, constitute perhaps the most exhaustive study of deserts, desert relations, and the influence of arid environments ever published. In addition to the studies of the director of the expedition, contributions from the following authors are included : Hubert Schmidt; Homer H. Kidder; Ellsworth Huntington; F. A. Gooch; R. Welles Pumpelly; J. Ulrich Duerst; G. Sergi; Th. Mollison; H. C. Schellenberg; Langdon Warner. The more strictly physiographic parts are the following : Ancient Anau and the Oasis-World, pp. 3–80; Physiography of Central Asian Deserts and Oases, pp. 243–337.

11. *Glacial Bowlders in the Blaini Formation, India ;* by Sir T. H. HOLLAND. *Records of the Geological Survey of India,* vol. xxxvii, part i, pp. 129–135. Calcutta, 1908.—The Blaini group of the Punjab, described by Medlicott in 1864, was assumed by Oldham (Records of the Geological Survey of India, vol. xx) to be of glacial origin, although definite proof was not forthcoming. Unmistakable glacial bowlders, recently found in this formation, are described by T. H. Holland. In connection with the announcement of this discovery, Dr. Holland takes occasion to discuss the age of these beds, which he no longer considers to be Permian, since it is not necessary to correlate them with the deposits of the Talchir (upper Carboniferous) glaciation in peninsular India. This conclusion clears up many difficulties in Indian stratigraphy and makes it possible to group the unfossiliferous systems of the outer Himalayas, and those of pre-Talchir (pre-upper Palæozoic) and post-Dharwar (post-Huronian) age in the peninsula of India. These formations, for which the name *Purana* has been suggested, are considered wholly or in part pre-Cambrian.   H. E. G.

12. *The Guadalupian Fauna ;* by GEORGE H. GIRTY. Prof. Paper 58, U. S. Geol. Surv. 1908 [Feb. 1909], pp. 651, pls. 31.— This extensive and very valuable monograph of the Permian or Guadalupian faunas of southeastern New Mexico and southwestern Texas describes in great detail 326 species, of which about 220 are specifically determined. Nearly all the species are new and the various biota are strikingly different from any other American late Paleozoic formations. In fact the author finds it very difficult to compare the Guadalupian faunas with any other because they maintain a highly individual facies. The only comparisons that can be made, and these but sparingly, are with the

Fusulina limestone of Sicily and the Salt Range and Himalaya of India. No comparison at all can be made with those of the Mississippi Valley, for the oldest part of the Guadalupian is younger than any part of the Kansas " Permian." " Probably the best correlation is that of the Guadalupian on one hand with the Artinsk and Permian on the other " (p. 40). " It would be unwise at present to correlate the Guadalupian series with any definite stage of the Russian section " (p. 41).

The Guadalupian faunas consist essentially of Protozoa (9), Sponges (24), Bryozoa (44), Brachiopoda (128), Pelecypoda (45), and Gasteropoda (42). The more characteristic elements are the large and very abundant *Fusulina elongata,* of brachiopods *Geyerella* (1 species), *Richthofenia* (1), *Leptodus* or *Lyttonia* (2), *Aulosteges* (5), *Productus* (25), *Pugnax* (12), *Spiriferina* (9), *Dielasma* (5), *Dielasmina* (2), *Notothyris* (3) and *Heterelasma* (2). The Mesozoic bivalve genus *Camptonectes* seems also to be present.

The new genera are, of sponges *Anthracosycon, Virgula, Pseudovirgula, Stromatidium, Guadalupia, Polysiphon, Cystothalamia;* a supposed cystid, *Coenocystis;* of brachiopods, *Heterelasma;* the pelecypod *Protrete;* the cephalopod *Peritrochia* and the trilobite *Anisopyge.*

We have in this book a valuable contribution to Permian faunas, but as the life is that of a distinct province harmonizing best with those of subtropical waters, there is not much guidance to be derived from it in ascertaining the exact time equivalent of the " Permian " of the Mississippi Valley.   c. s.

13. *Cambrian Geology and Paleontology.* No. 5.— *Cambrian Sections of the Cordilleran Area;* by CHARLES D. WALCOTT. Smithsonian Miscel. Coll., 53, 1908, pp. 167–230.—Here are described in detail six extensive Cambrian sections ranging in thickness from 5670 to over 13,000 feet. They are located in California, Nevada, Utah, Montana and British Columbia. Throughout the sections the fossils are listed and it is seen that *Olenellus* has a range of at least 4900 feet. One of the interesting facts is the recording in the Pacific province of the genus *Holmia,* one that is usually regarded as diagnostic of the Atlantic province. *Billingsella coloradoensis* ranges throughout the Middle Cambrian into the Upper Cambrian. The paper is illustrated by many half-tones of these the finest Cambrian sections.   c. s.

14. *Mount Stephen Rocks and Fossils;* by CHARLES D. WALCOTT. Alpine Club of Canada, Calgary, Alberta, Sept. 1908, pp. 232–248, plates 8.—The author describes in this paper the great Cambrian section, Mount Stephen, at Field on the line of the Canadian Pacific railway. Any one collecting the fine Middle Cambrian fossils first noted by Rominger will want this pamphlet as his guide to the locality and for the determination of his fossils.   c. s.

15. *Devonian Fishes of Iowa;* by CHARLES R. EASTMAN. Annual Report, Iowa Geological Survey, Vol. XVIII, pp. 29-386, pls. i–xvi and 41 text figures. 1907.—This is a very exhaustive work on the Devonian Fishes, not only of Iowa but also of the North American Devonian, while the fishes of Great Britain and Europe are of necessity treated for comparison. Chapter I is of an introductory character, in which the author discusses the aim and general outlook of paleontological inquiry, and the relations of paleichthyology to biology. Chapter II is geological and in it is considered the stratigraphy of the Devonian fish-bearing beds of Iowa, which form a belt averaging fifty miles in width, stretching along the Cedar river from the Minnesota line to Muscatine County and thence eastward into Illinois.

The Devonian fauna of the state is peculiar in its undiversified character, consisting almost exclusively of Chimæroids, Arthrodires and Lung fishes; there being a notable dearth of Selachians and but one certainly recognized genus of Crossopterygians. The fish-bearing stages are confined to the Middle and Upper Devonian, their greatest abundance being during the latter period.

In his discussion in Chapter III of the evolutionary history of fishes, Dr. Eastman denies the possibility of the derivation of fishes from the Arthropod phylum, but finds no theoretical objection to looking upon some of the worm-like Enteropneusta as the possible ancestors of the vertebrate stem. Documentary evidence of this will probably never be obtained, from the impossibility of the preservation of such soft-bodied creatures in the rocks. A further discussion of the main evolutionary changes of the fishes follows, showing remarkably sudden fundamental advances; the "expression points" of Cope: such as the acquisition (1) of paddle-like paired fins; (2) shortened fin-bases but persistent heterocercal tail; (3) complete balancing fins and homocercal tail and (4) a complete internal skeleton.

The discussion of the general classificatory scheme includes a tabular view of the classification to suborders.

Chapter IV discusses the systematic account of Devonian fishes, with special reference to those of Iowa and the adjoining states. Herein are carefully described and compared many species included in 32 well-known genera, and several more, the family position of which is doubtful. Chapter V embraces three admirable faunal lists; one of the Lower Devonian localities in New Brunswick, Nova Scotia, Quebec and Aroostook Co., Maine; and the Middle and Upper Devonian, both of which are included in Iowa. The excellent plates are from wash drawings and photographs and include three of Professor Schuchert's paleogeographical maps; that of Middle Devonian at the close of the Onondaga, at the close of the Hamilton, and during Upper Devonian time.

The work is a masterful one, written in Dr. Eastman's delightfully readable style, and will prove a great boon, not alone to the systematic paleichthyologist, but to the general student of paleontology and evolution as well. R. S. L.

16. *Der Unterkiefer des Homo Heidelbergensis aus den Sanden von Mauer bei Heidelberg. Ein Beitrag zur Paläontologie des Menschen* von OTTO SCHOETENSACK. Mit 13 Tafeln, davon 10 in Lichtdruck. Leipzig, 1908 (Wilhelm Engelmann).—In this volume Dr. Schoetensack tells the story of a remarkable discovery and interprets its meaning. The find was made the 21st of October, 1907, in a sand-pit near the village of Mauer, ten kilometers southeast of Heidelberg. Mauer lies in the valley of the Elsenz, a tributary of the Neckar. The human lower jaw came from the so-called Mauer sands at a depth of 24·10 meters from the surface and ·87 meters from the bottom of the deposit. The first 10·92 meters at the top of the section are composed of loess which is classed as upper Quaternary, while the rest of the section is lower Quaternary. The horizon from which the human lower jaw came has furnished other fossil mammalian remains including *Felis spelœa, Ursus arvernensis, Cervus latifrons,* Bison, Equus, *Rhinoceros etruscus* and *Elephas antiquus.*

The lower jaw was intact, but the stroke of the workman's shovel caused the two halves to separate along the line of symphysis. The absence of chin first attracts one's attention. The symphysial region is somewhat gorilloid, while the ascending ramus suggests rather the Gibbon. The teeth, however, are distinctly human and are relatively small in comparison to the size of the jaw. I have noted the same phenomenon in a collection of recent crania from Gazelle Peninsula, New Britain.* The dentition of *Homo Heidelbergensis* represents a youthful stage in the dentition of the modern European. That is to say, in the ontogeny of the latter, a stage representing adult dental characters when the race was young is now reached at the age of from nine to fourteen.

The ramus is characterized by its unusual breadth, 60^{mm}, as opposed to an average of 37 for recent examples. The processus coronoideus is exceedingly blunt and the incisura mandibulæ correspondingly shallow. The condyloid process has a large articular surface due to an increased antero-posterior diameter, since the transverse diameter is relatively short. In general appearance the lower jaw from Mauer resembles the restoration by Dubois of the lower jaw of *Pithecanthropus erectus,*† except in the dentition, to which Dubois gives a more anthropoid aspect.

The characters in the lower jaw of the Neandertal race, or so-called *Homo primigenius,* are well known through discoveries at La Naulette, Spy, Krapina, etc. That the latter race is intermediate between recent man and *Homo Heidelbergensis,* a comparison of the specimens in question furnishes ample proof. The lower jaw from Mauer is, therefore, pre-Neandertaloid. That it also exhibits pre-anthropoid characters gives it a fundamental position in the line of human evolution.

The remains of the Neandertal race are found in association with a Mousterian industry. The latter occurs in deposits that

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* Amer. Anthropol., N. S., iv, 474, 1902.
† This Journal, p. 475, June, 1896.

mark the close of the middle Quaternary and also in cavern deposits corresponding to the base of the upper Quaternary. It belongs to the latter part of the Riss glacial period and is known to extend well into the Riss-Würm interglacial, as at Wilkirchli in the Alps. The industry of the lower Quaternary is eolithic, the evolution of the Chellean type not taking place until the middle Quaternary. The probabilities are therefore that should Schoeten-sack find any artifacts in the horizon of *Homo Heidelbergensis* they will be of the eolithic type. Such a discovery would establish not only the identity of the maker of Quaternary eoliths but would also help immensely to solve.the riddle of Tertiary eoliths.   G. G. MacCurdy.

17. *The Commercial Products of India ;* by Sir George Watt. London, 1908 (John Murray).—This is an abridgment of the voluminous work well-known as the Dictionary of the Economic Products of India, published in 1885 and continued up to 1894. The many-volumed work has been out of print for some time. The recent increase in economic activity in all the educational centers as well as at the points where raw materials are inspected and appraised, has seemed to render necessary a revised edition of this standard treatise. It was, in its former shape, a very unhandy work, but it was so well filled with carefully prepared material, that the inconvenience of its clumsy volumes was always forgotten. The present work is in a very attractive one-volume edition, with a lavish use of marginal titles. Although this sys-tem of employing headings in the margin is most advantageous from every point of view, both in leisurely consultation and in hasty reading, its cost in the printing office has restricted its use in most of our scientific books. In this volume, practically every paragraph has been fitted with its appropriate caption, so that one can run down the page with great facility. To illustrate this, we may glance at Tea, taking the pages entitled History and Early Imports. Chinese Records ; Vegetable Tea (i. e., Tea used as a vegetable), Use as a beverage, Imperial duty, Silence of Marco Polo, Tea-drinking in China and Japan, First mention of Tea-drinking in India, Story of Black and Green Teas, Chinese plant in India, Taxation of Tea. By this method of indicating the nature of the paragraph, it has been possible to fill the page itself in the most economical manner. By a further use of a large page, and thin paper, the substance of the many volumes of the older edition, necessary for the student, is here given in a most accessible form. The book contains with its copious index, 1189 pages of rather small type.

The arrangement is alphabetical after a fashion, that is, the generic names follow each other in regular order, in their Latin form, but mingled with these are the common names, in English, of groups, such as Gem-stones, Live-stock, etc. The whole trea-tise has received careful attention at the hands of the revisers, and the subjects have been brought down to a recent date. For instance, such authorities as Winton's edition of Hanausek are quoted. The work has a wide range, and necessarily so, since it

is meant to exploit all of the commercial products of the Indian Empire. Minerals, animal-products, and all conceivable derivatives from plants find here a place and a proper treatment, under an exhaustive system of note-filing. The author and his assistants have laid under contribution current journals and newspapers in a discriminating manner, so that every source of information which is at all reliable has been made to contribute. When one uses this work in conjunction with J. C. Willis's admirable Flowering Plants and Ferns, with its enormous array of facts in regard to the genera and orders of plants, the study of eastern resources becomes a true pleasure.   G. L. G.

18. *The Forest Flora of New South Wales ;* by J. H. MAIDEN. —This valuable work is progressing regularly, and has now reached the third part of the fourth volume. The descriptions are clear and concise. The accounts of the technical applications and possible further extension of these uses must be of importance in the development of the colonies. The illustrations, to which we have before called attention, are of a high order of excellence.
                                                                    G. L. G.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *National Academy of Sciences.*—The annual Spring meeting of the National Academy was held at Washington on April 20–22; upwards of forty members were in attendance.

The following new members were elected: Joseph S. Ames, Johns Hopkins University; Maxime Bôcher, Harvard University; Oskar Bolza, University of Chicago; F. W. Clarke, U. S. Geological Survey; John M. Clarke, State Geologist of New York; J. M. Coulter, University of Chicago; Henry Crew, Northwestern University; Waldemar Lindgren, U. S. Geological Survey; Thomas H. Morgan, Columbia University; Henry L. Wheeler, Sheffield Scientific School.

The following were elected foreign associates: Albrecht Penck, University of Berlin; Gustaf Retzius, University of Stockholm; Wilhelm Waldeyer, University of Berlin; Wilhelm Wundt, University of Leipzig.

The list of the papers presented at the meeting is as follows :

G. C. COMSTOCK : The nature and possible origin of the Milky Way.

H. N. RUSSELL : Determination of stellar parallax from photographs made by Arthur R. Hincks and the writer.

C. H. MERRIAM : Strange ceremonial costumes of California Indians. Mythology of the Mewan Indians of California.

W. H. HOLMES : Archæological problems of the Titicacan plateau.

H. F. OSBORN : Discovery of a complete skeleton of *Tyrannosaurus* in the Upper Cretaceous. An Iguanodont Dinosaur (*Trachodon*) with the epidermis preserved.

F. H. KNOWLTON : Stratigraphic relations and paleontology of the lower member of the Fort Union formation.

J. Murray: The deep-sea bottom of the eastern tropical Pacific, from observations on the Albatross expedition.

H. B. Bigelow: The Medusæ of the eastern tropical Pacific, from observations on the Albatross expedition.

E. F. Nichols and G. P. Pegram: The radiation from gases heated by sudden compression.

E. F. Smith: The electrolytic separation of the chlorides of barium and radium.

T. Gill: The orders of teleostomous fishes (Pisces).

A. H. Clark; The distribution of the recent crinoids.

E. L. Nichols and E. Merritt: On the distribution of energy in the spectrum of the light from fluorescent substances.

W. M. Davis: A geographical excursion in northern Italy.

2. *Allgemeine Physiologie. Ein Grundriss der Lehre vom Leben;* von Max Verworn. Fünfte, vollständig neu bearbeitete Auflage. Pp. xvi + 742, with 319 figures.—Jena, 1909 (Gustav Fischer).—The appearance of this thoroughly revised new edition of a standard work will be welcomed by all biologists. Since the first edition fourteen years ago this book has occupied the first position among the general works dealing with vital phenomena, and its translation into other languages attests the favor it has received.

The book treats of the subject of physiology in its broadest sense—the manifestations of organisms, both animals and plants— a subject to which the term biology is often applied. The ground covered is the common property of anatomist and physiologist, of zoologist and botanist, of embryologist and evolutionist. An historical introduction is followed by an outline of the methods of physiological investigation. The physical and chemical structure of the living substance, the distinctions between living and lifeless bodies, metabolism, the sources of energy, conditions necessary for life, the origin of life, the significance of death, the reactions of living substance and of organisms to stimuli, the mechanism of life, the mechanics of the cell, and the nature of cellular differentiation are some of the topics discussed.

While the earlier editions have received the highest praise in all parts of the world, it must be admitted that this new edition, which incorporates the results of the most recent investigations, possesses such marked advantages as to be well-nigh indispensable to the professional biologist. The speedy translation of this edition into the English language is greatly to be desired.

W. R. C.

3. *Man in the Light of Evolution;* by John M. Tyler. Pp. xiv + 231. New York, 1908 (D. Appleton & Company).—A popular account of the theory of Darwinian evolution as applied to man's history, progress, and life. With little reference to anatomical structures, emphasis is laid on the physiological and psychological aspects of the problem, with special attention to man's social and family life and to his moral and religious powers. The book is pleasant reading, and so little fault can be found with the strictly scientific data employed that it can be unhesitatingly recommended to those who wish a clear and simple presentation of the evolutionary doctrine. W. R. C.

4. *Harvard College Observatory;* EDWARD C. PICKERING, Director.—Recent publications from the Harvard College Observatory are noted in the following list (continued from p. 269):

ANNALS.—Vol. LVIII, Part III. Observations and Investigations made at the Blue Hill Meteorological Observatory, Massachusetts, U. S. A., in the year 1905 under the direction of A. LAWRENCE ROTCH. Pp. 147–228, 2 plates.

Vol. LIX, No. III. Lunar Photometry and Photographic Sensitiveness at Different Temperatures; by EDWARD S. KING. Pp. 63–94. No. IV. Photographic Magnitudes of Bright Stars; by EDWARD S. KING. Pp. 95–126.

Vol. LXI, Part II. A Search for a Planet beyond Neptune; by WILLIAM H. PICKERING. Pp. 113–162.

Vol. LXVIII, Part I. Observations and Investigations made at the Blue Hill Meteorological Observatory, Massachusetts, U. S. A., under the direction of A. LAWRENCE ROTCH. Pp. 92, xi plates.

CIRCULARS—No. 143. Stars having Peculiar Spectra. 28 New Variable Stars. Pp. 4.

No. 144. Ephemeris of Morehouse's Comet (1908 c.), for 1909. Pp. 3, 2 plates.

No. 145. A sixth Type of Stellar Spectra. Pp. 4, 2 plates.

No. 146. The Constellation Camelopardalis. Pp. 3.

No. 147. Distribution of the Stars. Pp. 4.

No. 148. Morehouse's Comet, 1908 c. Pp. 3, 2 plates.

Sixty-third Annual Report of the Director of the Astronomical Observatory of Harvard College for the year ending September 30, 1908; by EDWARD C. PICKERING. Pp. 10.

5. *Publications of the Allegheny Observatory of the University of Pittsburgh.*—Recent publications from the Allegheny Observatory are as follows (see also p. 270):

Vol. I, No. 10. The Orbits of the Spectroscopic Components of α Virginis: by ROBERT H. BAKER. Pp. 65–74.

No. 11. The Orbits of the Spectroscopic Components of u Herculis: by ROBERT H. BAKER. Pp. 77–84.

No. 12. The Orbits of α Coronæ Borealis: by FRANK C. JORDAN. Pp. 85–91.

No. 13. The Orbits of the Spectroscopic Components of 2 Lacertæ; by ROBERT H. BAKER.

No. 14. On the Errors in photographing Positions caused by observing through glass; by FRANK SCHLESINGER.

6. *The Brooklyn Institute of Arts and Sciences.*—The following has b en recently issued: Cold Spring Harbor Monographs, VII. The Fresh Water Cyclops of Long Island: by ESTHER F. BYRNES. Pp. 43 with 15 plates. Brooklyn, March, 1909.

OBITUARY.

Dr. PERSIFOR FRAZER of Philadelphia, author of papers on chemistry, mineralogy and geology, died on April 7 in his sixty-fifth year.

New Circulars.

84: **Eighth Mineral List:** A descriptive list of new arrivals, rare and showy minerals.

85: **Minerals for Sale by Weight:** Price list of minerals for blowpipe and laboratory work.

86: **Minerals and Rocks for Working Collections:** List of common minerals and rocks for study specimens; prices from 1½ cents up.

Catalogue 26: Biological Supplies: New illustrated price list of material for dissection; study and display specimens; special dissections; models, etc. *Sixth edition.*

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CONTENTS.

SCIENTIFIC INTELLIGENCE.

THE

AMERICAN
JOURNAL OF SCIENCE.

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Art. XXXVIII.— *Quartz as a Geologic Thermometer;* by
Fred. Eugene Wright and Esper S. Larsen.

The term temperature has been defined as "the degree of
hotness of a body measured according to some arbitrarily
chosen scale." * It is regarded as a quality which can be
indicated in a thoroughly definite manner in terms of the
chosen scale. Heat, on the other hand, as something which
can be added to or taken away from matter, is treated as a
quantity, and the addition or subtraction of heat gives rise to
observed changes in temperature of a body. It is a fact of
observation that certain physical constants of matter change
slightly with the temperature, and these in turn have been
used to indicate the degree of hotness or temperature of
a body. Such temperature-indicating devices are called
thermometers and vary in type and construction with the tem-
perature ranges to be covered and the accuracy desired. The
most accurate method of expressing temperature is in terms
of the expansion of a perfect gas, and the gas thermometer is
the ultimate instrument for defining temperature at all points
of the scale. The gas thermometer, however, is less convenient
for ordinary use than other devices, and certain fixed points,
as the melting and boiling points of water and other chemically
pure substances, are first determined in terms of the gas ther-
mometer scale, and these in turn applied to other scales as
standard fixed points. In ordinary thermometers, the two
points of reference are the boiling and freezing points of pure
water under normal atmospheric pressure, and the interval
between them is divided into a definite number of equal spaces
depending on the scale adopted, whether centigrade, Fahren-

* Preston, Thomas, Theory of Heat (second edition), p. 13.

heit or Réaumur. For higher temperatures melting points of pure chemical elements, as gold, silver, copper, etc., serve as the standard fixed points.

Similarly in the study of rocks and minerals and their temperatures of formation, it is expedient to choose and to determine certain definite points of reference which serve to establish limits within which observed reactions must have been effected. Geologic phenomena take place at different temperatures, but at present very little exact information on the entire subject is available, and in many instances the temperatures are merely guessed at. Direct temperature measurements are seldom possible, and even then only rough approximations can be obtained because of the disturbing factors entering into the problem. Experiment and laboratory tests must, therefore, be largely relied upon for exact data bearing on such problems. Geologic problems are often complex and involved and require for satisfactory solution evidence from all possible viewpoints, especially data on the geologic mode of occurrence and on the physical and chemical relations of the rocks. The present tendency to consider eruptive rocks as the products of chemical systems and rock-making minerals as components of such systems or magmas, and, therefore, subservient to the laws of equilibrium governing physical chemical systems, is the natural result of applying the exact methods of physics and chemistry to geologic problems of a certain kind which have thus far been investigated in many respects only in a general qualitative or reconnaissance way. The geologic mode of occurrence of a rock or mineral is an exceedingly important fact to be carefully observed, since from it the original conditions of formation and consequent history may be inferred; but it is equally important to test such inferences and to render them precise if possible by using, wherever feasible, the exact methods of attack of physics and chemistry. For this reason accurate data, relating to equilibrium conditions and stability ranges of different minerals and aggregates of minerals over different temperatures and pressures, are of prime importance.

To illustrate: crystallized calcium metasilicate (wollastonite or pseudo-wollastonite) fuses at 1512°,[*] but at 1190° passes from wollastonite to pseudo-wollastonite, which on cooling does not revert in the solid state to wollastonite. The temperature of inversion, 1190°, can, therefore, be used as a point on the geologic thermometer scale, for the appearance of wollastonite in a rock signifies at once that at the time of formation of the wollastonite the temperature of the magma or solution was below 1190°, otherwise pseudo-wollastonite, the form stable

[*] This Journal, xxi, 101, 1906.

above 1190°, would have been precipitated. Since the specific volumes of wollastonite and pseudo-wollastonite are practically identical, it is probable that the effect of pressure on this inversion point is very slight, and can, therefore, be neglected.

Melting points of minerals and of definite aggregates of minerals (eutectics), melting regions of rocks, inversion temperatures of minerals and stability ranges for different forms of the same chemical compound, furnish the geologist with fixed points on his geologic thermometer scale, just as the freezing and boiling points of water are the two standard fixed points on the ordinary thermometer scale.

In like manner, experimental data may furnish points of reference for a geologic pressure gage, which is of equal import to the geologist.

Equipped with a satisfactory geologic thermometer scale and geologic pressure gage expressed in terms of stability ranges of different minerals and aggregates of minerals under different conditions, the geologist would be in a position to attack many problems which, at the present time, defy all solution. Exact data of this sort in turn tend to act as a governor on geologic theory establishing limits of temperature and pressure beyond or below which it is not safe to assume certain conditions; and at the same time they strengthen materially the foundation of fact on which geologic reasoning is based.

For such geologic thermometric purposes, quartz has been found by experience to be well adapted. It is plentiful in nature and occurs in many different kinds of rocks. SiO_2 in the form of tridymite melts at about 1625°,[*] while between that temperature and about 800° tridymite is the stable phase; below about 800° quartz is the stable phase. From evidence thus far gathered, it is probable that pressure has but slight effect on raising or lowering such an inversion point, and that, therefore, wherever quartz appears in nature, it was formed at a temperature below about 800°.[†]

Quartz itself undergoes a reversible change at about 575°. This was first observed by Le Chatelier[‡] in 1890, who noted a sudden change in the expansion coefficients and circular polarization of quartz heated to and above 575°. At the same time Mallard and Le Chatelier[§] found noticeable changes in the birefringence at about 575°, and recently O. Mügge[||] has

[*] The Lime-Silica Series of Minerals, A. L. Day and E. S. Shepherd, Optical Study by F. E. Wright, this Journal, xxii. 271–273, 1906.

[†] Vogt has shown that for a pressure corresponding to a depth of 100 km. this inversion point would probably be raised less than 135°.

[‡] Compt. Rend., cviii, 1046, 1889; cix, 339, 1890; Bull. Soc. Min., xiii, 112, 1890; xiii. 119, 1890.

[§] Compt. Rend., cx, 339, 1890; Bull. Soc. Min., xiii, 123, 1890.

[||] Neues Jahrb. Festband, 181–196, 1907.

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

T	I ω-ε	II ω-ε	III ω-ε	IV ω-ε	T	I ω-ε	II ω-ε	III ω-ε	IV ω-ε
12°				·00910	571°	·00809			
27		·00908			72	806	·00805	·00761	·00783
29	·00908				75	785	798		
79	902				76		781		
87				902	77			762	
89	898				80	776			
102	897				82	773		761	761
30	897				84		765		
48	899				89		766		
50				893	90	772			
65		900			92			762	757
83		891			98	774			
87	898				99		764		
95		891			602			761	760
207				881	7	776			
26	896				10		765		
49				874	12			762	760
58			.00880		19	777	767		
64		882			21	774			
69				873	22			763	762
73	890				32		765	762	762
307			875	871	37	778			
18	881				42			764	762
36	875				52		768	765	
43	874				62			765	763
56			863	859	70	776	767		
63	874	863			82				766
73	867				702				768
84	869				10		768		
405			853	848	18		768		
12	864	856			27				768
21	861				46	782			
31		856			52				769
35	857				77				770
54			838	835	89	786			
60		845			802				776
65			837		10		773		
75			836		12		773		
77	849				21		774		
80				830	38	786			
85			832		49	788			
95	846		830		52				780
504			826	823	57	787			
12	838				58	789			
14			820		78		774		
18		842			902				786
20	836				52				795
24			817		59		780		
29				813	1024		787		
30	834		812		30		787		
40	830				71		788		
43			807		1118		794		
50		824			70		798		
51	823		804	805	1207		802		
58			792		43		799		
60	818				46		805		
63		820	789	804	1320		810		
67		814	785		23		805		
68		806	762		57		803		
70	806	808	761		59		815		

considered the problem in detail, and by means of etch figures combined with crystallographic reasoning has been able to show that while the low temperature form of quartz stable below 575°, and called by him *a*-quartz, crystallizes in the trapezohedral-tetartohedral division of the hexagonal system, the high temperature *β*-form, stable above 575°, is also hexagonal but in all probability trapezohedral-hemihedral in its symmetry, the axial ratios of the two forms being, however, very nearly identical. Practically the only crystallographic change which takes place on the inversion is a molecular rearrangement, such that the common divalent axes of the high temperature *β*-form become polar in *a*-form, and this fact involves certain consequences which can be used to distinguish quartz which has been formed above 575° from quartz which has never reached that temperature. At ordinary temperatures all quartz is *a*-quartz, but if at any time in its history a particular piece of quartz has passed the inversion point and been heated above 575°, it bears ever afterward marks potentially present which on proper treatment can be made to appear just as an exposed photographic plate can be distinguished at once from an unexposed plate on immersion in a proper developer, although before development both plates may be identical in appearance.

To corroborate the data of Mallard and Le Chatelier, and at the same time to locate the inversion point more accurately, if possible, the birefringence and circular polarization of quartz were remeasured by means of a specially constructed thermal (electric resistance) microscope.* For the measurement of the birefringence, polished plates of different thickness cut parallel with the principal axis were used and readings with the Babinet compensator taken, both in white light and in sodium and lithium lights. The results of these observations are contained in tables I*a* and I*b* below, and are expressed graphically by the curves I, II, III of fig. 1. In Table I*a* the results of measurements of the birefringence in white light at different temperatures on four different plates are listed. In each column the readings taken while heating the plate have been combined with those obtained on cooling; these readings in every instance were practically identical and indicate a remarkably rapid and complete change at the temperatures of inversion and reversion. In Table I*b*, column I, the measurements of the bire-

* Described in this Journal, xxvii, 42–44, 1909.

Table 1*a*. Birefringence measurements with Babinet compensator on four different quartz plates at different temperatures in white light. In each column the readings taken while heating the plate have been combined with those obtained on cooling ; these readings in all four cases were practically identical and indicate a remarkably rapid and complete change at the temperatures of inversion and reversion.

TABLE I*b*.

T	I ω-ε	II ω-ε	III ω-ε	IV ω-ε	T	I ω-ε	II ω-ε	III ω-ε	IV ω-ε
17°	·00910	·00910			504°		·00825		
29			·00910		7	·00823			
33				·00902	8				·00820
59			905		16	821			
77	904				20		818		
84			901		23	817			
94	902				27	817	817		
111				890	28			815	·00807
17	899				29				804
27				887	36	811			
45			896		39		810		
49	894				40				799
58		892			42	807			799
59				88 2	47		810		
72	891				50	805			
83			890		56				795
85		888			57	801		802	
202		884			60			801	791
9				879	65	797			
16		882			68	792	794		
31	883				69	790			778
34			883		71				778
45				872	72			787	
55		877			73	783	783	766	749
62	878			870	74		760	760	748
65			878		75		761		749
83		873			76	762		760	749
85			874		77				749
304			872	864	78	761		760	
10	872				79				749
19		864			81			761	749
24	869				87	760	760		749
26			868		88			760	
35			867	857	90	760			
42	864	861			92				749
61		860			98			760	
63				854	99				749
65	·861				611			760	
79		855			21				748
88			854		25	761			
99	855				39				750
404				845	57	762			
5		850			62		762		
11			850		66				750
20	850				81				752
30	847				89				750
36				837	97	764			
41	844				708				752
52		840			27		765		
58	838				30				753
63				824	47	767			
66	837				49				754
69			835		53				754
71			836		69				754
78			834		89				756
81	832				807	770			
91	829	830			20				757
98				819	21				758
500		827	827		49				760
1	825				65				761

fringence of quartz at different temperatures in sodium light, taken while heating a quartz plate, are included ; in column II, the measurements at different temperatures made while cooling the same plate, are recorded ; in column III the readings of birefringence in sodium light, taken both during heating and cooling a second plate, are given, while in column IV the results of birefringence measurements in lithium light, both on heating and cooling a quartz plate, are included.

The most satisfactory readings were made in sodium light and there the inversion point is sharply marked. In the tables the actual readings of birefringence have been corrected very slightly to allow for change in thickness due to expansion, the coefficients of expansion normal to the principal axis being taken from the table of Le Chatelier.* As a matter of fact, however, the differences between the recorded and corrected values are very slight and might be disregarded without sensible error. On one thick plate (2·89^{mm}) the measurements of the birefringence with the Babinet compensator in white light were not satisfactory because of the disappearance of the dark band at high temperatures, due probably to such a relation of the rates of decrease of birefringence for different wave lengths that the cold quartz of the Babinet could not compensate all waves of the heated plates in precisely the same proportions, and that therefore perfectly correct compensation was not to be obtained. On thin plates this effect, which even in thick plates is slight, was not appreciable.

The curves of fig. 1 indicate that on heating, the birefringence of quartz decreases gradually but noticeably ; at 575°

*Loc. cit. The figures in the following table of expansion express the expansion in mm. of a quartz rod 100^{mm} long ; in column I, the relative expansion of quartz parallel to the principal axis *c* are listed and in column II the observed expansion for a rod normal to *c* ; the values of the second table were used in correcting for the change in thickness of the plate.

Temp.	I	II
270°	0·20	0·42
480	0·54	0·84
570	0·93	1·38
660	0·97	1·59
750	0·95	1·59
910	0·89	1·57
990	0·86	1·55
1060	0·86	1·55

Table 1*b*. Birefringence measurements with Babinet compensator on quartz plates at different temperatures in sodium and lithium lights. In column I the measurements in sodium light taken while heating a quartz plate are recorded : in column II, the readings taken while cooling the same quartz plate are included ; in column III the birefringence measurements made both during heating and cooling a second quartz plate are given ; while in column IV the results of birefringence measurements in lithium light, both on heating and cooling a quartz plate, are recorded.

Fig. 1.
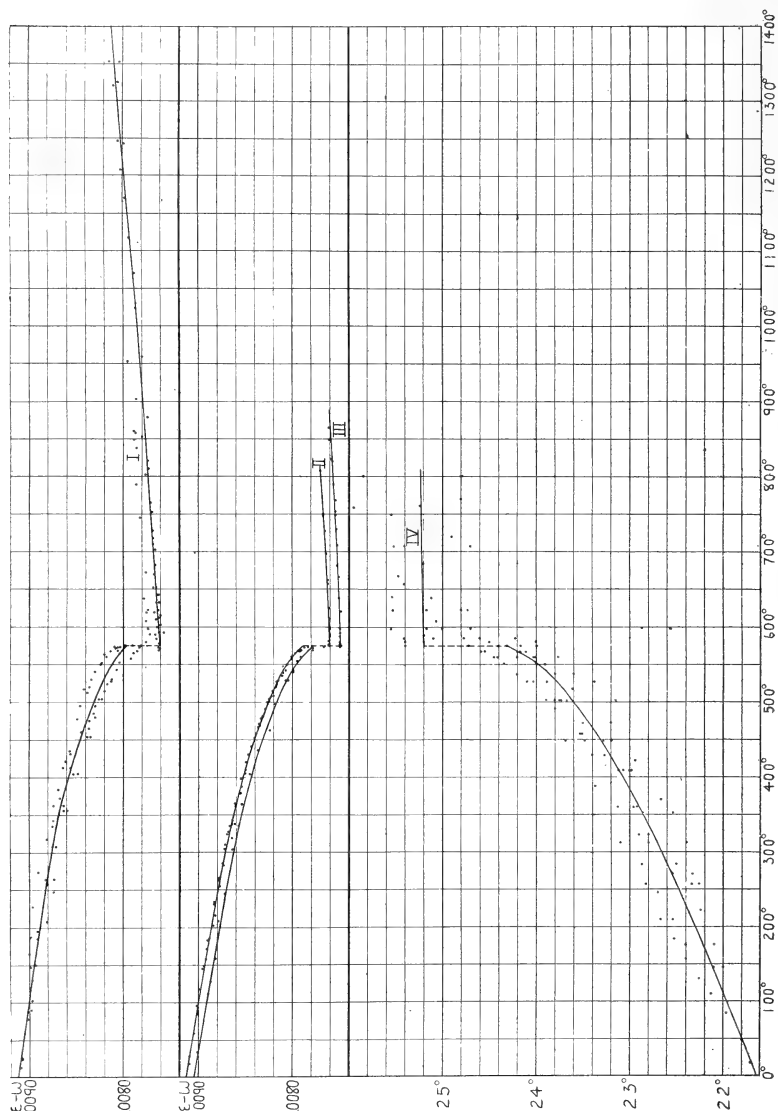
Fig. 1.   Curve I of this figure indicates the change in birefringence of quartz with increasing temperature.   The results of a number of measurements of the birefringence in white light with Babinet compensator and thermal microscope are plotted and curve I represents average values for the series.   The change at the inversion point is clearly shown.   Curve II indicates the combined birefringence observations on two quartz plates in sodium light.   The curve is exceedingly well defined and sharply cut, not-

there is a sharp decrease, while above that temperature the change is very slight, the birefringence increasing gradually. The birefringence for Li light appears to be slightly lower than that for Na light, but otherwise its rate of change is approximately the same throughout the scale.—Above 1000° the light from the furnace itself increases rapidly in intensity, and the light from the sodium or lithium flame becomes rapidly insufficient in relative intensity for satisfactory determinations, and intense white light (electric arc) should be employed.

In 1890 Mallard and Le Chatelier[*] measured the birefringence of quartz at different temperatures by means of interference fringes after the method of Fizeau and Foucault, and observed a sudden decrease in the birefringence at about 570°. For yellow light the following measurements (Table II, column I) are indicated on the curves of fig. 1 of Mallard's article.

TABLE II.

		I	II	
		Mallard	Wright and Larsen	Difference
Temperature				
15°	=	·00917	·00910	·00007
100°	=	·009045	·00902	·00003
220°	=	·008865	·00882	·00005
535°	=	·008145	·00811	·00004
570°	=	·00804	·00797	·00007
590°	=	·007765	·00760	·00016
665°	=	·00777	·00762	·00015
1060°	=	·00800	·00787	·00013

Table 2. Comparison of the measurements of birefringence of quartz at different temperatures by E. Mallard after the method of interference fringes of Fizeau and Foucault with those of Wright and Larsen using Babinet compensator.

In column II, the results of the measurements at the same temperatures in sodium light by the writers are included for comparison; while in column III the differences between I and II are given and show the relatively close agreement between the two sets of observations, Mallard's readings being slightly higher, especially for the β-quartz. In his paper Mallard gives a formula representing the birefringence-temperature curve below 575° and also a second formula representing the curve above 575°. His equations are of the second degree and parabolic in nature, and represent with a fair degree of

[*] Bull. Soc. Min., xiii, 123–129, 1890.

withstanding the relatively large scale. Curve III represents the observed birefringence data of quartz in lithium light ; curve IV, which is not so exact in its definition as II and III, indicates the change in the angle of rotation of a basal plate of quartz 1^{mm} thick, with rise in temperature. The measurements of the angles of rotation were less satisfactory owing to thickness of some of the plates used and also the difficulty of determining the exact angle of rotation in each case.

TABLE III.

T	1	2	3	4	5	6	7	8	9
17°	21.71	21.71	21.71	21.71	21.71	21.71	21.71	21.71	21.71
49									21.80
84						21.97			
109						22.13			
31			22.26						
46								22.10	22.00
57					22.40				
76							22.10		22.40
84									22.53
210					22.67				22.54
23						22.24			
46									22.70
57				22.26		22.34		22.27	22.83
71		22.54						22.33	
84							22.50		22.87
312	22.80			22.39					23.10
22		22.80					22.90		
52						22.86		22.54	
60		22.96	22.92						23.13
70				22.67					
88									23.37
409	23.07					23.12	23.00	22.98	
23				22.94					
29		23.27							23.40
49			23.68	23.48		23.28		23.20	
57		23.53			23.50				
73							23.50	23.20	
91									23.80
502		23.75		23.89	23.67	23.80		23.15	23.73
18								23.61	
28					23.88		24.10	23.38	24.03
37						23.80		23.60	24.20
50								23.90	
51									24.34
60		24.20	24.41		24.03	24.01		23.76	24.45
67				24.59	24.20	24.11	24.20	24.17	24.55
75		24.31		24.72	24.40	24.16		24.00	24.57
80							25.20	24.00	25.40
81					24.50				
84		24.77				24.22	25.10	24.60	25.40
86				25.41					
89					25.20				
97				25.00	25.17			24.70	25.55
607				25.07					
22					25.17	24.73		24.80	
29									25.53
39					25.12				
40				25.54					
57				25.41					
67									25.47
84					25.20				
707				25.41				24.70	25.52
20					24.90				
57				25.69					
67								24.80	25.50
70					24.90				
99									25.54
809				25.95					25.24
20					24.80				
50					24.80				25.84

accuracy the general course of the curves. Equations of similar nature have also been written down by the writers and the agreement of the calculated values with the observed data is fairly close, but in no case could more than approximate agreement over the entire range of the curve below 575° be obtained. Many equations were solved with a view to adjustment throughout the course of the curve, but every formula adopted proved more or less unsatisfactory at certain points along the curve. It can be stated, however, that the decrease in birefringence of quartz from 0 to 575° can be represented approximately by a parabolic curve, while above 575° the birefringence increases gradually and almost as a linear function of the temperature. A more detailed discussion of the different formulas obtained and comparison with Mallard's formula is interesting but of little direct value in the present instance, and may therefore be omitted.

The angle of circular polarization for different temperatures was also measured by the use of the thermal microscope. The results, however, are less concordant owing to the difficulty of determining accurately the exact position of total extinction, and also the difficulty of passing light waves through the plate exactly parallel with the principal axis. Basal plates of quartz of different thickness were cut and polished and the measurements carried on in sodium light.

To increase the sensitiveness of the method, the bi-quartz wedge-plate* was used. The results of these measurements are listed in Table II and expressed graphically by curve IV of fig. 1.† It will be noted that although the general agreement of single determinations is here less satisfactory than in the data on birefringence, the average value expressed by the curve IV indicates a rise of the angle with increasing temperature up to 575°, where an abrupt increase is observed, while above 575° the increase is slight.

The determinations by Joubert and Le Chatelier of the angle of circular polarization in sodium light for different tem-

* This Journal, xxvi, 349, 1908.
† The observed values of Table II and fig. 1 have been recalculated for a plate 1^{mm} thick. The increase in thickness due to expansion at different temperatures has also been taken into account, although this latter factor is of minor influence and practically negligible.

Table 3 contains the results of the measurements of the angle of rotation of different basal plates of quartz, calculated to the uniform thickness of 1^{mm} at different temperatures in sodium light. The noticeable lack of agreement between individual readings on plates at the same temperature is due in part to the difficulty of locating the position of total extinction accurately, and in part to the different size plates used where in large plates it is hardly possibly to preserve uniform temperature throughout the plate in such a small furnace. The difficulty of passing the light through the plate precisely parallel with the principal axis is still a third difficulty which it is not easy to eliminate under the conditions prescribed.

peratures are of interest for the sake of comparison and are included under column I of Table 4. In the second column the average result of the measurements of the present writers for the different temperatures is given, and a comparison of the two columns shows agreement as close as could be expected and well within the limits of error. The measurement of the angle of rotation of quartz is less accurate at all temperatures than that of the birefringence, and such close agreement between individual readings cannot be expected, especially if plates of different thickness are used, as in the present series of determinations.

<div align="center">Table IV.</div>

Temperature	Angle of rotation (Joubert and LeChatelier) I.	Angle of rotation (Wright and Larsen) II.	Difference
20°	21·72°	21·71°	0·01°
100 J*	21·98	21·96	0·02
280	22·68	22·58	0·10
360 J	23·04	22·90	0·14
415	23·40	23·15	0·25
448 J	23·46	23·30	0·16
560	24·30	24·10	0·20
600	25·26	25·20	0·06
840 J	25·26	- - - -	- - - -
900	25·32	- - - -	- - - -
1500 J	25·42	- - - -	- - - -

Table 4. In this table the measurements by Joubert and LeChatelier of the angle of rotation of basal plates of quartz 1^{mm} thick at different temperatures in sodium light are compared with those of Wright and Larsen for the same temperatures.

The actual point of change is still further emphasized by the behavior of the basal crystal plates themselves at the inversion temperature. In passing through 575° the optic phenomena become temporarily disturbed and there is no position of total extinction. As soon as this temperature is passed, however, the abnormal behavior subsides and accurate measurements can again be made. This effect, which is most pronounced on thick plates, may be due in part at least to unequal distribution of the heat and consequent lag in inversion of one part of the plate after another, while the optical effect observed is that from the whole plate.—To test this behavior still further, a plate parallel to the principal axis was taken and observed in parallel position between crossed nicols. In this instance, however, no lighting up of the field was observed at the inversion temperature, thus indicating that the change which takes place does not affect the vertical *c*–axis appreciably, it remaining strictly parallel throughout the inversion.

* Measurement by Joubert, Comptes Rendus, lxxxvii, 497–499, 1878.

The abrupt change in expansion-coefficient observed by Le Chatelier at the inversion temperature causes thick plates of quartz to shatter more or less completely, the planes of fracture running parallel with the unit rhombohedral faces ordinarily. This shattering is so characteristic that it is practically impossible to bring a thick quartz plate through the inversion temperature, either up or down, without some cracking, usually sufficient to spoil the plate for further use. Thin plates, on the other hand, bend noticeably. Mügge[*] observed the temporary warping of a thin plate of quartz ($\cdot 03^{mm}$ thick) through an angle of 3° at the inversion temperature. Above and below the inversion temperature, however, the plate appeared perfectly plane, thus indicating practical identity of the axial ratios of the a and β forms.

The above determinations of the inversion temperature were made with a direct reading Siemens and Halske millivoltmeter, the scale divisions of which registered temperature intervals of 10°, 0·1 division being equivalent to 1° and the absolute accuracy perhaps $\pm$ 5°. To standardize these readings and at the same time to test the sensitiveness of this inversion in quartz (which is exceedingly inert in its change to tridymite and also to the viscous amorphous state), a quartz plate about $\cdot 28^{mm}$ in thickness and parallel with the principal axis was selected and its birefringence bands in the Babinet compensator observed, while the readings of the thermoelement on which the plate rested were recorded on a potentiometer.[†] This system was sensitive to temperature differences of perhaps $\cdot 02°$ and its absolute accuracy was well within $\pm$ 0·5°. The point of change was indicated in the microscope by a sharp movement of the dark interference band of the Babinet compensator, and at this instant the reading on the potentiometer was recorded. The inversion, both on heating and on cooling, was observed a number of times and the temperature of inversion found to be remarkably constant and sharply marked. The readings are included in Table V, columns I–IV. The greatest difference in the observed temperatures of the inversion during heating is 2 microvolts, or about 0·2°, while that for cooling is somewhat greater. Although the thermoelement readings were expressed in microvolts, the equivalent temperatures in degrees are listed in Table V. It was found that notwithstanding differences in rate of heating, the inversion point on heating was practically constant, whereas the reversion point on cooling

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[*] Loc. cit.

[†] The methods here adopted for the testing and standardizing of the thermoelements used are due to Dr. A. L. Day, and to him the writers are further indebted for all thermoelectric measurements recorded in the following paragraphs.

TABLE V.

Thermoelement of Microscope. Temperature of change. Quartz-Plate I.				Freshly drawn thermoelement from standard thermoelement wire.											
				Temperature of change. Quartz-Plate II.								Temperature of change. Quartz-Plate III.			
Rising.		Falling.						Current in furnace reversed.							
Rate of heating		Rate of cooling		Rising	Rate	Falling	Rate	Rising	Rate	Falling	Rate	Rising	Rate	Falling	Rate
Fast	Slow	Fast	Slow												
576°.8	576°.7	574°.9	575°.2	573·7	*f*	572·7	*s*	573°.4	*f*	572°.4	*f*	576°.4	*f*	575°.5	*s*
576·8	576·7	575·0	575·3	573·4	*s*	572·7	*s*	573·6	*f*	572·8	*s*	576·5	*f*	575·5	*s*
576·7	576·8	574·8	575·3	573·4	*s*	572·6	*s*	573·5	*f*	572·8	*s*	576·1	*vs*	575·7	*s*
576·5	576·7	574·6	575·2	573·4	*f*	572·6	*s*	573·4	*f*	572·6	*f*	576·1	*vs*	575·6	*s*
576·7	576·6	575·0	575·2	573·4	*f*	572·4	*f*					576·2	*s*	575·4	*s*
576·7		575·2				572·5	*f*							575·4	*f*
576·7		574·9				572·5	*f*							575·4	*f*
576·8		574·9													
576·7		574·6													
		574·5													
576°.7	576°.7	574°.8	575°.2	573°.5		572°.6		573°.5		572°.6		576°.3		575°.5	

* *f*, fast ; *s*, slow.

Table 5. In this table the results of the determination of the temperature of inversion of quartz by means of the abrupt change in its birefringence at this temperature are recorded. In the first four columns the readings of the ordinary thermal microscope thermal element are given, while in the remaining six the readings on a standard thermoelement of specially thin wire are presented. The point of inversion was recorded both for rising and falling temperatures and different rates of heating and cooling the quartz plates.

varied slightly with the rate of loss of heat. To insure still further the accuracy of the determination of the temperature of inversion, a new and carefully calibrated thermoelement of fine wire drawn down from one of the laboratory standard thermoelements * was taken and the observations in the thermal microscope repeated, the readings being taken as before on the potentiometer. The results show again the extreme sensitiveness of quartz to minute temperature differences at the inversion point, and establish the temperature of inversion at 575·8°±1·0° for the first specimen (Quartz plate 1), 573·0° ±0·5° for the second (Quartz plate 2), and 575·9°±0·4° for the third (Quartz plate 3), or in general for this constant, 575°. ±2°. The results of these observations are recorded in Table 5 above. Plate 2 was ·232^{mm} thick and covered an area of

* It was found necessary to take this precaution and to use wire ·2^{mm} in diameter, in place of the standard theromoelement wire 0·6^{mm} in diameter, since the latter conducts away more heat in unit time than a small furnace can supply, and as a result the readings with it are uncertain and too low.

20·4 sq. mm.; plate 3 was ·224^{mm} thick and covered an area of 6·8 sq. mm., or one-third that of plate 1. This difference in size of the two plates might account, in part at least, for the differences in inversion temperature recorded.

The temperature determinations in the thermal microscope were furthermore checked by means of heating and cooling curves after the method of Frankenheim,* on a large mass of pulverized pure quartz. Although the most sensitive experimental conditions (temperature change of ·01° visible) were adopted, the thermal effect of the inversion was exceedingly slight and was furthermore distributed over a temperature interval of 20° or more. Nevertheless, on both the heating and cooling curves a slight absorption and corresponding release of heat could be observed in the inversion temperature region. To designate any particular portion of these temperature intervals for especial interpretation is little more than arbitrary where the total energy involved is so small, but the temperatures at which the rate of absorption (or release) was greatest are approximately as follows: On heating, 560°, 559°, 569°, 564°, average 563°; on cooling, 560°, 562°, average 561°. It is not even safe to say that these numbers represent the average inversion temperature for a great number of quartz fragments, for finely pulverized quartz is such a poor conductor for heat that the temperature of the charge cannot be assumed to be uniform from surface to center during such a measurement. The thermoelectric record accordingly lags and the temperatures given are necessarily low. The determination by this means is therefore only approximate and the method merely confirms in a general way an absorption and release of a small quantity of energy in this region, but is not competent to locate so small a quantity accurately.

Very recent and still incomplete measurements by Dr. W. P. White, of the Geophysical Laboratory, on the specific and latent heats of quartz indicate an abrupt change in the thermal capacity of quartz in the region of the inversion temperature. At about 575° the specific heat measures ·282±·017, where the (large) probable error (±·017) includes the energy change in passing the inversion point. The latent heat at 575° is 4·3 ±1 calories. There are some uncertainties in both the latent and specific heat values due to the fact that a sufficient number of observations has not yet been taken to determine, with sufficient accuracy, the character of the function near the discontinuity.

The above measurements and data prove definitely that quartz undergoes a small energy change at about 575° and that the change is reversible or enantiotropic. The amount of

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* Measurements by Dr. A. L. Day.

energy involved is, however, so small that thermal methods of study are relatively unproductive compared with optical methods.

It is of interest to note that in a substance like quartz, which in some respects is exceedingly inert and sluggish, certain changes of equilibrium are extremely sensitive to temperature differences, a difference of one tenth of one degree being sufficient to cause the shift from the one form to the other. It is indeed difficult to form an adequate and satisfactory picture of a mechanical system which shall satisfy the conditions of such nice equilibrium and adjustment. In the case of quartz, however, it is fortunate for the observer that certain physical properties which can be determined with great accuracy at different temperatures are extremely sensitive to the inversion, since the actual change in energy content, or amount of heat involved in the transformation, is extremely slight, and too small, in fact, to be detected by ordinary methods for measuring temperatures. Notwithstanding the comparatively insignificant amount of energy required in the transformation, it is still sufficient to cause a readjustment of the crystallographic forces, such that the low temperature a-quartz and the high temperature β-quartz crystallize in all probability in different subdivisions of the hexagonal system, and at the same time, intricate twinning phenomena may be set up, the effects of which are in general sufficient to enable the observer to distinguish a-quartz from β-quartz. The criteria which have been developed for accomplishing this distinction will now be considered briefly and these in turn applied to different quartzes as they occur in nature.

In a recent paper, Mügge* has proved that β-quartz crystallizes in all probability in the trapezohedral-hemihedral division of the hexagonal system, and that its axial ratios are practically identical with those of a-quartz.—The chief crystallographic change which takes place at the inversion point is a molecular rearrangement such that the common divalent axes of the high temperature β-form become polar in the a-form stable at low temperature, and a tendency to restore crystallographic equilibrium in the a-form by twinning after the prism is therefore active on the inversion from the high β-form. This twinning phenomenon is best studied by means of etch figures (obtained by immersing for $1\frac{1}{4}$ hours plates of quartz in cold commercial hydrofluoric acid) on the basal pinacoid. Mügge found that if a plate of untwinned quartz after (0001) be heated above the inversion point and, after cooling, etched, it is no longer a simple crystal, but an intricate complex of twins after ($10\bar{1}0$), the twinning lines being as a rule irregular and without definite

* Neues Jahrb. Festband, 181–196, 1907.

arrangement. If, furthermore, a regularly twinned crystal of quartz be heated above 575° and then etched on the basal pinacoid, the twinning lines are as a rule no longer straight and regular, but the field appears divided by small patches of irregularly twinned material. In passing from the tetartohedral a-form to the hemihedral β-form, the bivalent common axes lose their polarity and the tendency in the latter form to form twins, therefore, is much less strong than in the a-form. On reverting later to the a-form, the common axes of the β form become again polar and the tendency during the molecular rearrangement is again to form twins, and, in this instance, twins with irregular boundary lines, since the change takes place rapidly and in the solid state.—The form and character of twinning on basal sections of quartz can therefore be used as one of the criteria in determining whether or not quartz has been formed above or below 575° C.

Still a second fact of observation can be used to advantage in ascertaining the original temperature of formation of quartz.[*] Quartz is circularly polarizing and may rotate the incident plane polarized light waves either to the right or to the left. Experiments on the crystallization of circularly polarizing bodies have indicated that a slight change in the mother solution is often sufficient to change the character of the rotation of the crystal being precipitated. In quartzes formed at low temperatures, vein quartzes and the like, one might expect intergrowths of right- and left-handed crystals more frequently than in magma quartzes where rapid changes in the composition of the solutions are less likely to occur.—In the low temperature quartzes crystallizing out of quietly circulating solutions, moreover, the conditions are less violent than in a magma above 575° and the processes of precipitation might well be considered to proceed with more regularity and uniformity at the lower temperatures than above the inversion point. The tendency of intergrowths of right- and left-handed crystals of the low temperature phase should accordingly be toward regularity of outline of the intergrowths and toward hexagonal symmetry.—The fact of intergrowths of left- and right-handed quartz and the character of such intergrowths is a second factor to be considered in the investigation of any particular quartz.

A third feature which is of service in this connection is the shattering and cracking of quartz crystals on passing the inversion temperature as a result of the abrupt change in the coefficient of expansion. This occurs both on heating and on cooling. It is safe to assume, therefore, that large clear quartz plates free from fractures have in all probability never reached the inversion temperature. The fracture cracks in many small

[*] Mügge, O., loc. cit.

grains are present only potentially, and appear so distinctly on etching that an apparently clear plate of quartz which has been heated above 575° may crumble down in the etching acid and break up into a number of small grains, while the purely *a*-quartz remains intact and is etched with much greater uniformity.—The fact that thin plates of quartz may warp and bend temporarily at the inversion temperature, thus finding relief from the strains set up on the change, while thicker plates bend less easily and tend to fracture more readily, is a factor which should be considered in any particular case. Small grains, being thus less liable to fracture, may not show the phenomena of shattering as clearly as might be expected.

Crystallographically, the difference in crystal class between the *a*- and *β*-forms finds expression in the crystal habit. In the *β*-form, the pyramid faces are equally developed ; trigonal trapezohedrons are absent, the habit of the crystals being usually that of the simple dihexahedrons observed in quartz porphyries and allied rocks. Crystals of the low temperature *a*-form, on the other hand, are usually prismatic in habit and often show marked differences in the size and character of the rhombohedral faces. Trigonal trapezohedrons may occur and stamp the crystal on which they do appear at once as a low temperature form.

Briefly stated, the four criteria which can be used to distinguish, at ordinary temperatures, quartz which was formed above 575° from quartz which has never been heated to that temperature, are : (1) Crystal form, if crystals be available, the presence of trigonal trapezohedrons and other evidence of tetartohedrism, irregular development of the rhombs and the like, being indicative of the *a*-form. (2) Character of twinning, as shown by etch figures on the basal pinacoid. In the *a*-form, which crystallized from solutions at comparatively low temperatures, the twinning is usually regular and sharply marked, while in quartz plates originally of the *β*-form and now *a* by virtue of inversion in the solid state, the lines are usually irregular, and the twinning patches are small and bear no relation to the outer form of the crystal. (3) Intergrowths of right- and left-handed quartzes are more frequent and more

Table 6. In this table are assembled the results of the examination of 44 different quartzes occurring in nature. A number of basal plates of each of these quartzes were cut and polished and etched for 75 minutes in cold commercial hydrofluoric acid. The quartzes were examined particularly with respect to: (1) the occurrence and character of intergrowths of right- and left-handed individuals of quartz ; (2) the frequency and character of the twinning of the quartz plates as brought to light by means of the etch figures obtained by immersion of the plates in hydrofluoric acid ; (3) the character of the plates themselves, whether clear and comparatively free from cracks or much shattered and often crumbling after immersion in hydrofluoric acid. Wherever crystals were used these were examined still further for evidences of tetartohedrism.

TABLE VI.

No.	No. plates cut.	Average size of plate, in mm.	Degree of Shattering.	Intergrowths				Twinning		
				No. Right-handed R.	No. Left-handed L.	No. L. & R.	Character of intergrowth	No. not Twinned	No. Twinned.	Outline of Twinned areas.
1	6	5	Few cracks, clear	6	--	--	-----	--	6	c*
2	21	2	"	6	9	3	Straight & regular	2	14	c
3	11	8	"	2	--	8	Regular	3	7	b
4	10	7	"	10	--	--	-----	10	1	a
5	24	3	"	2	18	--	-----	14	10	d
6	12	3	"	8	--	4	Straight & regular	11	1	a
7	11	6	"	--	11	--	- ---	--	11	c
8	8	5	"	5	2	1	Regular	2	1	d
9	16	6	"	8	8	--	-----	4	12	a
10	6	8	"	2	2	--	-----	4	--	--
11	5	10	"	5	--	--	-----	1	4	a
12	11	12	"	--	11	--	-----	2	9	a
13	8	8	"	4	4	--	-----	1	4	a
14	8	10	"	--	8	--	-----	6	6	a
15	15	6	"	--	1	11	Regular	1	10	a
16	14	5	"	8	3	1	"	4	9	a
17	10	3	"	--	4	--	-----	2	2	d
18	15	5	Some cracks	9	4	1	Regular	8	3	f
19	7	7	Few cracks, clear	--	--	7	"	--	7	a
20	9	2	"	9	--	--	-----	5	4	a
21	12	2	Many cracks	1	11	--	-----	8	3	d
22	12	2	"	9	3	--	-----	2	10	f
23	13	1·5	"	2	11	--	-----	8	5	f
24	11	1	Much fractured	3	8	--	-----	5	5	f
25	21	2	"	--	21	--	-----	--	5	f
26	6	2	"	--	6	--	-----	1	4	f
27	11	3	Some cracks	3	5	--	-----	--	4	e
28	11	2	"	4	4	3	Irregular	8	3	e
29	13	3	"	4	9	--	-----	--	8	f
30	4	2	"	4	--	--	-----	1	3	f
31	14	2	"	7	3	--	-----	--	3	f
32	4	1	Much fractured	2	2	--	-----	--	3	f
33	3	1	"	1	2	--	-----	--	3	f
34	4	2	"	--	4	--	-----	--	3	f
35	7	2	"	2	5	--	-----	1	3	f
36	10	2	"	4	5	--	-----	2	5	f
37	3	2	"	2	--	2	Fairly regular	2	1	f
38	10	2	"	5	4	1	"	1	7	f
39	2	2	"	--	2	--	-----	1	1	f
40	6	3	"	1	3	--	-----	--	4	f
41	3	3	"	--	3	--	-----	--	3	f
42	16	2	"	7	9	--	-----	2	7	f
43	16	1	"	5	7	--	-----	--	8	f
44	5	1	"	5	--	--	-----	--	5	f

* In this column the letter *a* signifies regular; *b*, usually regular; *c*, often irregular, tendency toward regularity; *d*, rather irregular; *e*, small, rather irregular; *f*, irregular and small.

Specimens used in Table VI.

1. White vein quartz. Auburn, Maine (U. S. Nat. Mus. Spec. No. 75,530). Specimen of glassy quartz, transparent in spots and comparatively free from fine cracks. Fracturing after $(10\bar{1}1)$ noticeable.

2. White milky vein quartz in limestone, associated with galena and sphalerite. North Arm, Moira Sound, Prince of Wales Island, Alaska. (Charles W. Wright, collector.)

3. Quartz crystals. Forms : $(10\bar{1}0)$, $(10\bar{1}1)$, $(01\bar{1}1)$, $(11\bar{2}1)$, U. S. Nat. Mus. No. 45,205). Crystal Mt., near Hot Springs, Arkansas. Clear, transparent crystal groups.

4. Large quartz crystal traversed by shearing planes almost at right angles with principal axis. Parts of crystal clear and transparent. Locality unknown.

5. White vein quartz near Canaan, Conn. Vein occurs in metamorphosed Cambrian limestone directly overlying Vermont quartzite. Quartz is associated with tremolite. (A. C. Spencer, collector.)

6. Quartz vein in Cheshire quartzite, Ashley Falls, Mass. White, transparent in spots. Occasional flakes of muscovite occur in this quartz. (A. C. Spencer, collector.)

7. Quartz associated with magnetite and garnet. Lover's Hole, Barton Hill, N. Y. Quartz is fairly massive and clear in spots. (A. C. Spencer, collector.)

8. Vein quartz. Group of crystals $(10\bar{1}1)$, $(01\bar{1}1)$, $(10\bar{1}0)$. Glacier Basin near Wrangell, Alaska. Zonal structure well developed. Crystals massive. (Fred E. Wright, collector.)

9. Vein quartz in Precambrian schists. Sugar Loaf, Md. Crystals bounded by $(10\bar{1}0)$, $(10\bar{1}1)$, $(01\bar{1}1)$. Rhombohedral development prominent. In general quartz is milky in color. Small crystals are transparent. This group contains specimens from three different veins a mile or more apart in the schists. (E. S. Larsen, collector.)

10. Quartz crystal. Herkimer County, N. Y. Doubly terminated crystal $(10\bar{1}0)$, $(10\bar{1}1)$, $(01\bar{1}1)$, occurring in metamorphosed limestone.

11. Rose quartz. New Milford, Conn. (U. S. Nat. Mus.) Massive and comparatively clear quartz.

12. Rose quartz from quarry P. H. Kinkle's Sons, Bedford, N. Y. Occurs in large pure masses in coarse pegmatite, associated with large masses of pure feldspar, both minerals grading into graphic intergrowths of feldspar and quartz. Spec. 753. (E. S. Bastin, collector.)

13. Rose quartz. Paris, Maine. (U. S. Nat. Museum.) Massive and clear rose-colored quartz.

14. Rose quartz. Maine. (U. S. Nat. Museum.) Massive and pale rose-colored quartz.

15. Smoky quartz. Berry feldspar quarry, Poland, Maine. Crystals project inward from walls of gem-bearing pockets

of large pegmatite dike. Massive and clear material. Spec. 539. (E. S. Bastin, collector.)

16. White quartz. J. A. Fisher feldspar quarry, Topsham, Maine. Large mass of pure quartz several feet across in pegmatite dike. The masses of pure quartz and feldspar at this quarry grade irregularly and without break into coarse to fine graphic intergrowths of these two minerals. Spec. 699. (E. S. Bastin, collector.)

17. White quartz from pegmatite dike one mile northwest of Cumberland Mills, near Portland, Maine. Dike cuts mica schist and granodiorite. Large quartz masses grade into coarse granite pegmatite, either gradually or abruptly. Large quartz masses appear to form end product of the pegmatite crystallization. Spec. 717. (E. S. Bastin, collector.)

18. Quartz associated with rounded lepidolite and bladed albite. Berry feldspar quarry, Poland, Maine. This specimen was taken from the gem-bearing portion of the pegmatite dike from which the Spec. No. 15 of smoky quartz was derived. The portion of the dike bearing lepidolite and albite is marked by pockets containing crystal quartz and occasional gem tourmaline, and appears to have been without doubt the last to crystallize out. Spec. 402. (E. S. Bastin, collector.)

19. Quartz from pocket in very coarse-grained pegmatite. Major Willis feldspar quarry, Topsham, Maine. Spec. 371. (E. S. Bastin, collector.)

20. Quartz from coarse-grained pegmatite. Old feldspar quarry, Northwest side of Mt. Ararat, Topsham, Maine. Quartz crystal with faces projecting into feldspar. Spec. 361. (E. S. Bastin, collector.)

21. Quartz from pegmatite in granodiorite two miles east of Dress Pt., Hassler Island, Behm Canal, Alaska. Aplitic pegmatite, coarse-grained and consisting essentially of quartz and oligoclase with some muscovite and biotite. Spec. 5 F.W. 50. (Fred. E. Wright, collector.)

22. Quartz from small granite pegmatite dike. Railway cut opposite Rumford Falls near Rumford Falls, Maine. Typical pegmatite from southern part of Maine. Spec. 440. (E. S. Bastin, collector.)

23. Quartz from graphic pegmatite. Andrews feldspar quarry, Portland, Conn. Specimen fairly coarse-grained and consisting essentially of quartz and feldspar. (E. S. Bastin, collector.)

24. Quartz from granodiorite pegmatite, West Entrance Point, Bailey Bay, Behm Canal, Alaska. Aplitic pegmatite, coarse grained and similar in composition to No. 19. Spec. 5 F.W. 40. (Fred. E. Wright, collector.)

25. Quartz from graphic pegmatite. J. A. Fisher feldspar quarry, Topsham, Maine. This specimen was taken from the same quarry as No. 16 and is interesting because it appears to have been formed above 575°, while the large masses of

No. 16 appear to have formed below that temperature, thus indicating a temperature of formation of the large part of the pegmatite at about 550°–600°. Spec. 701. (E. S. Bastin, collector.)

26. Quartz from graphic pegmatite. Ilmen Mts., Miask District, Urals, Russia. Coarse pegmatite consisting essentially of microcline and quartz in characteristic graphic intergrowth. (U. S. Nat. Museum.)

27. Quartz from ore-bearing pegmatite vein in sodalite-syenite. Bancroft, Ontario, Canada. Quartz is associated with siderite, arsenopyrite and various sulphides. (A. C. Spencer, collector.)

28. Quartz from irregular pegmatitic mass adjacent to magnetite ore, in Precambrian gneiss. O'Neil Mine, Monroe County, N. Y. Dark colored rock, coarse-grained and consisting essentially of abundant hornblende, microperthite and quartz with some biotite and secondary chlorite. (A. C. Spencer, collector.)

29. Quartz from coarse pegmatite mass near magnetite ore body. Stirling Mine, Lakeville, N. Y. Specimen consists of magnetite, hornblende (uralite?), biotite, quartz feldspar and some secondary chlorite. Quartz occurs in small patches and granules, scattered throughout specimen. (A. C. Spencer, collector.)

30. White quartz from pegmatite in gneiss. Great Barrington, Mass. Specimen consists chiefly of quartz with occasional prisms of brown transparent tourmaline. (A. C. Spencer, collector.)

31. Quartz from pegmatitic mass in gneiss on John Keleyl's farm, northwest end of Mt. Eve, Orange County, N. Y. Specimen consists chiefly of magnetite, quartz and some feldspar. (A. C. Spencer, collector.)

32. Quartz from granite. Near Lake Bennett, B. C., Canada. Medium-grained pink biotite granite. Spec. 314. (F. E. Wright, collector.)

33. Quartz from granite gneiss one-half mile north of Carpenter Knob, Cleveland County, N. C. Gneiss consisting of feldspar, quartz, biotite and muscovite. (Arthur Keith, collector.)

34. Quartz from altered granite, near Cambourne, Cornwall, England. Specimen taken near tin ore deposits and consisting essentially of pink feldspar quartz and black tourmaline. (F. E. Wright, collector.)

35. Quartz from altered granite near Cambourne, Cornwall, England. Specimen from near tin ore deposits and intensely altered. Much quartz and gray green altered feldspar, muscovite and tourmaline. (F. E. Wright, collector.)

36. Quartz from granodiorite. Near Log Cabin, White Pass, B. C., Canada. Essential components of specimen are quartz, oligoclase, orthoclase, and biotite. Gray medium-grained intrusive. Spec. 303. (F. E. Wright, collector.)

37. Quartz from granite. East slope of El Sobranti, near Corona, California. Gray medium-grained granite consisting essentially of quartz, alkali and soda, calcic feldspars and biotite. Spec. 10. (E. S. Larsen, collector.)

38. Quartz from granite. Near Pevey, Lake Bennett, B. C., Canada. Pale pink medium-grained granite consisting essentially of quartz, orthoclase, oligoclase and biotite, and some visible magnetite. Spec. 312. (F. E. Wright, collector.)

39. Quartz from granite near Meissen, Saxony, Germany. Pink, fresh, medium-grained granite consisting essentially of quartz and feldspar with some biotite. (Charles W. Wright, collector.)

40. Quartz from granite. Marble Falls, Burnett County, Texas. Medium to coarse-grained pink granite, consisting essentially of quartz, feldspar and biotite. Spec. 38,824, U. S. Nat. Museum.

41. Quartz from miarolititic pegmatitic cavity in granite. Railway cut near Glacier, Skagway, Alaska. Granite is exceedingly variable in granularity and consists essentially of quartz and feldspar with some biotite. Spec. 282. (F. E. Wright, collector.)

42. Quartz from granite porphyry, Bassett Mine, Cambourne, Cornwall, England. Granite porphyry with phenocrysts of dihexahedral quartz, orthoclase and tourmaline. (F. E. Wright, collector.)

43. Quartz from granite porphyry. Yankee Creek, Brooks, Mt. Seward Peninsula, Alaska. Gray granite porphyry with phenocrysts of quartz and orthoclase. (Adolf Knopf, collector.)

44. Quartz from quartz porphyry. Verdugo Protero, ten miles south of Corona, California. Phenocrysts, quartz and feldspar. Fresh, gray dike rock in andesite. Spec. 190. (E. S. Larsen, collector.)

regular in boundary lines in the a-than in the β-form. (4) Plates of originally β-quartz but now a-quartz by inversion show the effect of the inversion by the shattering which should be most evident on large plates.—Into all these criteria an element of probability enters, and in testing quartz plates, with this end in view, a number of plates should be examined to strengthen the validity of the inferences drawn.

It was of interest to apply these criteria to actual occurrences of quartz in nature, and for this purpose 44 specimens of quartz and quartz-bearing rocks from different localities were chosen, 10 specimens of quartz from veins and geodes, 21 from pegmatites of different types and 13 of granites and granite porphyries. From each specimen from 3 to 25 plates after the basal pinacoid were cut and polished on both sides.—Each plate was then examined with reference to its circular polarization and the character of its twinning. All plates were etched

uniformly in cold commercial hydrofluoric acid, the time of exposure in every instance being 75 minutes. The etched plates were examined at first both in reflected and transmitted light, but experience soon indicated that the best results were obtained by observing the etched surfaces and figures in transmitted light, the rays being obliquely incident at such an angle as to cast proper lights and shadows across the small etch pits and hills. Even in the process of etching the difference between the high and low forms was often evident. The crystal plates of the a-form were as a rule clear and without fractures, and although on etching all such cracks were promptly discovered and emphasized by the acid, the general appearance of the plates after etching was nevertheless uniform and continuous. Plates of original β-form, on the other hand, even though clear, before etching, developed after short exposure in the acid numerous cracks, potentially present before, which frequently caused the plate to crumble and break up into smaller grains. As a rule etch figures on such plates were also the least satisfactory.

The character of the circular polarization of the different plates was ascertained in sodium light, the lenses of the condensor system of the microscope having been removed and the plates observed with a low-power objective. After etching the plates were re-examined, the disturbing influence of reflections on the etched surfaces being eliminated temporarily by immersing the plates in a liquid of refractive index 1·554, equal to ω of quartz.

A detailed discussion of the results assembled in Table 6 substantiates in a general way the theoretical inferences. Of vein quartzes, 10 specimens were used, 125 basal plates cut and polished and etched; of these 49 showed right-handed circular polarization, 50 left-handed, 16 left- and right-handed intergrowth of fairly regular outlines; 50 plates were not twinned, while 63 were twinned, the outlines of the twinned areas being in general regular and indicative of hexagonal symmetry. Practically all of these plates were free from fracture cracks of any importance. Twenty-one specimens of pegmatite were examined and found to fall naturally into two groups. Nos. 11 to 20 were taken from large masses of quartz in pegmatite dikes and masses and in certain cases were definitely stated by the field relations to be the last portions of the pegmatite to crystallize out. In behavior they resemble vein quartz and have in all probability never been heated above the inversion temperature. From these specimens 11 to 20, 102 basal plates were cut and polished and etched; of these 35 were right-handed in circular polarization, 35 left-handed, and 20 intergrowths of right- and left-handed individuals, the outlines of the different intergrowths being in general regular and

hexagonal in character; 30 were not twinned, while 58 were twinned and the outlines of the twinned areas were on the whole regular and indicative of hexagonal symmetry. The plates were as a rule clear and free from fracture cracks.— The remaining eleven specimens of pegmatite were from pegmatites showing graphic intergrowths of quartz and feldspar or coarse-grained aggregates of these minerals. The quartzes from these pegmatites accord in their behavior with original β-quartz later inverted to a-quartz. Of these 128 basal plates were cut and polished and etched; 37 of which were of right-handed quartz, 81 of left-handed and 3 intergrowths of right- and left-handed individuals, the outlines of the intergrown areas being irregular; 31 plates were not twinned while 53 were twinned, the twinned areas being small and irregular in outline. The plates were in general much fractured and shattered.—Thirteen specimens of granites, granite gneisses and porphyries were examined and of these 89 plates cut, polished and etched; 34 plates showed right-handed rotatory polarization, 46 were left-handed while 3 were intergrowths of right- and left-handed individuals, the outline of the latter being on the whole fairly regular; 11 plates were not twinned, while 53 were intricately twinned, the boundaries of the twinned patches being small and irregular and without reference, so far as could be observed, to hexagonal symmetry. These plates were without exception small and traversed by fracture cracks which rendered it difficult to obtain satisfactory results from etching. The average diameter of the surface of the plates of vein quartz was 5^{mm}; of the quartz from the vein pegmatites, 7^{mm}; of the quartz from the granite pegmatites, 2^{mm}; of the granite quartzes, 2^{mm}.

Summarizing these data still further, it may be stated that the quartzes from veins and geodes and certain vein pegmatites are in general clear and free from intricate fracture-cracks and show frequent regular intergrowths of right- and left-handed quartzes; they are also frequently twinned after the unit prism and the outline of the twinned areas is usually regular and hexagonal in aspect. The quartzes from graphic and granite pegmatites, granites and porphyries, on the other hand, are smaller in size, frequently fractured and cracked in an intricate manner; they show rarely intergrowths of right- and left-handed individuals and the outlines of such intergrowths may or may not be regular. They are as a rule intricately twinned and the twinned areas are usually small and irregular and bear no apparent relation in outline to the hexagonal symmetry.—The observed characteristics of the first group of quartzes are those deduced theoretically for low temperature a-quartzes, while the features recorded for the second group are essentially those

deduced theoretically for β-quartzes formed above 575°. This places the temperature of final solidification of an intrusive granite mass above 575°. With the quartzes examined in the course of this investigation, a number of other minerals, garnet, magnetite, albite, lepidolite, etc., were associated, and in certain instances where, from the degree of idiomorphism and similar criteria, the relative periods of precipitation of the associated mineral can be ascertained, temperature limits of formation of the latter can thus be established. By thus determining stability ranges of certain minerals, points on the geologic thermometer scale are gained which in turn serve to fix limits for the temperatures of formation of other associated minerals.

Summary.

In the foregoing pages, attention is directed to a geologic thermometer scale the points for which are to be sought in the stability ranges of the different phases of rock-making minerals (their melting and inversion temperatures), and also in the melting temperatures of certain mineral aggregates (eutectics). Quartz is well adapted to furnish at least one and possibly two points for the geologic thermometer scale, since on heating at 575° it suffers an enantiotropic change to a second phase, called β-quartz by Mügge, while above 800° it is no longer stable at ordinary pressures, but passes into tridymite. Following the example of Le Chatelier and Mallard, the point of inversion of a- and β-quartz was redetermined by observing the abrupt change in the birefringence, circular polarization and expansion coefficient at that temperature. The most accurate optical determinations place this inversion temperature at 575° ± 2°. Proofs that these represent an energy change were obtained by the perceptible variation in heat capacity in this region by the Frankenheim method of heating and cooling curves; and also by direct determination of the specific and latent heats in this region. Crystallographic proof of the change has been studied in detail by O. Mügge, who finds the high temperature phase, β-quartz, to be in all probability hexagonal and trapezohedral-hemihedral, while the low temperature a-quartz is hexagonal and trapezohedral-tetartohedral. This particular relation between the two phases entails certain consequences which can be used as criteria to distinguish quartz which has been heated above 575° from quartz which has never reached that temperature. These criteria were in large part indicated by O. Mügge and have been applied above to a number of natural quartzes occurring in different kinds of rocks; the net result of the investigation being that vein and geode quartzes and certain large pegmatite quartz masses and pegmatite veins were formed

below 575°, while graphic and granite pegmatites and granites and porphyry quartzes were in all probability formed above 575°. With the quartzes thus examined were associated other minerals, the order of precipitation of which relative to that of the quartz could be determined in certain instances and thus temperature limits for the formation of these in turn ascertained.

The writers desire to express their indebtedness to Dr. A. L. Day for the precise thermoelectric measurements noted in the foregoing pages; to Dr. W. P. White for data on the specific and latent heats of quartz; and to Messrs. A. C. Spencer, E. S. Bastin, Arthur Keith, A. Knopf, Charles W. Wright, of the U. S. Geological Survey, and Professor G. P. Merrill of the National Museum, for specimens of quartz from the localities cited in the descriptions above.

Art. XXXIX.—*The Precipitation of Copper Oxalate in Analysis;* by F. A. Gooch and H. L. Ward.

It has been shown by Peters, in a paper from this laboratory on the volumetric estimation of copper as the oxalate,* that copper oxalate may be precipitated by oxalic acid with practical completeness from solutions of copper sulphate, provided the volume of the liquid is not too great and that the amount of copper present in solution exceeds a certain minimum value. It was shown that when the amount of copper present falls below a certain minimum either precipitation does not take place or it is incomplete. It was noted that the minimum was variable with the concentration of the precipitant, oxalic acid, and to some extent dependent upon the condition of the precipitant, the minimum being smaller when the oxalic acid was added in crystalline form rather than in solution to the liquid containing the copper salt. Peters' observations in respect to the effect, concentration and condition of the oxalic acid in solution of 50^{cm^3} are summarized in the following statement:

Minimum amount of copper, taken as the sulphate, which must be present in order that nearly complete precipitation may take place grm.	Amount of oxalic acid used. Crystalline grm.	In solution grm.	Volume of liquid cm^3.
0·010	5	5†	50
0·025	2	3·5	50
0·040	1	- -	50
0·050	0·5	- -	50

† Saturated solution poured upon the copper salt dissolved in the least amount of water.

It was also noted that when a saturated solution of oxalic acid, containing 0·1 grm. of oxalic acid to 1^{cm^3}, was slowly added to a drop of the copper solution containing 0·0003 grm. of copper the precipitated oxalate first formed dissolved completely in a volume of 5^{cm^3} of the precipitant.

In the procedure for the quantitative determination of copper by precipitation as the oxalate, Peters recommends a volume of 50^{cm^3}, with 0·5 grm. to 2 grm. of crystallized oxalic acid as the precipitant for 0·15 grm. of copper. An increase of the oxalic acid beyond this degree up to the point of saturation of the solution is apparently without effect. In subsequent work

* This Journal, x, 359, 1900.

involving separations Peters used volumes as high as 85^{cm^3}, of which concentrated nitric acid made up 5^{cm^3}, with 3 grm. of oxalic acid.

With regard to the time required for completing the precipitation, Peters showed that when no added nitric acid is present precipitates formed in the hot solutions at a volume of 50^{cm^3} may be filtered, either at once or after cooling, without loss ; but that when the nitric acid is added the mixture must stand before filtration, best over night.

The fact that small amounts of precipitated copper oxalate may be redissolved in a sufficient excess of the precipitant points to an appreciable degree of solubility of the precipitate in the solution of oxalic acid. The observation that very considerable amounts of copper oxalate fail to come down at all until a certain minimum of the copper salt is present, while precipitation is nearly complete when that minimum is reached, indicates supersaturation of the precipitant by copper oxalate ; while the capacity of the liquid for supersaturation is apparently limited to some extent by increase in concentration of the oxalic acid. The solubility coefficient of the copper oxalate under the conditions is made up, therefore, of at least two factors, of which one depends upon the normal solubility in the solution of oxalic acid which constitutes the medium of precipitation, while the other depends upon the solubility due to supersaturation. In order that small amounts of copper may be precipitated it is necessary to find means of eliminating or at least limiting the capacity of the medium for supersaturation ; and in order that large amounts, as well as small amounts, of copper may be determined with the highest degree of accuracy it is necessary to reduce to the lowest point the normal solubility of the oxalate under the conditions of precipitation. The present paper is an account of the experimental study of conditions under which small as well as large amounts of copper may be determined by the oxalate method.

The Normal Solubility of Copper Oxalate.

It is to be noted in the first place that the character of precipitated copper oxalate depends upon the conditions of precipitation. When oxalic acid is added to a cold concentrated solution of a salt of copper the copper oxalate precipitated is of extreme fineness and tends to pass through the closest filters. The precipitate formed in hot solution is, on the other hand, crystalline and easily separated by filtration of this liquid. The solubility of the precipitate, as well as the ease with which it may be separated from the liquid, turns upon the conditions of precipitation and treatment. In the experiments to be described, attention is first called to the degree of insolubility to

be expected in the case of a precipitate formed by oxalic acid in hot aqueous solutions of neutral copper sulphate or copper nitrate and in amounts in excess of the precipitable minimum. In the experiments of which details are given in Table I, definite portions of a solution of the copper salt were diluted with water to the volume stated, heated to boiling, and treated with crystallized oxalic acid. After standing over night in contact with the solution, the precipitate was collected upon asbestos in a perforated crucible and washed carefully with small amounts of water. The crucible with its contents was placed in a beaker and covered with about 200^{cm^3} of hot water containing 25^{cm^3} of dilute sulphuric acid $(1:4)$, and approximately $N/10$ potassium permanganate of known standard was added to coloration. Pure copper sulphate was used for the experiments of A ; and in those of B, copper nitrate, made by dissolving pure electrolytic copper in nitrate acid, evaporating off the excess of acid and dissolving in water, was used. The solutions of these salts were standardized electrolytically by the method of the rotating cathode.* The permanganate used in these and in all succeeding experiments was standardized against $N/10$ arsenious acid by acting with a measured volume of it upon a known amount of the standard arsenious acid, adding potassium iodide and titrating the excess of the arsenious acid in presence of acid potassium carbonate, by iodine also standardized against the arsenious acid, the difference between the arsenious acid taken and the arsenious acid determined by the iodine being the measure of the value of the permanganate.

Throughout the series of experiments, the error of the determination increases with the dilution. That the errors found in titration actually represent approximately losses in copper, at least for the smaller volumes, is shown by the difference, in two cases, between the result of titration and the electrolytic determination of copper in the filtrates from the precipitated oxalate. For a volume of 10^{cm^3}, the average error in the titration of the oxalate precipitated, either from the solution of the sulphate or from a solution of the nitrate, is 0·0002 grm. ; for 50^{cm^3} it is 0·0011 grm.; for 100^{cm^3}, 0·0053 grm. ; for 200^{cm^3}, 0·0203 grm. For similar concentrations of the copper salt and of the oxalic acid the deficiency in the copper indicated by titration of the precipitated oxalate increases more rapidly than the dilution, a fact which suggests some specific action of water, perhaps hydration affecting the solubility or hydrolysis affecting the composition of the copper oxalate. That time and temperature are not essential factors

* This Journal, xv, 320, 1903.

TABLE I.

Effects of Concentration in Water Solution.

Copper taken grm.	Volume at precipi- tation cm³.	Oxalic acid used grm.	Copper found grm.	Error grm.	Average error grm.
			A		
		Experiments with copper sulphate.			
0·0100	10	0·5	0·0097	—0·0003	
0·0100	10	0·5	0·0098	—0·0002	0·0002
0·0502	10	0·5	0·0500	—0·0002	
0·0502	50	2·0	0·0491	—0·0011	
0·0502	50	2·0	0·0491	—0·0011	0·0012
0·0504	50	2·0	0·0491	—0·0013*	
0·0504	100	4·0	0·0468	—0·0036†	
0·0502	100	4·0	0·0448	—0·0054	0·0052
0·0502	100	5·0	0·0449	—0·0053	
0·0502	100	5·0	0·0437	—0·0065	
0·0506	200	10·0	0·0303	—0·0203	0·0203
			B		
		Experiments with copper nitrate.			
0·0455	10	0·5	0·0457	+0·0002	0·0002
0·0570	50	2·0	0·056	—0·0009	0·0009
0·0455	100	5·0	0·0402	—0·0053	
0·0455	100	5·0	0·0395	—0·0060	0·0056

* Copper determined electrolytically in filtrate = 0·0013 grm.
† Copper determined electrolytically in filtrate = 0·0039 grm.

in the precipitation of the oxalate, at moderate dilution from solutions of the neutral salt, was shown when Peters filtered, without appreciable loss, precipitates from 50$^{cm^3}$ of hot solution either at once and hot or as soon as the liquid had cooled. The experiments of Table II show in addition that the precipitates, whether thrown down in hot solution or in cold solution, possess after long standing the same degree of insolubility.

TABLE II.

Effects of Temperature at Precipitation and Titration after Standing Over Night.

Copper taken grm.	Volume cm³	Oxalic acid grm.	Copper found grm.	Error grm.	Precipi- tation	Filtra- tion
0·0502	50	2·0	0·0491	0·0011	hot	cold
0·0502	50	2·0	0·0492	0·0010	hot	hot
0·0502	50	2·0	0·0490	0·0012	cold	hot
0·0502	50	2·0	0·0491	0·0011	cold	cold

If any part of the apparent loss of copper oxalate precipitated from solutions of oxalic acid is due to hydrolysis of the normal oxalate, and formation of a basic oxalate as the product of hydrolytic action, it should be possible to obviate such apparent loss by increasing the active acidity of the solution and thus inhibiting hydrolysis, providing that the solubility of the normal oxalate is not made greater thereby.   The experiment shows that beyond a reasonable degree of concentration the results are not affected by the use of oxalic acid up to the point of saturation of the solution.   It is worth while therefore to look somewhat more carefully into the effect of stronger acids present at the time of precipitation.   In Table III are shown the details of experiments in which the active acidity was increased by the addition of either free sulphuric acid or free nitric acid to the solution of the copper salt before precipitation was brought about by oxalic acid.   These experiments were made under conditions otherwise similar to those of Table I.   The copper sulphate was used in standard solutions.   The copper nitrate was prepared in solution for each experiment by dissolving weighed electrolytic copper in nitric acid, evaporating the solution to dryness, moistening the residue with a few drops of nitric acid and dissolving in water.

A comparison of the results of Table III with the results of corresponding experiments in Table I brings out the facts that the apparent error is actually diminished by the presence of even very small amounts of sulphuric acid or nitric acid in the liquid, while, within reasonable limits, the addition of more acid produces no further effect.   At the higher dilution, the effect of the active acid is marked.   At a volume of 100^{cm^3} the average error of deficiency shown in Table I is cut in two by the addition of 0.1^{cm^3} to 5^{cm^3} of nitric acid and of 0.5^{cm^3} to 2^{cm^3} of sulphuric acid.   At smaller volume of 50^{cm^3} the effect is not so marked, but it is still obvious.   These results favor strongly the hypothesis that copper oxalate is increasingly subject to hydrolysis as dilution increases, and that the tendency to form a basic salt may be checked by the presence of the stronger acids in suitable amounts.   Even very large amounts of nitric acid produce a surprisingly small increase in the apparent solubility of the oxalate.

Losses due to solubility of copper oxalate may evidently be kept at low limits by restricting the volume of the solution of oxalic acid in which precipitation takes place; but too much concentration is likely to introduce error due to mechanical inclusion of oxalic acid in the precipitates.   The natural alternative to a close restriction of the volume of the aqueous solution is the limitation of the solvent power of a larger volume of liquid by partially substituting for water some other

<div align="center">

TABLE III.

The Effect of Active Acids.

</div>

Copper taken grm.	Volume of the liquid cm³.	Oxalic acid used grm.	Volume of sulphuric acid or of nitric acid cm³.	Copper found grm.	Error grm.	Average error grm.
			A			
		Volume at precipitation approximates 100 cm³.				
			H_2SO_4			
0·0502	100	4·0	0·1	0·0454	−0·0048	
0·0502	100	4·0	0·5	0·0481	−0·0021	
0·0502	100	4·0	1·0	0·0484	−0·0018	−0·0024
0·0502	100	4·0	2·0	0·0474	−0·0028	
0·0502	100	4·0	2·0	0·0481	−0·0021	
			HNO_3			
0·0515	100	4·0	0·1	0·0499	−0·0016	
0·0530	100	4·0	0·1	0·0505	−0·0025	
0·0502	100	4·0	0·1	0·0471	−0·0031	
0·0502	100	4·0	0·1	0·0472	−0·0030	
0·0502	100	5·0	5·0	0 0471	−0·0031	−0·0031
0·0502	100	5·0	5·0	0·0468	−0·0034	
0·1500	100	2·0	0·1	0·1476	−0·0024	
0·2377	100	4·0	0·1	0·2356	−0·0021	
0·2530	100	4·0	0·1	0·2497	−0·0033	
0·2897	100	4·0	0·1	0·2880	−0·0067	
			B			
		Volume at precipitation 50 cm³.				
0·1333	50	4·0	0·1	0·1327	−0·0006	
0·1366	50	2·0	0·1	0·1360	−0·0006	
0·1443	50	2·0	0·1	0·1434	−0·0009	
0·2388	50	2·0	0·1	0·2384	−0·0004	
0·0502	50	2·0	4·0	0·0494	−0·0008	
0·0504	50	4·0	25·0	0·0491	−0·0013	
0·0504	50	4·0	40·0	0·0487	−0·0017	

miscible liquid less capable of dissolving the precipitated oxalate. The experiments of Table IV were made to test the effect of alcohol as suggested by Gibbs.* The results given in A show the effects of alcohol without nitric acid ; those of B show the effect of alcohol with nitric acid.

It is plain that the presence of alcohol improves the results of the process as compared with the results obtained at similar dilutions of the oxalic acid solution, either with or without nitric acid ; and, if the effect of nitric acid in the aqueous

* This Journal, xliv, 214, 1867.

<div align="center">

TABLE IV.

The Effect of Alcohol.

</div>

Copper taken grm.	Volume of liquid cm.	Per cent of alcohol in liquid	Oxalic acid used grm.	Nitric acid present cm³.	Copper found grm.	Error
			A			
		Precipitation in absence of nitric acid.				
0·0502	100	20	1·0	_ _ _ _	0·0492	—0·0010
0·0502	100	20	2·0	_ _ _ _	0·0491	—0·0011
0·0502	100	40	2·0	_ _ _ _	0·0491	—0·0011
0·0502	50	50	2·0	_ _ _ _	0·0499	—0·0003
0·0202	50	50	2·0	_ _ _ _	0·0499	—0·0003
			B			
		Nitric acid present in the liquid.				
0·0502	100	20	1·0	5	0·0493	—0·0009
0·0502	100	20	2·0	5	0·0491	—0·0011
0·0502	100	40	4·0	5	0·0497	—0·0005
0·0502	50	40	2·0	2	0·0497	—0·0005

solution is to prevent the formation of a basic salt, it would seem that the alcohol not only makes the precipitate more insoluble but checks hydrolytic action as well. In a volume of 100^{cm^3} containing 20 per cent of alcohol the error approximates -0.0010 grm.; and for a volume of 50^{cm^3} containing 50 per cent alcohol the error is still negative though reduced to -0.0003. The effect of nitric acid accompanying the alcohol is not marked.

In further experiments it was found that the addition of acetic acid, as proposed by Classen,* is even more effective than the use of alcohol, or of alcohol with nitric acid. In Table V are given the details of experiments in which the precipitation of copper oxalate was made in presence of considerable amounts of acetic acid. When considerable amounts of copper are present the precipitates formed in solutions containing acetic acid are apt to be very finely divided and consequently difficult to filter. A better condition of the precipitate is obtained, however, if, with the acetic acid, there is also present a moderate amount of nitric acid. The results of experiments in which both acetic acid and nitric acid were used are given in the table. The results of experiments in which sulphuric acid was present with acetic acid are also appended.

From these results it is apparent that acetic acid when present to the amount of 25 per cent of the liquid produces in volumes

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* Ber. Dtsch. Chem. Gesellsch., x, b, 1316.

TABLE V.

The Effect of Acetic Acid.

Copper taken grm.	Volume of liquid cm³.	Per cent of acetic acid	Stronger acid used cm³.	Oxalic acid used cm³.	Copper found grm.	Error grm.
			A			
		Precipitation in presence of acetic acid.				
0·0511	100	25	_ _ _ _	2·0	0·0502	—0·0009
0·0511	100	33	_ _ _ _	2·0	0·0504	—0·0007
0·0511	100	50	_ _ _ _	4·0	0·0510	—0·0001
0·1533	100	50	_ _ _ _	4·0	0·1530	—0·0003
			B			
		Precipitation in presence of acetic acid and nitric acid.				
0·0511	105	50	5	4·0	0·0510	—0·0001
0·0511	110	50	10	4·0	0·0506	—0·0005
0·0511	100	50	10	4·0	0·0510	—0·0001
0·1530	100	50	10	4·0	0·1529	—0 0001
0·1520	100	50	10	4·0	0·1530	—0·0000
			C			
		Precipitation in presence of acetic acid and sulphuric acid.				
0·0511	100	50	5	2·0	0·0508	—0·0003
0·0511	100	50	10	2·0	0·0413	—0·0098
0·0511	100	50	10	4·0	0·0512	+0·0001
0·0511	100	50	10	4·0	0·0513	+0·0002

of 100$^{cm^3}$ about the same effect as alcohol, and when present to the amount of 50 per cent it diminished still further the solvent power of the medium for the oxalate. The presence of nitric acid to 10 per cent of the entire volume does not materially affect the solubility. Sulphuric acid to 10 per cent of the volume of the liquid is without apparent effect upon the solubility of copper oxalate, provided the oxalic acid is also present in the proportion of 4 grm. to 100$^{cm^3}$ of the liquid. Treatment by oxalic acid in a medium consisting of acetic acid of half-strength, with or without nitric to the extent of 10 per cent by volume, is plainly the best of the procedures studied for the complete precipitation of copper oxalate in ideal condi tion; provided, however, that the copper is present in amount sufficient to break up the condition of supersaturation, let us say to the amount of 0·0500 grm.

The Prevention of Supersaturation.

Various means have been tried in the effort to break up supersaturation of the precipitating medium with small amounts

of copper oxalate.   Of these details an account is given below, in Table VI.

The supersaturated solution (A) was frozen and the mass melted, following procedure which has been found to be success- ful in hastening the deposition of small amounts of ammonium magnesium arsenate :* the supersaturated solution (B) was evaporated to dryness, and the residue extracted with water : alcohol was added (C) to the solution of the copper salt before attempting precipitation by oxalic acid : acetic acid of 50 per cent strength (D) was used as the medium in which precipita- tion was attempted by oxalic acid.

TABLE VI.

The Precipitation of Small Amounts of Copper.

Copper taken grm.	Volume of liquid cm³.	Oxalic acid grm.	Alcohol at pre- cipitation cm³.	Acetic acid at precipi- tation cm³.	Nitric acid at precipi- tation cm³.	Copper found grm.	Error grm.
			A				
		The effect of freezing, melting and boiling.					
0·0010	50	1·0	- - -	- - - -	- - - -	none	- - - -
0·0020	50	1·0	- - - -	- - - -	- - - -	0·0005	—0·0015
0·0030	50	1·0	- - - -	- - - -	- - - -	0·0024	—0·0006
0·0040	50	1·0	- - - -	- - - -	- - - -	0·0030	—0·0010
0·0050	50	1·0	- - - -	- - - -	- - - -	0·0039	—0·0011
0·0100	50	1·0	- - - -	- - - -	- - - -	0·0088	—0·0012
0·0200	50	1·0	- - - -	- - - -	- - - -	0·0188	—0·0012
0·0502	50	1·0	- - - -	- - - -	- - - -	0·0490	—0·0012
			B				
The effect of evaporation to dryness and extraction of the residue with 50ᶜᵐˢ. of water.							
0·0010	50	1·0	- - - -	- - - -	- - - -	0·0004	—0·0006
0·0020	50	1·0	- - - -	- - - -	- - - -	0·0018	—0·0002
0·0030	50	1·0	- - - -	- - - -	- - - -	0·0027	—0·0003
0·0040	50	1·0	- - - -	- - - -	- - - -	0·0036	—0·0004
0·0100	50	1·0	- - - -	- - - -	- - - -	0·0095	—0·0005
0·0200	50	1·0	- - - -	- - - -	- - - -	0·0196	—0·0004
0·0502	50	1·0	- - - -	- - - -	- - - -	0·0499	—0·0005
			C				
		The effect of precipitation in 50 per cent alcohol.					
0·0010	50	2·0	25	- - - -	- - - -	none	- - - -
0·0020	50	2·0	25	- - - -	- - - -	none	- - - -
0·0030	50	2·0	25	- - - -	- - - -	0·0015	—0·0015
0·0040	50	2·0	25	- - - -	- - - -	0·0020	—0·0020
0·0050	50	2·0	25	- - - -	- - - -	0·0016	—0·0034
0·0100	50	2·0	25	- - - -	- - - -	0·0085	—0·0015
0·0200	50	2·0	25	- - - -	- - - -	0·0198	—0·0002
0·0502	50	2·0	25	- - - -	- - - -	0·0499	—0·0003

* Gooch and Phelps, this Journal, xxii, 488, 1906.

TABLE VI (continued).

The Precipitation of Small Amounts of Copper.

Copper taken grm.	Volume of liquid cm³.	Oxalic acid grm.	Alcohol at precipitation cm³.	Acetic acid at precipitation cm³.	Nitric acid at precipitation cm³.	Copper found grm.	Error grm.
					D		
The effect of precipitation in acetic acid.

The effect of precipitation in acetic acid.
Volume 50cm³ : 50 per cent acetic acid.

Copper taken grm.	Volume of liquid cm³.	Oxalic acid grm.	Alcohol at precip-itation cm³.	Acetic acid at precip-itation cm³.	Nitric acid at precip-itation cm³.	Copper found grm.	Error grm.
0·0010	50	2	----	25	----	0·0010	0·0000
0·0020	50	2	----	25	----	0·0021	+0·0001
0·0031	50	2	----	25	----	0·0027	—0·0004*
0·0041	50	2	----	25	----	0·0041	0·0000*
0·0051	50	2	----	25	----	0·0049	—0·0002*
0·0102	50	2	----	25	----	0·0098	—0·0004*
0·0204	50	2	----	25	----	0·0098	—0·0006*
0·0511	50	2	----	25	----	----	----†
0·0010	50	2	----	25	5	0·0010	0·0000
0·0020	50	2	----	25	5	0·0021	+0·0001
0·0031	50	2	----	25	5	0·0033	+0·0002
0·0041	50	2	----	25	5	0·0042	+0·0001
0·0051	50	2	----	25	5	0·0043	—0·0002
0·0102	50	2	----	25	5	0·0103	+0·0001
0·0204	50	2	----	25	5	0·0204	+0·0000
0·0511	50	2	----	25	5	0·0512	+0·0001

Volume 100cm³ : 50 per cent acetic acid.

Copper taken grm.	Volume of liquid cm³.	Oxalic acid grm.	Alcohol at precip-itation cm³.	Acetic acid at precip-itation cm³.	Nitric acid at precip-itation cm³.	Copper found grm.	Error grm.
0·0010	100	4	----	50	3	0·0010	0·0000†
0·0020	100	4	----	50	3	0·0021	+0·0001‡
0·0031	100	4	----	50	5	0·0031	0·0000
0·0041	100	4	----	50	5	0·0041	0·0000
0·0051	100	4	----	50	5	0·0051	+0·0002
0·0102	100	4	----	50	5	0·0103	+0·0001
0·0204	100	4	----	50	5	0·0196	—0·0008§
0·0511	100	4	----	50	5	0·0510	—0·0001

Volume 150cm : two-thirds acetic acid.

Copper taken grm.	Volume of liquid cm³.	Oxalic acid grm.	Alcohol at precip-itation cm³.	Acetic acid at precip-itation cm³.	Nitric acid at precip-itation cm³.	Copper found grm.	Error grm.
0·0010	150	4	----	100	----	0·0013	+0·0003
0·0010	150	4	----	100	5	0·0012	+0·0002

* Filtration imperfect. † Filtration impossible.
‡ Precipitation formed slowly. § Filtration imperfect.

From these results it appears, first, that by precipitating at a volume of 50cm³, freezing, melting, and boiling, the condition of supersaturation may be broken up, the oxalate obtained being soluble in the proportion of about 0·0011 grm. to 50cm³ of liquid ; secondly, that by precipitation at a volume of 50cm³, evaporation to dryness, and extraction with the same volume of water, the copper may be recovered to an amount within

about 0·0004 grm. of that taken; thirdly, that treatment by oxalic acid in 50 per cent alcohol fails to precipitate about 0·0020 grm. of copper from amounts less than 0·0200 grm., while for amounts exceeding that limit the copper is nearly all recovered; and, fourthly, that in volumes of 50$^{cm^3}$ or 100$^{cm^3}$, consisting of 50 per cent acetic acid, the copper oxalate is thrown down completely, the presence of nitric acid to the extent of 10 per cent making the filtration more effective without influencing the solubility, while at a volume of 150$^{cm^3}$ the precipitation is complete provided the acetic acid makes up two-thirds of the volume.

The best and most convenient procedure for the precipitation of small amounts as well as large amounts of copper oxalate ideal in composition consists, therefore, in adding 2 grm. or 4 grm. of oxalic acid to 50$^{cm^3}$ or 100$^{cm^3}$, respectively, of the 50 per cent acetic acid solution of the copper salt containing 5 per cent to 10 per cent of nitric acid. The permanganate titration of the washed oxalate, in presence of sulphuric acid, gives very accurate determinations of the copper.

ART. XL.—*The   Yakutat   Coastal   Plain   of   Alaska :*   A combined   terrestrial   and   marine   Formation;*   by   ELIOT BLACKWELDER.

THE reconstruction of the climatic, physiographic and biologic conditions of past ages has long been one of the chief objects of geologic study.   Many lines of search have been pursued with various degrees of success.   Some facts have been deduced from the fossils, others from the constitution of the atmosphere, and still others from the rocks themselves. Like most other questions, these have been investigated now with caution and a full realization of the complexity and uncertainty of the factors, and now with easy confidence and blindness to difficulties.   Some interpretations of sedimentary deposits made in an off-hand way have been little better than guesses.   An encouraging number of others, however, are firmly based so far as they go, and, best of all, the facts and inferences are duly separated.

In the interpretation of the older sedimentary rock formations we have to deal with what may be called fossil products of aggradation.   There are two ways in which one may approach a given problem of this sort: (a) having studied the many facts carefully, we may reason out, from our knowledge of physiographic, climatic and biologic principles, what conditions must have prevailed at that time and place; or (b) we may compare the fossil deposit with various modern deposits of known origin and decide to which of them it corresponds.   Both of these methods are used and often in combination.   In order to put the second into practice it is necessary for us to know intimately the characteristics of many modern deposits, and also all the conditions under the influence of which those deposits are now being made. The careful description of modern formations in many parts of the world is, therefore, essential to progress in this study, and this paper is presented as a small contribution to the mass of information needed.

From near the mouth of the Alsek River to Controller Bay, the southern coast of Alaska is fringed by a narrow plain.   From Yakutat Bay westward it is partly covered by the Malaspina piedmont glacier.   The part with which I am familiar is that between Yakutat and the Alsek River.   Oceanward the plain dips beneath the water level, leaving a tolerably regular shore line.   On the north it is hemmed in by the Brabazon range, the front of which rises abruptly 2000–4000 feet without either foothills or fringing talus-slopes.

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

The climate of the coast is humid and cool, with compara-
tively slight temperature changes.   Winds roll in from the

FIG. 1.
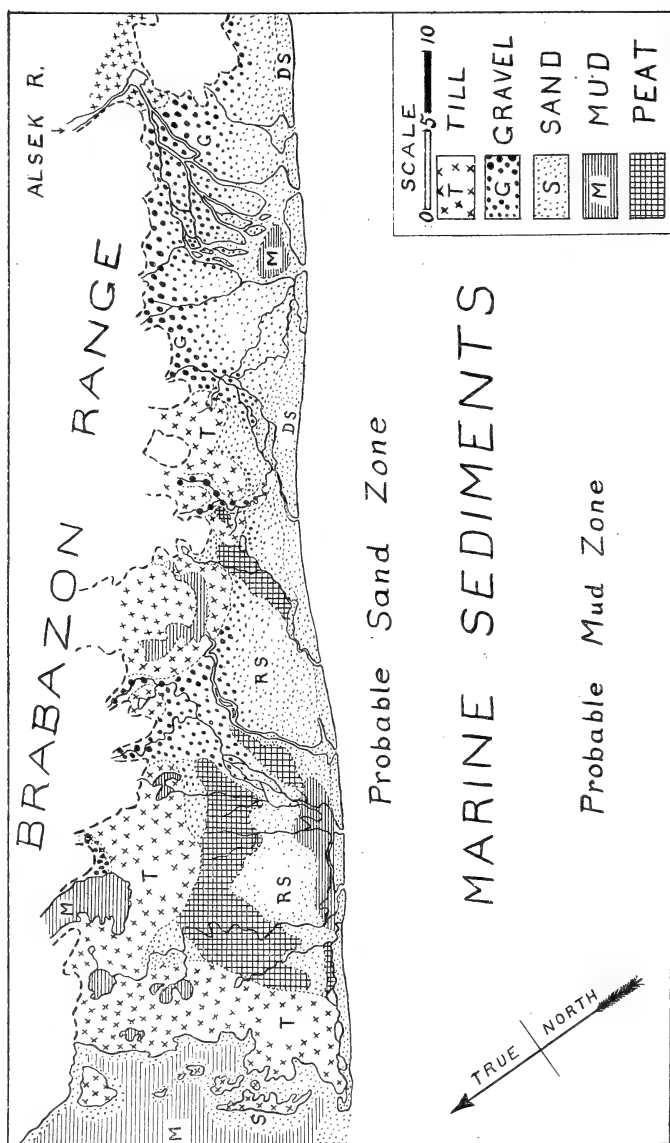
FIG. 1.   The coastal plain from Yakutat Bay east to the Alsek River.
Shows roughly the distribution of modern sediments. (Compiled from
maps and notes by Maddren, Brabazon, Netland and others.)

warm Pacific ocean and keep the mountains enveloped in nimbus clouds for days at a time, with only occasional sunny intervals. Showers and fogs are of frequent occurrence. The climate in summer has, therefore, been aptly characterized as "damp and chilly." In winter the snowfall is heavy, but the freezing of both soil and streams checks the operation of the processes we have to consider.

Under the influence of this climate a dense growth of boreal vegetation covers the plain. On the flat undrained parts, grassy marshes and willow swamps prevail. On moraines, sandy ridges, and, in fact, wherever the soil is subject to drainage, there are dense spruce forests with a dank undergrowth of mosses, ferns and "devils-club." Everything there is soggy, even on the drier days.

Needless to say the rivers are permanent and brimming, although subject to fluctuations according as the rains are heavy or light. All but the Alsek are short streams, but some even of these rise in the abundant glaciers which choke the mountain valleys. The glacial rivers are swift, and are milky with fine sediment; but the others, which draw their water through many swamps and lakes, are clear. In the history of the plain the glacial streams are probably of far more importance than the others. The rivers which cross the plain are engaged in aggrading. They have no valleys, and their immediate channels are sunk but a few feet beneath the plain.*

Having this picture of the district and its conditions, we may now consider the structure and composition of the plain itself. The foreland is composed entirely of unconsolidated Quaternary sediments. Near Yakutat Bay, and subordinately elsewhere, low glacial moraines make the surface. The rest of the material was deposited by water or wind, and is stratified.

The plain seems to have been built out into the ocean by shifting aggrading rivers. These rivers are swiftest near the mountains and become slack at tide-level. On this account the sediments are graded in coarseness. Near the mountains, coarse gravel predominates; but as one passes seaward he may trace the gravel into sand and finally into silt. This zonal arrangement of gravel, sand and silt probably persists roughly with depth, for the conditions of gradient have doubtless been similar through much of the history of the plain.

In composition the sediments have certain distinctive features. The colors are limited to black and grays of various intensities. Tinges of green are not uncommon but are faint. When examined closely the sediments are found to consist of

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* The work of these streams as seen in front of the Malaspina glacier has recently been described by Tarr, Zeitschrift für Gletscherkunde, iii, 88-93.

particles of slate, greenstone, quartz, feldspar and ferromagnesian minerals, with a varying admixture of carbonaceous material. A lack of the usual products of oxidation is the striking characteristic of all the deposits.

In general the sediments do not show evidence of long continued attrition. Although the pebbles and sand grains are moderately round, many particles are angular or irregular in

Fig. 2.

Fig. 2. The delta of the Alsek River as seen from the Brabazon Range on the north. A type of the constructing rivers of the foreland (photograph by Netland, U. S. Boundary Survey).

shape. The assortment and segregation of the particles, both as to size and lithologic character, is also markedly imperfect. The gravels are heterogeneous mixtures of bits of slate, graywacke, granite and other rocks. The sands contain feldspar, magnetite, hornblende and slate in addition to the usual quartz. In the matter of size also the same lack of assortment prevails, large pebbles and small being bound together by a matrix of muddy sand; while the silty beds contain much sand and mica. Heterogeneity is therefore another distinguishing property of these sediments.

Upon the surface, the distribution of the various deposits is determined by their origin. At the mouths of the largest valleys there are glacial moraines. Along the more powerful streams there are sheets of bare gravel and mixed sands. In the swampy intervening areas peaty material is accumulating. Along the ocean beach, exposed to the storm waves and high winds, pure quartz-sands are being heaped into low dunes; while in the tidal lagoons and estuaries just back of the shore,

sticky mud forms the bottom. Although we can not see what is being deposited on the bed of the ocean, yet we need not doubt that the ceaseless milling of the breakers and currents is comminuting the sediment and distributing the different kinds of detritus in belts varying with the depth of the water and the exposure. This part of the formation should be well assorted and the individual deposits of sand and mud tolerably homogeneous in composition and texture.

For a picture of the gross structure of the beds we can not rely upon actual observation, for there are no sections which expose more than a few feet of the deposits. But from the nature of the agents engaged in building the plain we may infer with confidence that the structure is complex. The

Fig. 3.
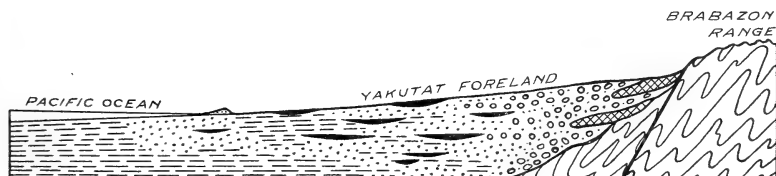
FIG. 3. Ideal cross-section of the foreland, showing the relations of the different kinds of sediments. Vertical scale exaggerated. (The cross-lined pattern denotes moraines.)

glaciers have probably been subject to advance and retreat, as all well-known glaciers are, and, if this is true, they have left sheets of till between beds of gravel. The streams are bordered by gravel wastes through which old stumps protrude,— remnants of forests invaded by the rivers. These and other facts show that the rivers are constantly changing their courses so that river gravels are interlaminated with peaty layers made in bogs and forests. It has been said that the larger rivers are subject to marked fluctuations in volume. In time of flood gravel is spread far out over the sands, and at low-water stages such sheets of gravel are again covered by sandy beds. As these changes recur frequently, the sediments must consist of rapidly alternating coarse and fine beds. The coast line itself must be subject to shifting; for even if there have been no changes of level the plain must have been built out into the ocean. If, on the other hand, this is a region of tectonic disturbance, as shown by Tarr and Martin,[*] then we should expect to find yellow dune sands, gray estuarine clays and

* R. S. Tarr and Lawrence Martin, Recent changes of level in the Yakutat Bay region, Alaska : Bull. Geol. Soc. Amer., xvii, 29–64, 1906.

mixed fluviatile deposits lying one upon the other and perhaps alternating in successive wedge-shaped beds.

The stratification planes of the various classes of deposits have peculiarities of importance, and these surface features are in turn reflected in the minor structures seen in cross-section. The aggrading streams are all filled with fan-shaped bars which have gentle back slopes and steep outer slopes. The deposition of sediment in this form produces prominent cross-bedding. More intricate cross-bedding is caused by the alternate cut and fill of the shifting rivers and by the migrating sand dunes. Cross-bedding is also doubtless a common feature of the deposits now forming near the zone of breakers in the ocean. On the whole, therefore, much of the deposits of the foreland must be cross-bedded.

Ripple-marks, although absent in the deposits of the swamps and quiet lagoons, are characteristic of the beach and river sediments. On the ocean shore, regular ripple-marks of the long parallel type are made by the water currents below tide-mark and by the wind currents above that line. In the channels of the streams the ripple-marks are usually shorter and of the spatulate type, with gentle back slopes and steep fronts. They are even more numerous there than along the littoral zone. Some which were observed by our party near the head of the Alsek delta were exceedingly large. These were composed of bowlders and coarse gravel and had a relief of 4 to 6 feet with wave-lengths of scores of feet. In fact they were so large that I did not recognize their true character while clambering over them, but only when I saw them in panorama from a considerable elevation. Ripple-marks of such magnitude would of course express themselves in cross-section as strong cross-bedding. They give some idea of the power of the current in the Alsek River when it is in full flood.

Sun-cracks, another feature of terrestrial and tide-water sediments, appear to be uncommon here. I do not remember having seen any. The explanation is doubtless to be sought in the climate, which is so moist that muds rarely become dry enough to crack. If the cracks occur anywhere, the tidal sounds would furnish the most favorable conditions.

Organic remains are being preserved between some of the layers to-day and they offer a further means of identification of deposits of this general class. In the submarine zone of the plain, shells of mollusks, echinoderms and other aquatic animals lie upon the bottom; but as life is not very abundant in this boreal sea, the shells preserved should be somewhat scarce. In the terrestrial zone, driftwood is buried by the dune sand, while forest trees are undermined by the rivers and enveloped in deposits of gravel or sand. In the finer sedi-

ments of swamps and estuaries, leaves of ferns and other plants find lodgment and are doubtless being preserved. Animal remains, on the other hand, are rarer. Bones of salmon are buried in the river sediments in some quantity, for millions of them die each year on the spawning grounds; but, since they frequent chiefly the gravelly bottoms, their opportunities for preservation are not the best. Land mammals are too scarce on the plain to leave many skeletons. It thus appears that fossils must be tolerably rare in the entire series of beds. In the marine portion plants would be deficient, while mollusks, crustaceans, worms and echinoderms would predominate. In the terrestrial part, bits of wood and even leaves would be locally abundant, but animal remains would be rare and comprise little but the fishes.

The characteristics of the sediments in the Yakutat plain may be summarized as follows:

1. Origin : partly terrestrial and partly marine, the phases either interleaved near the contact or the one transgressing upon the other.
2. Types of sediments : till, gravel, sand, silt, mud, and peat.
3. Composition : heterogeneous.
4. Color : gray to black, due to the lack of oxidation products and the abundance of carbonaceous matter.
5. Texture : subangular as well as round particles, alternately finer and coarser.
6. Assortment : very imperfect except in the marine phase. Fragments of many rocks of many sizes intermingled confusedly.
7. Stratification : complex and irregular in the terrestrial phases. Cross-bedding, lense-structure and ripple-marks prevalent in the sandy beds. Effects of contemporaneous erosion common. Sun-cracks rare.
8. Fossils : in the terrestrial portion leaves and wood common, animals rare (chiefly fishes). In the marine portion shells fairly common, plants rare.

Although my subject is the modern sediments of the plain, I may call attention here to the interesting fact that these sediments have analogs in the hard rocks of the mountains behind them. The Brabazon range and the Puget peninsula are composed largely of the Yakutat series,* which has been referred to both the Carboniferous and the Jurassic systems. This formation presents clearly many, although not all, of the characteristics of the sediments in the plain just described. The rocks are black slates, dark graywackes and conglomerates.

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* The lithology of the beds is described in many papers, among them the following: Harriman Alaska Exped. Report, iv, pp. 44–56 ; I. C. Russell, Nat. Geogr. Mag., iii, 166–170 ; U. S. Grant, U. S. Geol. Surv. Bull. 284, p. 79–80 (Orca series).

They consist of many materials, usually poorly assorted, and often imperfectly rounded. The minerals are not oxidized, and carbonaceous material is abundant. Conglomerates are interleaved with graywackes at many horizons. Ripple-marks and cross-bedding are found in the coarser beds. Fossils are very rare, and of those discovered the commonest may perhaps be plant stems or worm trails. Only a single identifiable shell has been found* and that not in this vicinity. There are even beds suggestive of glacial action.†

I interpret this to mean that, at a much earlier time, this part of the Alaskan coast had much the same cool, rainy climate that it has to-day, that it was bordered by a growing foreland covered with dense vegetation and was backed by rugged highlands

Russell‡ describes a series of rocks, younger than the Yakutat formation, which he found on the slopes of the St. Elias range and named the Pinnacle series. This comprises 1800 feet of dark gray sandstone and shale with beds of conglomerate. Some of the beds contain marine shells ; others have coal seams. Here again there is a lack of oxidation products and an alternation of dark clastic sediments suggestive of the modern coastal deposits.

In one of the coarse conglomerates of the Yakutat series I observed a bowlder, itself composed of an older conglomerate, and among the pebbles in the latter were hard quartzitic graywackes of the same unoxidized carbonaceous character. That this represents a still earlier epoch of similar conditions is at least suggested.

Taken together, these facts seem to indicate that certain climatic and physiographic conditions have recurred at widely separated intervals in this single region. In each case the record is purely sedimentary rather than paleontological.

University of Wisconsin, March 1, 1909.

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* E. O. Ulrich, Harriman Alaska Exped. Rep., iv, pp. 125–148.
† Eliot Blackwelder, Jour. of Geol., xv, p. 11–14. The probable glacial origin of certain folded slates in southern Alaska, 1907.
‡ Loc. cit. p. 170–173.

ART. XLI. — *Pyrite Crystals from Bingham, Utah;* by
AUSTIN F. ROGERS.

THE pyrite crystals described in this note were kindly pre-
sented to the writer by Dr. A. L. Inglesby of Bingham, Utah.
They were obtained by him from the Highland Boy mine in
Carr Fork, about a mile and a half above Bingham.   The
crystals, which average about 5^{mm} in diameter, are well
developed, have brilliant faces, and are often highly modified.
The best groups of crystals in Dr. Inglesby's collection are
magnificent specimens, rivaling those from Leadville and from
Central City, Colorado, in attractiveness.
    The observed forms are as follows :   cube, $a\{100\}$; pyrito-
hedrons, $e\{210\}$, $\theta\{430\}$, $\delta\{610\}$; trapezohedrons, $n\{211\}$,
$m\{311\}$, $\mu\{411\}$; positive diploids, $s\{321\}$, $\phi\{12\cdot9\cdot1\}$. $\rho\{10\cdot7\cdot1\}$;
negative diploids, $\Upsilon\{8\cdot10\cdot5\}$ and $O\{371\}$.   Of these the last
four are new for the mineral pyrite.
    The habit is determined either by the cube or by the pyrito-
hedron $\{210\}$, often in about equal development.   No tendency
toward an octahedral habit was noticed :—$a\{100\}$ varies from
a mere line face to the dominant form.   It is often striated
parallel to its intersection-edge with $\{111\}$; $e\{210\}$ is on most
of the crystals the dominant form.   It is sometimes striated
parallel to its intersection edge with $\{111\}$ and $\{321\}$ and only
rarely vertically striated; $o\{111\}$ is present on all the crystals
and sometimes prominent.   Its faces are bright and usually
marked by concentric triangles which represent oscillations in
the zone of trapezohedrons; $s\{321\}$ is present on many of the
crystals; $n\{211\}$ occurs on every crystal and is often rather
prominent; $m\{311\}$ and $\mu\{411\}$ are subordinate forms present
on about half the crystals; $m\{311\}$ is the more frequent of
the two and usually the larger; $\delta\{610\}$ and $\theta\{430\}$ are the
only pyritohedrons in addition to $\{210\}$.   They are narrow and
unimportant forms.
    Each of the new forms is present on several crystals and
they are well established by measurements. $\phi\{12\cdot9\cdot1\}$ is in a
vertical zone with $\{430\}$. $\rho\{10\cdot7\ 1\}$ is near $\{12\cdot9\cdot1\}$ in position
but is sharply defined. $\Upsilon\{8\cdot10\cdot5\}$ is a negative diploid in the
vertical zone with $[210:211:213]$ and hence only one measure-
ment was necessary for its identification. $O\{371\}$ is present
on several crystals.   Its faces are striated and apparently there
is a (370) face.   Measurements in the cube and pyritohedron
zone give an image for the (370) position, but in the $[37\overline{1}:37\overline{1}]$
zone there were multiple images but no definite one for (370).
This example, it is thought, shows an advantage of one-circle
measurements over two-circle measurements.

The following is a list of combinations and habits, the forms under each being arranged according to their prominence. The list begins with dominant cubic habit and ends with dominant pyritohedral habit.

1. *a e o n*
2. *a e o n*
3. *a e o n m s μ O*
4. *a e n s o m μ*
5. *a e o n*
6. *a e o n δ μ*
7. *e a n o s m μ δ φ ρ* Y

8. *e a o n μ s* Y *δ θ φ m ρ* (see fig. 1).
9. *e a o n m s O θ*
10. *e a o n s*
11. *e o a n O m*
12. *e o a n s m*
13. *e o n m*
14. *e o n*

Data for the identification of the new forms are given in the following comparison of the measured with the calculated angles:

	Cryst. 7	Cryst. 8	Cryst. 11	Calculated
211 ⌢ 10·5·8	11° 28′	11° 31′	_ _ _ _ _ _	11° 30′
10·5·8 ⌢ 213	17 44	17 41	_ _ _ _ _ _	17 42
430 ⌢ 12·9·1	3 48½	_ _ _ _ _ _	_ _ _ _ _ _	3 49
371 ⌢ 37Ī	_ _ _ _ _ _	_ _ _ _ _ _	14° 58′	14 58
210 ⌢ 10·7·1	9 34	_ _ _ _ _ _	_ _ _ _ _ _	9 38
211 ⌢ 7·1·10	34 32	_ _ _ _ _ _	_ _ _ _ _ _	33 33½
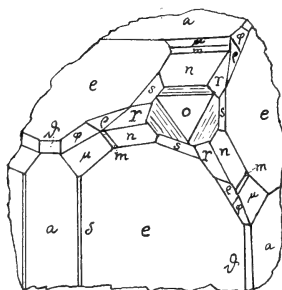
FIG. 1.

Fig. 1 represents crystal No. 8. This gives a general idea of the average habit and shows three of the four new forms. This figure is simply a sketch inked in with a straight edge and not the regulation clinographic projection.

In addition to the forms characteristic for this locality, the most remarkable feature of these crystals is the prominence of the zone [100 : 411 : 311 : 211 : 111]. This is shown not only by the presence of the three trapezohedrons indicated but also by oscillatory striations on the octahedron faces and occasionally on the cube faces. The poverty of pyritohedrons is also striking, there being but two pyritohedrons besides {210}. This is also substantiated by the fact that vertical striations rarely occur either on the cube or on the pyritohedron {210}.

Stanford University, Feb., 1909.

Art. XLII.—*The Composition of Stony Meteorites compared with that of Terrestrial Igneous Rocks, and considered with reference to their efficacy in World-Making;* by George P. Merrill.

[Read before the Geological Society of Washington, March 24, 1909.]

Speculation relative to subjects the actual proof of which lies entirely beyond his reach, has ever been a favorite pursuit of the thinking man. Nowhere is this more manifest than in questions relating to the age and origin of the earth. Of all the theories which have been evolved, and which have stood the test of any considerable length of time, only that known as the Kant-Laplacean, and the more recent hypotheses of Professor Chamberlin of Chicago, need our present consideration. Any and all of these call for the world-making materials, whether gaseous or solid, from sources beyond our immediate universe. It is but natural, therefore, that those substances which reach our earth from space in a solid form, and which give the only really tangible illustrations of what materials of space may be, should be regarded as of value in aiding our arrival at the desired conclusions. This fact was recognized over one hundred years ago (1794) by Chladni, who regarded meteorites as remnants of cosmic materials employed in the formation of worlds, or, as he expressed it, as "Weltspäne." The idea, with various more or less important modifications, has been repeated by subsequent workers,* and is brought up for consideration with renewed force by the recent papers of Professor Chamberlin, which have been so clearly summarized under the heading of the "Origin of the Earth" in his work on geology.†

It should be stated, however, that Professor Chamberlin is not an advocate of the meteoric theory of the earth; in fact, he states definitely that the origin of meteorites is but an incidental result of stellar and planetary action, their genesis being wholly a secondary matter, and furnishing no grounds for regarding them as the parent material of great nebulæ or of stellar systems. Chamberlin inclines rather to what he calls the "planetesimal hypothesis," which assumes that the solar system was derived from a spiral nebula consisting of finely divided solid or liquid materials, which revolve independently about a common nucleus, and which are gathered into larger aggregates through the crossing of the elliptical orbits of the

* See Lockyer's Meteoric Hypothesis for discussion. Arrhenius' Worlds in Their Making is perhaps the latest work in which the matter is seriously considered.

† Geology, vol. ii, Earth History, pp. 1–81.

individual members.   It is obvious, however, that whatever
theory is adopted,—the Laplacean, meteoric, or the planetesi-
mal—the kind of material, and presumably the ultimate origin
of all, remains the same.   It is this thought which has led me
to enter upon the present discussion.

Meteorites as they come to our earth, as is well known, are
roughly grouped into three general classes; first, those which
consist essentially of nickeliferous iron nearly or quite devoid
of silicate material; second, those which consist of a spongy
mass of iron, including globular aggregates of silicates; and
third, those which are nearly or quite all of silicate material,
with more or less sporadic iron.   These forms, it is true, grade
into one another, but, nevertheless, the classification is much
easier than one would be at first led to suppose.

Researches into the composition of our earth have led us to
assume that it is composed of an outer zone of comparatively
rich silicate material, in which free silica is an important con-
stituent, and an inner zone of material which is essentially
metallic, with perhaps an intermediate zone showing a transi-
tion between the two extremes.   Regarding meteorites as
world materials, as has been done by certain workers, we
might consider the purely metallic varieties as representing the
deep-seated, probably nucleal, material of some pre-existing
planetary body; the stony meteorites as representing the
crustal material ; and the spongy irons with the mixed silicates
(pallasites) as representing the intermediate portion.   The
fact, however, that a part, at least, of the iron of stony mete-
orites has been repeatedly shown to be of secondary origin—
to result from the reduction of some compound subsequent to
the consolidation of the silicates, is difficult to harmonize with
any such view.

Inasmuch as the nucleal material of the earth is quite beyond
reach for purposes of investigation, and as the intermediate
zone, if such there be, is represented, if at all, only by extrusions
of deep-seated igneous rocks, I have for the time being limited
my considerations to a comparison of the stony meteorites
with the great group of igneous rocks as existing to-day upon
the earth's surface.   It will be seen at once that in doing this,
I have accepted for the purpose the most acid group of the
ultra-terrestrial rocks.

There are many difficulties in the way of obtaining anything
like an accurate average of the composition of these materials.
This, for reasons which can be fully appreciated only by those
who have attempted their study, and more particularly, the
making of chemical analyses.   One of the chief difficulties, it
may be said, lies in the separation of the metallic from the
non-metallic portion.   The method of statement of the results,

and the proper interpretation to be put upon the same, add to the difficulties. Several of the constituents, moreover, occur in such extremely small quantities, or like the chloride of iron (lawrencite), undergo such rapid deterioration, that their determination has been largely overlooked, particularly in the older analyses. Or, again, if such determinations were made, the results as given are at least open to doubt in the light of more recent investigations. In going over all of the literature available, I have found but ninety-nine analyses which were made, as it seemed to me, with sufficient care, were sufficiently complete, or stated in such a way as to render the results comparable with one another. Even in these ninety-nine, all of the constituents were not determined, and in many instances, where the presence or absence of a certain element was not stated, one is left in doubt as to whether such was looked for, or whether it was looked for and found lacking. Out of the ninety-nine analyses, however, silica, alumina, iron, ferrous oxide, lime, magnesia, potash and soda were found determined in a sufficient number of cases to make the matter of an average a fairly safe approximation, the metallic iron affording the most difficulty. Of the remaining constituents, as given in the table below (No. 1), the manganese is an average of forty-one determinations, the phosphorus of thirty-one, the chromic iron of sixty-seven, the sulphur of ninety-two, and the nickel-cobalt of ninety-three. The percentage amount of sulphur has, in many cases, been arrived at by calculation, since the results

Average composition of stony meteorites as calculated from 99 analyses for all constituents but P, which is from 31 determinations; MnO from 41 determinations, $Cr_2O_3 + Fe_2O_3$ from 67 determinations; Ni,Co from 93 determinations; and S from 92 determinations.

	I Average of Results as given				II Recalculated on basis of 100
SiO_2	38·98				38·732
Al_2O_3	2·75				2·733
Fe	11·61				11·536
FeO	16·54				16·435
CaO	1·77				1·758
MgO	23·03				22·884
Na_2O	0·95				0·943
K_2O	0·33				0·328
$Cr_2O_3 + Fe_2O_3$	0·84	Av. of 67 dets.			0·835
Ni,Co	1·32	"	93	"	1·312
S	1·85	"	92	"	1·839
P	0·11	"	31	"	0·109
MnO	0·56	"	41	"	0·556
	100·64				100·00

were sometimes given as simply ferrous sulphide and sometimes as sulphur. Where such calculations were necessary, the percentage of iron was added to the amount given in the analyses as existing in the metallic state.[*]

The following list shows the highest and lowest percentages of any given constituent in the analyses here averaged.

	Highest	Lowest
SiO_2	61·15	26·05
Al_2O_3	11·05	0·00
Fe	27·00	0·00
FeO	30·44	0·99
CaO	7·03	0·00
MgO	39·04	6·44
Na_2O	3·94	0·00
K_2O	4·31 [†]	0·00
$Cr_2O_3 + Fe_2O_3$	6·33	0·00
NiCo	4·21	0·00
S	7·47	0·00

[†] It would seem that this must be an error, since the stone (that of Zsadany, Hungary) is described as consisting essentially of olivine and pyroxene, and no reference made to feldspars.

For comparison of these results with terrestrial rocks, the following are given :

Average composition of terrestrial igneous rocks as calculated by (III) Clarke and (IV) Washington.[†]

	III	IV
SiO_2	60·91	58·239
Al_2O_3	15·28	15·796
Fe_2O_3	2 63	3·334
FeO	3·46	3·874
MgO	4·13	3·843
CaO	4·88	5·221
Na_2O	3·45	3·912
K_2O	2·98	3·161
H_2O at 100°_	0·41	0·363
" above 100°	1·49	1·428
TiO_2	0·73	1·039
P_2O_5	0·26	0·373
	100·61	100·583

[†] Bull. 330, U. S. Geol. Survey, 1908.

[*] The writer regards these results as only approximations, and suggestive. The recalculation of many of the analyses is attended with so many uncertainties, that it is even probable that slightly different results would be obtained in going over the same ground a second time. So far as the main constituents—the silica, alumina, lime, magnesia, potash and soda—are concerned, he believes the averages as good as can be obtained with available material.

It may be well to add that the approximate weight, so far as known, of all the stones represented by these ninety-nine analyses, was 4,014 kilograms or about 4·4 metric tons. An average of 77 determinations, as given, of specific gravities gave 3·51, of which the lowest, that of the Orgueil, France, carbonaceous stone was 2·50, and the highest, that of Limerick, Ireland, 3·92.

It will at once be noted that there is a wide and striking difference in composition between the meteorites and the terrestrial rocks,—a difference not merely in the relative proportion of the various elements, but also, in one case at least, in their method of combination. The most striking feature is, for the meteorites (columns I and II), the low silica content, and the high percentage of metallic iron, ferrous oxide, and magnesia, with the corresponding low percentages of alumina, lime, and the alkalies.* Compared with Washington's averages for terrestrial rocks, it will be noted that there is a difference of nearly twenty per cent in the amount of silica in favor of the latter, and of some thirteen per cent in the amount of alumina. These differences are so striking that they cannot be considered as due to errors of analyses, or of their interpretation. They must be fundamental.

Should we disregard entirely the metallic iron of the meteorites with its included nickel, cobalt, and phosphorus, and also the iron disulphide (amounting all together to 14·79 per cent), and recalculate Analyses II on the basis of 100, we get the results shown in column V below. In column VI is given the average of seven analyses of terrestrial peridotites† which, as will be at once apparent to the petrographer, afford the closest approximation, in chemical as well as mineral composition, to meteorites. These, it should be stated, have been recalculated on a water-free basis. It is scarcely necessary, however, to call attention to the fact that the peridotites represent the most basic of known terrestrial rocks, while the meteoric analyses which I have given represent the most acid type that have come to us from space. It is evident, therefore, that

* The composition as shown by these analyses does not, so far as sodium is concerned, seem to harmonize with spectroscopic analyses, or Arrhenius' statement to the effect that the nucleus of comets, like the meteorites falling upon our earth, consists essentially of silicates, and *particularly of the silicates of sodium.* See Worlds in Their Making, pp. 104-105. For the benefit of those not familiar with the subject, it may be well to state that the principal mineral constituents of meteorites, aside from the metallic portions, are the silicates of magnesia and iron, olivine and enstatite, with less commonly monoclinic pyroxenes and basic feldspars. Silicates of sodium must be rare, as shown by a simple glance at the analyses given.

† The number was limited, since nearly all reported analyses were of altered and highly hydrated examples, while for purposes of comparison materials as nearly anhydrous as possible were needed.

	V	VI
SiO_2	45·46	43·59
Al_2O_3	3·21	5·30
FeO	19·29	8·40
Fe_2O_3	----	2·03
CaO	2·06	4·11
MgO	26·86	35·62
Na_2O	1·11	0·60
K_2O	0·38	0·36
MnO	0·65	----
$Cr_2O_3 + Fe_2O_3$	0·98	----
	100·00	100·01

as world-making materials they are insufficient, and if we are to regard our earth as an aggregate of cosmic matter, we must assume that the materials were of a much more highly siliceous type than any that have been reaching us from space within historical periods. This is presumably the proper interpretation to be placed upon the results here shown.

It is impossible through any process of magmatic differentiation to derive from such materials, in even approximate proportions, a series of rocks as widely variant and, in extremes, as highly siliceous, aluminous and alkaline, as are the igneous rocks of the earth. In fact, it would seem that they (the meteorites) themselves must represent an extreme phase of magmatic differentiation from a more acid magma.

Whether we consider the meteorites that have reached us within this period as but the fragmental remains of comets, or whatever their origin, it is certainly not going beyond the realm of legitimate hypothesis to assume that the relative proportions of the elements which go to make up the mineral matter in these various bodies in remote space, may vary widely; that the earth to-day, in its course, is but passing through[*] and receiving from space a deposit of materials representing one and the same original body, and that body one of an exceedingly basic nature, not necessarily resembling, in percentage composition, the materials which may have reached us during past and earlier stages of earth history.

[*] "Meteoriten und Planetoiden sind daher die vorübergehenden Zeugen einer vorübergegangenen Episode in der Geschichte unseres Planetensystems." Ed. Suess, Ueber Einzelheiten in der Beschaffenheit einiger Himmelskörper, Sitz. kais. Akad. der Wiss., vol. cxvi, 1907.

ART. XLIII.—*Notes on the Family Pyramidellidæ ;* by K. J. BUSH, PH.D.

THERE has recently been published by the Boston Society of Natural History an article on the very interesting family of Pyramidellidæ, written by Mr. Paul Bartsch,* Assistant Curator in the Department of Mollusks of the U. S. National Museum at Washington City, D. C.

In his introduction the author carefully reviews all of the literature relating to this family from the northeast coast of America, naming the species in each work, from Thomas Say, in 1821, to George W. Tryon, in 1886. He states that his paper is largely based on the U. S. National Museum collections; that he had also for study the collection from the Philadelphia Academy of Sciences and the large private collection of Rev. H. W. Winkley, etc. etc. Quoting, as regards the synonymy : "In the present paper we have confined ourselves to the specimens at hand and to citations of literature necessary to a complete understanding of the nomenclature." A further review of the work on this family, undertaken since 1886, and overlooked by Mr. Bartsch, may prove of interest to those studying this group.

The Pyramidellidæ† belonging to the fauna of the east Atlantic have never been studied as a whole, but several students of Malacology had described a comparatively few species, those of special interest in this connection being from different localities along the coast of New England, West Indies, and Florida ; in many instances without figures and, most unfortunately, if figures were attempted, they are at the present time considered too poor for accuracy in determining the species.

About 1896 the entire, very large collection of the Pyramidellidæ made by the U. S. Fish Commission during the years from 1872 to 1887, from the Bay of Fundy and the Banks of Newfoundland, south to Cape Hatteras, N. C., as well as many collections made by others at Labrador, Florida, and the Bermudas, in the Museum at Yale University were given into my charge to prepare for publication. In this connection a card catalogue of between 250 and 300 specific names referred to about 75 genera or subgenera was made.

* Pyramidellidæ of New England and the adjacent region. Proceedings Boston Society of Natural History, vol. xxxiv, pp. 67-113. plates 11-14, 1909.

† This group as given by Tryon (Manual of Conchology, vol. viii. parts 32 and 33, pp. 294 to 413, pls. 72 to 79, 1886) is a compilation of all known species with their descriptions and figures ; a new name is proposed where a former one proves preoccupied.

There were in existence at that time three or rather four small collections of species belonging to the genera *Turbonilla* and *Odostomia* of special interest; one at the Museum at Amherst College; one at the State Museum at Albany, New York; one at the Academy of Sciences of Philadelphia; and the fourth in the National Museum at Washington. The first contained the types of C. B. Adams;* the second the specimens used in W. G. Binney's Gould;† the third those who by G. W. Tryon in his Manual of Conchology; and the last the species described by Dr. Dall‡ from Florida.

On visiting Amherst College I found that the C. B. Adams' specimens had been misplaced, [and for the time lost track of, (I understand they were subsequently studied at the National Museum). Professor John W. Clarke, then in charge of the Albany Museum, failed to find the specimens belonging to this group in the Gould collection. On request, those at Philadelphia were loaned me for study and proved of so great interest that I published a short report on them with one plate in the Proceedings of the Philadelphia Academy, in 1899.§ Cotypes and other specimens were also sent me by Dr. Dall.

After several months of arduous work I had the collection ready for the descriptions of the numerous new species, fine figures of which had been prepared and arranged in plates. This work was then laid aside for other of more importance on different groups of mollusks; and most unfortunately has never been completed and published; although an attempt was being made to do so in the near future.

In 1900, jointly with Professor Verrill,‖ I published a report on the mollusks from the Bermudas, in which we described some new species of *Turbonilla* and *Odostomia* and in several instances reëstablished some of the genera or subgenera described by A. Adams, restricting them to definite types for the first time.¶

* Descriptions of Supposed New Species of Marine Shells which Inhabit Jamaica.   Contributions to Conchology, No. 5, pp. 72-75, 1850.

† Report on the Invertebrata of Massachusetts, pp. 324-333, text figures, Boston, 1870.

‡ On a Collection of Shells sent from Florida by Mr. Henry Hemphill. Proceedings U. S. National Museum, vol. vi, p. 332, Washington, D. C., 1883.

§ Descriptions of new species of *Turbonilla* of the western Atlantic Fauna, with notes on those previously known. Proceedings Academy Natural Sciences of Philadelphia, pp. 145-177, pl. viii, 1899.

‖ Additions to the Marine Mollusca of the Bermudas.   Transactions of the Connecticut Academy of Sciences, vol. x, pp. 528-535, pls. lxiv-lxv.   New Haven, Conn., 1900.

¶ *Pyrgostelis* Monterosato, 1884 ; type—*P. rufa* (Philippi). V. & B., 1900 + D. & B., 1904.   *Mumiola* A. Adams, 1864 ; type—*M. spirata* A. Adams, 1860.   V. & B., 1900 + D. & B., 1904 (not *Mumiola* Monterosato, 1884 = *Odostomiella* B. D. & D., 1883).   *Mormula* A. Adams, 1864 ; type—*M. rissoina* A. Adams.   V. & B., 1900 + D. & B., 1904.   *Cyclodostomia* Sacco, 1892 ;

In 1902, I visited the National Museum and found that Dr. Dall had given the species from the west coast of America, belonging to this group, to his assistant, Mr. Bartsch, to work up, as I had those of the east coast.   In this connection rare species and types, both fossil and recent, were loaned by foreign museums,* (especially the Berlin Museum, in which were the collections of H. and A. Adams, Pætel, Dunker, and Hilgendorf ; and the British Museum, where are the collection of D'Orbigny and many others having species belonging to this group ; as well as the Museum at Copenhagen.)   Figures were being made so that in the future there could, or rather would, be but small chance for errors in the identification of species.

In 1903, an extensive report on fossils of California was published by Mr. Arnold, in the California Academy of Sciences.   In this, Dr. Dall and Mr. Bartsch furnished the part on mollusks, and the senior author credited the work on the family Pyramidellidæ to Mr. Bartsch.

Also, in 1904, a "Synopsis of the Genera, Subgenera, and Sections of the Family Pyramidellidæ" was published by these authors in the Bulletin of the Biological Society of Washington.†   Quoting from the introductory remarks, " The synonymy, which is very involved, is reserved for another paper in which the species of the west coast of America will be monographically treated.   It was thought best to put on record the classification adopted, so that before the paper referred to appears the authors may have the benefit of criticism from other students."

Since the publication of my article in 1899, collectors of mollusks from California, Florida, and various places along the coast of New England have sent or brought their specimens to me for the identification of the species.   This has been a source of great pleasure, as well as profit, as it enabled me, not only to become acquainted with rare species, as there was often but one specimen of a kind, but in instances where there were several, duplicates were given me, which were placed in our museum collection.   When new forms appeared from the west coast they were referred to Mr. Bartsch ; and those from

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type—*C. mutinensis* Sacco.   V. & B.,   1900 + D. & B., 1904.   *Evalea* A. Adams, 1860 ; type—*E. elegans* A. Adams.   V. & B., 1900 + D. & B., 1904. *Cingulina* A. Adams, 1860 ; type—*C. circinata* A. Adams.   V. & B., 1900 + D. & B., 1904.   *Miralda* A. Adams, 1864 ; type—*M. diadema* A. Adams. V. & B., 1900 + D. & B., 1904.   In three instances (*Mumiola, Mormula,* and *Cingulina*), although citing the same type, these authors differ in the interpretation of the generic relations of these subgenera.

* Dall, in Dall and Bartsch.   Notes on Japanese, Indopacific, and American Pyramidellidæ.   Proceedings U. S. National Museum, vol. xxx, pp. 221–269, pls. xvii–xxvi.   Washington, 1906.

† Vol. xvii, pp. 1–16.

Florida to Dr. Dall; those from the New England localities were given an initial letter, as it was not considered advisable to give out manuscript names. In one instance, as a report on a collection from Coldspring Harbor, L. I., by Mr. Balch* of Boston, these initial letters were published and full credit given me.

Among the most frequent visitors at the Museum was Rev. Henry W. Winkley, then of Branford, Connecticut, who is a most enthusiastic student and collector of New England mollusks; principally at Prince Edward Island, N. S., Casco Bay, Woods Holl, Mass. and Branford, Conn. His collection is unique in having numerous perfect specimens of the various species, and was of inestimable value in enabling me to decide many difficult questions of the correct identification in this puzzling group. To Mr. Winkley I also refused to give my new unpublished names, but used the same initial letters as for Mr. Balch. There were in his collection representatives of many of the new forms found in that of the U. S. F. C. as well as a few unique ones, not among the U. S. F. C. specimens.

These specimens from Mr. Winkley's collection are cited by Mr. Bartsch (p. 475), but no mention whatever is made of the fact that any student had seen the specimens or determined them.

Among the thirty-eight (38) species cited and described in his report, and in most cases figured, there are seven (7) which he has never seen (*E. ventricosa* V. (not Forbes), *T. polita* V., *T. æqualis* (Say) V., *O. bruneri* V., *O. morseana* B. for *O. sulcata* V. (not *A.* Adams). *O. dealbata* (St.) Binney-Gould, *O. eburnea* (Stimpson) V.); six (6) from Winkley's collection, as types, with two (2) (*P. producta* (C. B. Adams) and *T. mighelsi* B. for *T. costulata* V. (not Risso). Fifteen (15) are represented in the Winkley collection, as well as in that of the U. S. F. C. in the National Museum; and eight (8) are from the U. S. F. C. collection alone. Of these, three (3), *T. cascoensis, T. verrilli,* and *O. bushiana* are described as new. The new subspecies or varieties, *T. abyssicola, T. branfordensis, T. senilis, O. bedequensis,* and *O. ovilensis,* are not included in this enumeration.

The two specimens identified as *Eulimella ventricosa* Verrill, 1880 (not Forbes, 1843), have proved to be two distinct species. The worn one from Eastport, Me., is now considered identical with *Eulimella polita,* Verrill, 1872, and the one from Station 873 is an *Aclis tenuis* Verrill, 1882. Therefore the name *Pyramidella (Eulimella) ventricosa* Bartsch (p. 70) is superfluous.

* Proceedings Boston Society of Natural History, vol. xxix, pp. 145–146, 1899.

The referring in 1884, of the three species *chariessa, nitida,* and *lucida* to the genus *Eulimella,* instead of *Eulima,* was probably an accidental error overlooked in reading the proof. This correction, noted on p. 71, has long stood on our distribution sheets, but never having been published was a MS. name. As *lucida* is a true *Eulima,* the name does not now conflict with *Eulimella (Syrnola) lucida* A. Adams, 1870; but the name *nitida* Verrill, 1884, is preoccupied by *Melania nitida* Philippi, 1844=*E. intermedia* Cantraine, 1835, and by *Eulima nitida* A. Adams, 1866=*E. nitidula* A. Adams, 1861; also by *Leiostraca nitida* A. Adams, 1861=*Eulima* Tryon, 1886, and will therefore take the new name, *Eulima verrilliana.**

There seems to be no reason for dropping the final *i* used in the original spelling of *smithii* Verrill (p. 71), nor for placing the species in the subgenus *Syrnola,* rather than in the subgenus *Eulimella,* used by Verrill in 1882. The use of *Turbonilla* for *Syrnola tryoni* is a typographical error for *Eulimella.*

The referring of *fusca* C. B. Adams from New Bedford, Mass. (p. 73) to *Pyramidella (Syrnola?)* seems unnecessary. The species, although brown in color, has the form of a typical *Odostomia,* and should be reëstablished in that genus, as given by Gould, 1840. Adams' figure is poor and is like our *bisuturalis* without sculpture. Gould's two figures 1840 and 1870 are larger with more flattened whorls and more gradually tapered spire.

There is great variation in the relative stoutness among the many specimens of *Turbonilla bushiana* Verrill (p. 79), as well as in the relative strength of the axial ribs; those having well-developed ribs received the subspecific name, *abyssicola* suggested as a variety by Verrill and Bush in MS. There are comparatively few specimens which differ from both the typical and subspecific forms, going to the opposite extreme, in being entirely destitute of definite axial ribs, the surface smooth and shining, often iridescent; for these we propose the new subspecific or varietal name *inornata.* All the specimens which I have studied are destitute of spiral lines,

* *Eulima distorta* Verrill, 1881=*Eulima perversa,* new name. It is similar to *E. arcuata* C. B. Adams. 1850=new name?, not *E. arcuata* Sowerby, 1866=*E. major* Sowerby, 1834; Dall, 1889; not *Odostomia arcuata* A. Adams, 1860.

Like *E. distorta* G. O. Sars, pl. 11, fig. 23, 1878, not *E. distorta* Deshayes (Compared with typical specimens from Monterosato). not *Melania distorta* Philippi, 1836=*E. incurva* Renieri, 1804; not *Melania distorta* Defrance, 1824=new name?, not *Leiostraca distorta* Pease, 1860=*Eulima,* new name?

Eulima intermedia Verrill, 1881=*Eulima Sarsi,* new name; not *E. intermedia* Cantraine, 1835; not *Dunkeria intermedia* Carpenter, 1857=*Odostomia (Dunkeria)*; not *Odostomia intermedia* Brusina, 1869=*Odostomia canaliculata* Philippi, 1844.

as the exceedingly fine microscopic striæ, always discernible under high power objectives, are not taken into consideration. Therefore its relation to the subgenus *Strioturbonilla* (p. 79) seems imaginary. This subgenus is described by Sacco, " Testa sicut in *Turbonilla* (stricta sensu) sed transversin striolæ parvillimæ (sub lente vix visibiles)," etc., etc., and his figure of *S. apicina* shows many very fine, distinct, incised spirals between the ribs and on the base, similar to the sculpturing found in the true *T. interrupta* (p. 481).

The *Turbonilla polita* Verrill, 1882 (p. 75) does not conflict with *Odostomia polita* Bivona, 1832 ; nor Pease, 1867.

For discussion of the genus *Turbonilla* (p. 76) and type see p. 483. The name *nivea* is extensively used in this group, but *Turbonilla nivea* (Stimpson, 1851 and 1853) from 40 fms. off Grand Menan, N. B., has priority. The shallow water species described and figured as *nivea* by Bartsch (p. 77) is not like the typical specimen from U. S. F. C. Station 871, off Newport, R. I. in 115 fms., 1880, described by Verrill* in 1881, (the specimen cited from Station 949 is the true *nivea*). The axial ribs end just above the deep suture ; the intercostal spaces showing a basal curve, thus leaving a very narrow, smooth, sutural area. The whorls are less rounded than indicated in the figure, p. 484, f. 1. The *nivea* Bartsch is a typical *T. stricta* Verrill. In a lot of over 20 specimens, from Vineyard Sound, there is great variation in the number and width of the axial ribs. The largest specimen, having 10 postnuclear whorls, is like Bartsch's figure 9, Plate II, but is not the *T. stricta* Bartsch, figure 6, which is a typical *T. æqualis* Say (p. 78). [See p. 484, f. 5, from Woods Holl, Mass., 1882.]

The *Triptychus niveus* Mörch, 1875 (type and only species of the genus) is described as having a few spiral liræ ; the liræ extending into the aperture forming three plications on the columella. Aperture subemarginate anteriorly, somewhat excavated below the liræ. Nucleus reversed.

The nucleus is the only character showing any relation to the Pyramidellidæ. The aperture would exclude it, as it shows nearer affinity to the genus *Cerithiopsis*. Dr. Dall, 1889 (also Dall and Guppy, 1896), suggested its being synonymous with *Oscilla*, which seems hardly possible ; *indiscreta* Guppy, 1896, is described and figured as *Triptychus (Oscilla)*. The *Pyramidellida vincta* Dall is placed as a synonym of *T. niveus* Mörch by Tryon, 1886. Although stating that " The shell is scarcely a *Pyramidella*—the sculpture and plications are different," Tryon uses *Triptychus* as a section of the Pyramidellidæ, and Dall and Bartsch, 1904, p. 5. as a subgenus. The *Dunkeria falcifera* Watson, 1885, from Bermuda may prove to have affinity to this group.

* Proceedings U. S. National Museum, vol. iii, 1881, p. 379.

The genus *Peristichia* Dall, 1889 (type *P. toreta* Dall, 1889), used as a subgenus of *Turbonilla*, 1904, p. 9, seems to have more affinity to *Rissoina* than to any genus among the Pyramidellidæ.

The name *Turbonilla areolata* Verrill is not preoccupied by *Turritella areolata* St., 1851, nor *Chemnitzia areolata* Rayneval, 18—, which is equal to *Turbonilla indistincta* Montagu (teste Jeffreys, 1884). This rare species, p. 484, f. 4 (type from New Haven, Conn.), described by Verrill, 1874, has flattened whorls, giving it an obelisk-like form. The axial ribs are narrow, with wide, shallow, intercostal spaces, crossed by five distinct, incised lines or series of pits. In some specimens the axial ribs appear only as interruptions of the spiral sculpture. The *areolata* of Bartsch (p. 86, pl. 12, figs. 19, 24) is another species similar to *Turbonilla (Pyrgiscus) vineæ* Bartsch (p. 83).

TURBONILLA INTERRUPTA (Totten) Bush, 1899, pp. 148–151.

> *Turritella interrupta* Totten, 1835, p. 352, fig. 7. Type locality,—Newport Harbor, R. I.
> Not *Chemnitzia interrupta* A. Adams, 1853.
> Not *Turbonilla interrupta* C. B. Adams in Amherst collection.
> Not *Turbonilla (Pyrgiscus) interrupta* Bartsch, 1909.
> Not *Eulima interrupta* Sowerby, 1834, = *Niso* Sowerby, 1854.
> Not *Eulima interrupta* A. Adams, 1884, = *Eulima secunda*, new name.

An historical sketch of this species was given by me in 1899. Figure 9, produced here for the first time, is from an U. S. F. C. specimen dredged in 1880, at station 770, Narragansett Bay, in 8 fathoms. The specimen measures about 5^{mm} in height and about 1·5^{mm} in breadth. Figure 10 is a piece of the shell greatly enlarged to show the character of the microscopic sculpture, especially the incised or impressed spiral lines. These incised lines, varying in width, produce an alternating series of apparently raised ones, often arranged indistinctly in pairs, and agree well with the description given by Totten. The specimen described (p. 87) and figured by Bartsch, unfortunately does not agree with this, therefore I would distinguish it as *Turbonilla pseudointerrupta*, new name.

The shells, as a rule, are of a lustrous white color, semitransparent when fresh, often with one, sometimes two, delicate median, or sutural and median bands of rufous ; in some of the most mature specimens this color entirely covers the whorls, especially the upper ones.

Turbonilla (Pyrgiscus) buteonis Bartsch (p. 89) is the same as sp. f′ in our U. S. F. C. collection.

Turbonilla (Pyrgiscus) sumneri Bartsch (p. 92), type and only specimen, is probably the young of a more common species. The young often appear disproportionately stouter than the adult forms.

Odostomia (Chryssalida) bushiana Bartsch (p. 99) is like specimens in our U. S. F. C. collection from shallow water off Cape Hatteras, N. C. There is also a small lot from Vineyard Sound, Mass. (Not *Odostomia bushiana* Jeffreys, 1884.)

The *Odostomia (Iolæa) hendersoni* Bartsch (p. 101) is identical with specimens from Woods Holl, Mass., in our own collection, identified as an immature *Aclis striata* Verrill, 1880. Its generic affinity needs further study, as it is very doubtful whether it can be related to the Pyramidellidæ. As *Iolæa* (p. 101) is described as having spiral cords and axial riblets, this species is erroneously referred to this subgenus, for it has but a few very fine spiral incised lines.

Odostomia (Menestho) bruneri Verrill, 1882 (p. 102). Type and only specimen is lost.

Odostomia (Menestho) sulcata Verrill, 1880 and 1882 (p. 484, f. 2, from Georges Bank, in 45 fms.), is *O. sulcosa* Mighels, 1843 (*Phasianella* Mighels and *Rissoella* Stimpson ; Binney-Gould, 1870). The name *morseana* Bartsch (p. 104) is, therefore, not needed.

There is so great variation found among a large series of specimens of *Odostomia bisuturalis* Say and *O. trifida* Totten (pp. 104–108) that it seems desirable to unite the two forms under *bisuturalis*, with subspecies *trifida ;* the *exigua* Couthouy, 1838 (p. 106) also being a possible subspecies. The subspecies *ovilensis* Bartsch (p. 107) is simply a very large form. The subspecies *bedequensis* Bartsch (p. 106) is much more nearly related to *O. impressa* Say (p. 103). In fourth line of the description, axial is undoubtedly intended for "spiral." In a marginal note p. 328 in Binney-Gould, 1870, Prof. Verrill has written : "Have seen shell figured (597). It is a genuine *O. trifida.*" Below, under *O. trifida*, he adds "*Pasithea sordida* Lea (this Journal, vol. xlii, p. 110, pl. i, fig. 6) to the synonymy.

Odostomia (Odostomia) modesta Bartsch (p. 108, pl. 13, fig. 50) is distinct from the *O. modesta* Verrill, from Eastport, Me. (p. 484, f. 8), which has flattened whorls and a somewhat angular body whorl, and much more prominent nucleus. Therefore it requires the new name *Odostomia gibbosa*, not preoccupied by the *Chemnitzia gibbosa* Carpenter, 1857, which is a *Turbonilla.*

The *Odostomia (Liostomia) eburnea* (*Rissoa* and *Rissoella* Stimpson), 1851 (p. 109) is not the same as that in Binney-Gould, 1870, p. 297. Specimen, p. 484, f. 7, is from Mt. Desert, Me., collected by W. E. Cleaveland, 1862.

Odostomia (Odostomia) dealbata (Stimpson) (p. 108) is not the same as fig. 595 given in Binney-Gould, p. 327. This, as indicated in a marginal note, represents a " much larger and different species " which may be called *O. Gouldii*, new name. F. 6 is a typical form from Vineyard Sound, Mass., 1875.

Odostomia producta (C. B. Adams) Gould, 1840 (p. 72) from Wood's Holl, Mass., is shown on p. 484, f. 11.

Turbonilla elegantula Verrill (p. 84). The type is from Vineyard Sound, Mass., 1875 (f. 12, p. 484).

Turbonilla costulata Verrill, 1874. The type from New Haven, Conn. (p. 484, f. 3), is not the *Turbonilla (Pyrgiscus) mighelsi* (Bartsch), p. 88. It is a very stout form of *Turbonilla interrupta* (Totten) and may be designated as variety *obesa*, new name.

At the time of defining the genus *Turbonilla* Risso, 1826, (1899, p. 147), I had failed to notice that the genus had been proposed for three fossil species, as stated by Jeffreys in his British Conchology, vol. iv, p. 108. "In 1862 [for 1826] Risso (Hist. Nat. l'Em. Mer., iv, p. 224) formed the genus *Turbonilla*, on the MS. authority of Leach, for three fossil species;" etc., etc. Although I may have erred in naming the recent species, *T. lactea* (Linné) = *T. elegantissima* (Montagu) for the type species, I did not in any way interfere with the correct interpretation of the genus.

I also divided and subdivided it (pp. 172–174), according as the species had not, or had, spiral sculpture; the second division according to the character of these markings. Clearly defined these and designated them by initial letters, as I did not feel competent to make use of the names which had been proposed by Adams and others. In no case had Adams designated a type species, as such, and in many instances he had grouped several dissimilar forms. The difficulty of correctly interpretating these was greatly increased by the lack of good figures. Lists of the species, which had been discussed in the foregoing pages, were given under each division, so that it was hardly possible for any one to misunderstand my meaning. In 1900, Professor Verrill and I did adopt some of Adams' names, restricting them to definite types for the first time, as well as the names proposed by Monterosato, Sacco, and others (p. 476).

As no complete synonymy was given by Messrs. Dall and Bartsch in 1903 and 1904, these facts were not mentioned, but why Mr. Bartsch in 1909 should fail to note them, as they seriously affect the correct authorities for the combination of names, does not appear.

There seems to be no reason for the new name *T. typica* Dall and Bartsch, 1903 and 1904 (Bartsch, 1909, p. 76) for *T. plicatula* Risso not Scacchi, for not only should my type of 1899 stand, having priority and also being the first one designated for the genus, but some authors, followed by Tryon, 1886, make *plicatula* Risso, *elegantissima* Montagu, and *lactea* Linné synonymous. Sacco, 1892 (p. 654) gives *lactea* as his first species under *Turbonilla*, with sixteen (16) named varieties; *Chemnitzia elegantissima* (Montagu) as a synonym of the first, *var. Campanellæ*.
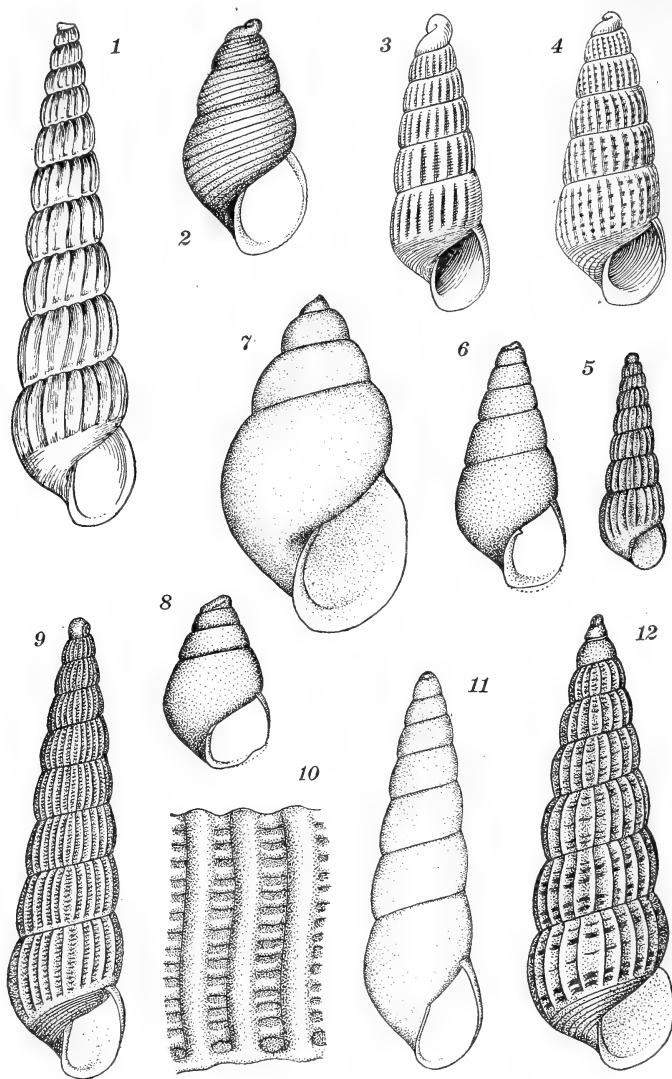
Fig. 1.—*Turbonilla nivea* (St.) V., × 10, p. 480.
Fig. 2.—*Odostomia sulcosa* (M.), × 10, p. 482.
Fig. 3.—*Turbonilla interrupta* (T.) var. *obesa* n. n., × 10, p. 483.
Fig. 4.—*Turbonilla areolata* V., × 10, p. 481.
Fig. 5.—*Turbonilla æqualis* (Say) V., × 8, p. 480.
Fig. 6.—*Odostomia dealbata* (St.) Gld., × 9, p. 483.
Fig. 7.—*Odostomia eburnea* (St.) Gld., × 13, p. 483.
Fig. 8.—*Odostomia modesta* St., × 9, p. 482.
Fig. 9.—*Turbonilla interrupta* (T.) Bush, × 12, p. 481.
Fig. 10.—The same. Sculpture, much enlarged.
Fig. 11.—*Odostomia producta* (C. B. Ad.) Gld., × 9, p. 483.
Fig. 12.—*Turbonilla elegantula* V., × 13, p. 483.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Liquid and Solid Radium Emanation.*—Gray and Ramsay have made some interesting observations upon the remarkable gas which is spontaneously evolved from radium. Having collected some of the emanation in a state of fair purity, they compressed it in a capillary tube with the very fine bore of 0.08^{mm} diameter. When sufficiently small, there was seen at the conical point of the tube a minute column of liquid, easily visible under low microscopic power. By altering the volume more or less liquid could be condensed, and by transmitted light all the phenomena of condensing and evaporating a liquid could be observed. By transmitted light the liquid appeared colorless like water, but when the illumination from behind was extinguished the liquid was visible by its own illumination as a greenish or bluish green phosphorescent layer, not very luminous, but more so than the gaseous layer. Its vapor pressure was measured at several temperatures, but as the gas was not quite pure, an allowance had to be made for this, so that the results given in the following table are only approximate :

Pressure.	Temperature.
100^{mm}	$-74.5°$ C
200	-66.1
500	-53.6
760	-48.5
1000	-43.1
2000	-31.0
5000	-12.8
10000	$+ 1.5$

The density of the liquid was estimated with rough approximation as about 7, assuming the gaseous emanation to be 100 times as dense as hydrogen, and the conclusion was reached that it is considerably more dense than xenon, namely 3.52. While the liquid was only feebly phosphorescent, when it was cooled by touching the tube with liquid air it became brilliant, the color changed to light steel-blue and blazed with light. Continued application of the liquid air caused the color to change, first to white, then to yellow, and finally to orange. Through the microscope it looked like a brilliant little arc light. On removing the liquid air the reverse changes in color took place, and these changes could be repeated again and again. There was no doubt that the brilliantly luminous substance was a solid.— *Chem. News*, xcix, 165.   H. L. W.

2. *The Gases Evolved by the Action of Cupric Chloride upon Steels.*—The usual method of determining carbon in steels consists

in treating the metal with a strong, nearly neutral solution of potassium and cupric chlorides in order to dissolve the iron, and then making a combustion of the filtered residue. It has been known for some time that this operation involves the loss of small quantities of carbon, and recently GOUTAL has carefully studied the matter. He has found that when steels are attacked by very slightly acid solutions of potassium and cupric chloride at a moderate temperature and in a current of nitrogen gas, there is a loss of gaseous compounds of carbon amounting to from 0·01 to 0·05 per cent. He states that this loss may be diminished nearly one-half by making the combustion of the carbonaceous residue directly after draining it with the filter pump, and without drying it in the oven, for under these circumstances the carbon dioxide formed remains entirely condensed in the residual carbon. He states further that the loss of carbon may be perhaps entirely avoided by boiling the copper solution resulting from the operation, passing the gas which comes off with an excess of oxygen through a glass tube provided with a red-hot platinum wire, and collecting the resulting carbon dioxide in baryta water.— *Comptes Rendus*, cxlviii, 988.   H. L. W.

3. *The Radiation of Potassium Salts.*—That potassium salts show a faint amount of radio-activity was first observed by Campbell and Wood, and the fact has been confirmed by others. E. HENRIOT has now made a further study of this phenomenon, and finds that while others have announced that the rays from potassium are very heterogeneous, his own observations lead him to the conclusion that they are practically homogeneous. He studied the absorption of the radiation by tin-foil of varying thickness, and since the radiation-activity of potassium is of the order of $\frac{1}{10000}$ of that of uranium, be used 1 kg. of salt spread over a surface of 1300^{cm^2}. From the results of his experiments he concludes that potassium emits β-rays only, that there is little probability that the radiation is due to an already known radio-active element, and that the activity is probably caused either by potassium itself, or by an unknown body which is always associated with it.— *Comptes Rendus*, cxlviii, 910.   H. L. W.

4. *A Course of Qualitative Chemical Analysis of Inorganic Substances ;* by OLIN FREEMAN TOWER. 8vo, pp. 83. Philadelphia 1909. (P. Blakiston's Son & Co.)—The large number of text-books on Qualitative Analysis which have appeared, and are constantly appearing, is due to the fact that nearly every teacher of the subject desires to present it to the student in a manner somewhat different from that used by anyone else, either in regard to the course of analysis followed, or in connection with the theoretical and explanatory details.

The book under consideration gives a well-chosen course of analysis, with abundant and excellent explanatory notes, and in these respects the book appears to be an unusually good one.

The author has attempted to lead up to the facts by basing them upon the theory of ions—a method of teaching which has

become somewhat popular. Whether this course is the best one or not is a matter of opinion, but it appears to the reviewer that qualitative analysis should be presented in the attitude that it teaches certain facts, for instance, the fact that acids, bases and salts readily exchange their radicals in solution, thus leading to the precipitation of insoluble compounds, and the removal of volatile compounds by evaporation. When these facts have been grasped it may be desirable to call attention to the ionic theory as a method of explaining these facts ; but to base facts upon a theory is not the logical way, for the theory is actually derived from such facts. H. L. W.

5. *A Suggested Method of Ascertaining the Existence of Chlorophyll on Planets.*—N. UMOW suggests the application of the following method : Paper discs covered with chlorophyll reflect the light of a Nernst lamp into an optical apparatus consisting of an objective, a cylindrical lens, a Savart polariscope with a tourmaline plate ; a direct vision spectroscope and finally a small power telescope in a reversed position. The Savart striæ run horizontally through the spectrum and are modified in a striking way by the presence of the chlorophyll. The author gives a figure of the appearance which is presented ; and since he has not the proper facilities recommends the method to astronomers. —*Physik. Zeitschrift*, April 15, 1909, pp. 259–260. J. T.

6. *Condensation of the Radium Emanation.*—RUTHERFORD and SODDY showed in 1903 that the radium emanation condensed from the gases with which it was mixed at a temperature of about $-150°$ C. Rutherford has now worked with larger quantities of radium. He finds that the density of the liquid emanation is not less than 5, and its atomic weight 222. The absence of combining properties indicate that it is an inert gas, the heaviest known having a density of 111 times that of hydrogen. (Cf. No. 1 on p. 485.)—*Phil. Mag.*, May, 1909, pp. 723–729. J. T.

7. *Electric Origin of Molecular Attraction.*—WILLIAM SUTHERLAND has previously brought forward evidence in support of the view that molecular attraction varies as the fourth power. He considers, in connection with this view, the attraction between two small magnets, directed along a straight line which also varies as the fourth power ; and is led to consider a bipolar electric attraction of molecules, with reference to cohesion. He alludes to papers by Fessenden and Reinganum, on the electrical origin of cohesion which might arise from a bipolar condition of molecules. Sutherland points out that there is no theoretical or experimental justification of the literal truth of Fessenden's assumption for gases. Nevertheless, J. E. Mills has discovered a remarkable relation which seems to justify the assumption completely. Mills' application of his law to gravitation was erroneous, but the law can be applied to electric attraction, and is expressed as follows : The total potential energy of a number of like molecules is the same as if each caused its own domain to be uniformly electrized with an electric moment proportional to the

linear dimension of the domain, the direction of electrization being such that in general any molecule attracts its six immediate neighbors. It is proposed to look upon atoms as electrized, just as we speak of a magnet as being magnetized. In regard to total energy, each molecule behaves as if it had an electric moment proportional to the linear dimensions of its domain, whereas in the matter of mutual energy each molecule has an electric moment of amount E S (E charge, S distance between poles) which is investigated in connection with the laws of molecular attraction.—*Phil. Mag.*, May, 1909, pp. 657–670.   J. T.

8. *Physical Measurements ;* by A. WILMER DUFF and ARTHUR W. EWELL. Pp. 211. New Haven, 1908 (Dorman Lithographing Co.).—This is an excellent laboratory manual containing ninety-one experiments of considerable range of difficulty. The introductory discussions and the descriptions of experiments are marked by a very commendable brevity and by a generality of treatment which gives the essential principles of the matter without going into the details of apparatus which vary from one laboratory to another. References are given to standard text-books in which details can be looked up if necessary. The experiments are well chosen, and the whole atmosphere of the book is that of sound and accurate work. A somewhat unusual feature is the inclusion of a section on physical chemistry, in which are grouped some experiments not often found in text-books on physics, together with others which are ordinarily found scattered among the various subdivisions of the subject (heat, electricity, light), but of which the chief interest is physico-chemical. The figures are simple line drawings of small size ; they are usually clear, but some of the more complicated diagrams would be improved by being drawn to a larger scale. As a whole the book should prove very useful to laboratory teachers.   H. A. B.

II. GEOLOGY AND NATURAL HISTORY.

1. *Monograph on the Higher Crustacea of the Carboniferous Rocks of Scotland ;* by B. N. PEACH. Mem. Geol. Surv. Great Britain, Pal., 1908, pp. 82, pls. 12.—In this quarto work are described in great detail 41 species and varieties of Schizopoda based on more than 2000 specimens from the Carboniferous rocks of Scotland, the accumulation since 1880. The excellent wash drawings are by Dr. Peach and are reproduced by the Collotype process. There are 34 named forms grouped under the genera *Tealliocaris*, new (with 6 species), *Pseudogalathea* (3), *Anthrapalœmon* (1), *Pygocephalus* (1), *Perimecturus*, new (6), *Palœocaris* (2), *Palaemysis*, new (3), *Anthracophausia*, new (2), *Crangopsis* (10). All of these are grouped under existing families as defined by Sars, of the Mysid and Euphausiid groups of Schizopoda, except *Perimecturus*. The individuals rarely attain a length of $1\frac{1}{2}$ inches, but a species of the last-named genus has a body length of 5 inches.   C. S.

2. *Fossils from the Silurian Formations of Tennessee, Indiana and Illinois;* by Aug. F. Foerste. Bull. Denison Univ., April, 1909, pp. 61–107, pls. i–iv.—Here are described 74 forms of Silurian fossils, most of which are new. Of these 40 derive their specific names from localities or men. Seven new subgeneric names are proposed not one of which is clearly established. Two of these are coral subgenera, *Craterophyllum* and *Platyaxum ;* of brachiopods, *Stegerhynchus, Cliftonia, Schizonema,* and *Platymerella,* and the bivalve *Newsomella.* c. s.

3. *Illinois State Geological Survey. Bulletin No. 9. Paving Brick and Paving Brick Clays of Illinois ;* by C. W. Rolfe, R. C. Purdy, A. N. Talbot and I. O. Baker. Pp. xiii, 316 ; 3 plates and 33 figures. Urbana, 1908 (University of Illinois).— This Bulletin is devoted to a detailed discussion of a subject of much general economic importance. The geology of clays with particular reference to their origin and their distribution in the State is described in the opening chapters by C. W. Rolfe. The chapters following, by R. C. Purdy and A. N. Talbot, present the facts in regard to the properties of high-grade paving brick, the tests used in determining them, and the qualities of the clay demanded. The final chapter by I. O. Baker is devoted to a discussion of the proper construction and care of brick pavements.

4. *Wisconsin Geological and Natural History Survey.* E. A. Birge, Director, W. O. Hotchkiss, Economic Geologist.— The Wisconsin Survey has recently issued six geological maps of the Lead and Zinc district, together with a leaflet, serving as a Supplement to Bulletin XIV, by U. S. Grant (noticed in vol. xxi, p. 470).

5. *A new Locality of Diamonds in Africa.*—The discovery of diamonds in German Southwest Africa in May, 1908, was announced some months since in the public press. An account is now given by H. Lotz of their method of occurrence, while E. Kaiser adds a description of the crystalline form. It appears that the gems occur in a loose material consisting of from 70 to 80 per cent of reddish fine sand, and the remainder of fine gravel ; associated with the last named are small finely striated pebbles, chiefly of agate and jasper. The principal locality is at Lüderitzbucht, but extends also along the coast to Angras Juntas, half way to the mouth of the Orange River, a distance of 130 kilometers.

The author expresses the view that the diamond deposits are old coast formations in part rearranged by the wind. They are probably connected with the general flood region of the Orange River, the stones offering many points of resemblance to those obtained on the banks of the Orange and Vaal rivers in the interior. The uniform size of the stones is a matter of interest; the majority range from $\frac{1}{4}$ to $\frac{1}{5}$ carat, the largest stone weighing 2 carats, while stones of $\frac{1}{2}$ carat are comparatively frequent. The quality is unusually high. Lotz calculates, from the somewhat insufficient data thus far available, that a production of

180,000 carats a year may be hoped for.— *Centralblatt für Mineralogie,* etc., pp. 235, 251.

6. *Interferenzerscheinungen im polarisirten Licht.* Photographisch auf genommen ; von Dr. HANS HAUSWALDT, Dritte Reihe. Magdeburg, 1908.—The scope and value of this work, of which the third series of plates has recently been published, has been somewhat fully presented in the notice of the First Part (on p. 397 of volume xviii). This series consists of 72 plates which, in beauty of execution, are fully equal to those which have preceded. The phenomena illustrated are quite varied in character. Some of the subjects covered are as follows : Phenomena in converging polarized light with circular polarizer and analyzer ; various combinations of quartz plates in converging polarized light ; phenomena presented by highly absorptive media as andalusite, also magnesium-platinum and yttrium-platinum cyanides.

7. *Complete Mineral Catalog ;* compiled by W. M. FOOTE. Twelfth edition. Pp. 320. Philadelphia, 1909 (Foote Mineral Company).—This twelfth edition of the Foote Mineral Catalogue appears in much enlarged form and is made attractive by its excellent topography and the introduction of numerous well-executed figures. It gives the names of all recognized mineral species, including those recently described, which will be included in the Second Appendix to Dana's Mineralogy, now in press. The composition of each species is given, and also the more important physical characters.

8. *Introduction to the Study of Rocks ;* by L. FLETCHER. Brit. Mus. Nat. Hist., Guide to Mus. Coll. Fourth edition. 8°, pp. 155, 1909. — This is a new edition of the guide book published in 1895. Although considerable of the original material has been retained, much new matter has been added to bring the work up to date. The same general grouping of the rocks is retained, but greatly expanded to include recently described kinds and so altered as to make the primary divisions on the mineralogical basis, the secondary ones those of texture. The numbers of the exhibition cases in the Museum are added on the margin, so that specimens illustrating the phenomena discussed may be readily found. Although the work is intended for a definite local purpose, at the same time petrographers will find much that is of general interest in it, especially with respect to the author's views on classification. It is clearly and simply written, the subject matter well chosen, and it will without doubt be of great service in the field for which it was designed.   L. V. P.

9. *Determination of Rock-forming Minerals ;* by A. JOHANNSEN. New York, 1909 (Wiley and Sons).—In a previous notice of this work (this Journal, vol. xxv, p. 529, 1908), it was stated that a method of cutting the edges of the pages was indicated, by which an indexing was produced to facilitate the use of the tables. In practice this proved cumbersome and may have hindered the use of this very useful work. Since then the publishers have devised an extremely neat and efficient method of doing this

themselves, and those who now obtain the book in this form will find it very convenient for use. L. V. P.

10. *Trees, A Handbook of Forest Botany for the Woodlands and the Laboratory ;* by the late H. MARSHALL WARD, Professor of Botany in the University of Cambridge (England). Vol. V. Form and Habit. Cambridge, 1909 (The University Press).— The volumes of this series are perfect of their kind. They are handy, well printed, well planned, and well up to the times. The present volume has been prepared from the notes left by the lamented and accomplished botanist, Dr. Ward, who had a remarkable facility in presenting difficult subjects in an attractive manner. Some of our readers will remember the charm which he threw around the mysterious activities in the laboratory of green leaves, imagining himself a guide conducting an inquiring person into the leaf itself. Dr. Percy Groom has managed his task with skill and success. He has not changed Dr. Ward's text in any manner, but he has selected, from abundant material at hand, effective illustrations for every part of the subject. There is not a botanist who cannot derive instruction from this modest and rich treatise on Form. Furthermore the adaptations are clearly described in a thoroughly scientific manner but without the use of too many technical terms, so that it would be possible for any intelligent person, unfamiliar with botany, to gain from these pages a clear notion of the marvelous fitness of organisms to their surroundings. Unquestionably Dr. Ward would have expanded the chapter on Bark somewhat more, but Dr. Groom has done wisely in leaving it about as it was. It will not lead any one astray. The convenient volume, although very small, is provided with an excellent index, rendering it even more useful to every reader. G. L. G.

11. *Mendel's Principles of Heredity;* by W. BATESON, F.R.S., Professor of Biology in the University of Cambridge (England). Cambridge, 1909 (The University Press); New York (G. P. Putnam's Sons).—Professor Bateson has rendered great service by his clear account here given of Gregor Mendel's interesting and buried researches. Few incidents in the history of biological science are more surprising than the utter ignoring of important work by contemporaries who would have gladly acknowledged their merit if they had been properly brought to general notice. The comprehensive work by Sprengel in regard to the relations of flowers to insects fell stillborn from the press, and was absolutely neglected by all of his associates and soon was totally forgotten, until after fifty years it came into prominence as an important factor in the literature of adaptation. Goethe's treatise on Metamorphosis was likewise neglected and did not receive any recognition as a suggestive speculation until chance brought it to the notice of two botanists who saw that it contained a solid although small grain of truth. Mendel's case is harder to explain, for his treatise appeared to be in proper form for due consideration by students in biology, but it was completely lost

to the scientific world until the merest chance brought it to light. In an extended notice which we hope to give in the next number of the Journal, we shall call attention to the attractive manner in which Professor Bateson has presented the Mendel essays and illustrated them by confirmatory critical studies. We cannot too strongly advise our readers to avail themselves of this convenient annotated reprint. G. L. G.

12. *Catalogue of the Lepidoptera Phalœnæ in the British Museum.* Vol. VII. *Catalogue of the Noctuidæ;* by SIR GEORGE F. HAMPSON. Pp. xv, 709, with 184 figures; also plates cviii–cxxii. London, 1908.—The earlier volumes of this important catalogue of Moths have been repeatedly noticed in this Journal. The present volume is the seventh of the series and contains the first part of the large sub-family Acronyctinæ. It is characterized by the trifid neuration of the hind wing combined with spineless tibiæ and smooth eyes not surrounded by bristle-like hairs. This sub-family comprises some 3000 species, belonging to over 300 genera, and two additional volumes will be required to embrace them all. The manuscript for these is stated to be ready for the press and it is expected that they will appear in 1909. The supplementary volume contains 15 plates each with from 22 to 32 beautifully executed figures.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Bulletin of the Mount Weather Observatory:* Prepared under the direction of WILLIS L. MOORE, Chief U. S. Weather Bureau. Vol. ii, Part I. Pp. 54, 6 charts. Washington, 1909.— The Mount Weather Observatory is making very important contributions to the investigation of the meteorological conditions of the upper atmosphere, as determined by kite flights and balloon ascensions. These topics form the subject of an article in the present number by W. J. Humphreys. It may not be generally appreciated, although the facts have been presented from time to time, that the observations of the past ten years, carried on by balloons and by kites, equipped with suitable registering apparatus, have brought out a large number of important facts in regard to the atmosphere. Three more or less distinct regions are recognized : 1. That of terrestrial disturbance extending up to an elevation of about 3,000 meters, in which the temperature-gradient is usually irregular and often shows reversion. This includes the principal region of clouds and precipitation. 2. A region of uniform changes, lying between that just mentioned and the 10,000 meter level in which the temperature-gradient is nearly constant and approaches the adiabatic. This region is comparatively free from condensation and precipitation, and while at times the seat of vertical convections its normal condition is one of stability. 3. Above this is the region of perma-

nent inversion, or all the explored portion of the atmosphere above the 10,000 meter level. Here the temperature-gradient is small and usually positive, so that vertical convection is impossible. Various suggestions have been made to explain the inversion of temperature in this upper region, but no one of these is entirely satisfactory.

Another chapter gives the results of observation of upper air temperatures at Mount Weather, Trapp and Audley by the Aerial Section in charge of W. R. Blair. The charts show the upper air isotherms for the period covered, in July, August and September. A chapter by W. R. Gregg describes the auroral displays and magnetic disturbances of September, 1908, at Mount Weather. The observations show a period of maximum of auroras in 1908 corresponding to a long-time cycle of sixty or sixty-one years, the culminations being in 1728, 1787, 1847 and 1908. As previously noted, these periods correspond also to times of maximum sun-spot frequencies.

2. *Field Columbian Museum, Chicago.*—The following are recent publications :

No. 129. Geological Series. Vol. III, No. 7. Notes on Various Minerals in the Museum Collection ; by OLIVER CUMMINGS FARRINGTON, Curator, Department of Geology, and EDWIN WARD TILLOTSON, JR. Pp. 131–163, 6 figures, plates xliv–liv. Among the species described and figured the following may be noted : Anglesite and olivenite from the Tintic District, Utah ; anglesite, linarite and mimetite from Eureka, Nevada ; bertrandite from Albany, Me. ; orpiment and realgar from Mercur, Utah.

Publication 133. (Field Museum of Natural History.) Report Series. Vol. III, No. 3. Annual Report of the Director, FREDERICK J. V. SKIFF, to the Board of Trustees for the year 1908. Pp. 216–323, plates xxxiii–xliii.

3. *Formeln und Hilfstafeln für Geographische Ortsbestimmung ;* von TH. ALBRECHT. Vierte Auflage. Pp. viii, 348. Leipzig (Wm. Engelmann). — A complete exposition of the theory and practice of Geodesy. This is the standard work on this subject, and is indispensable to computers. It is divided about equally between the tables and the discussion of formulæ and their development. W. B.

4. *An Astronomer's Wife ;* by her son, ANGELO HALL. Pp. 129. Baltimore (Nunn and Co).—This is the biography of Angeline Hall, wife of Asaph Hall, a woman of the pioneer stock of Western New York, of lofty character, unusual mental power, and the worthy helpmeet of a great scientist. W. B.

5. *Comparison des Anciennes Meures ;* by JEAN MASCART, Astronomer in the Observatory of Paris. Pp. 5, from the Bulletin of the Astronomical Society of France, August, 1808.—Various tables of length, weight, etc., published originally in a volume of 500 pages by Robustel and Charles Osmont. "Ingénieurs du Roi pour les instruments de mathématique," Paris, 1725, and here reprinted as of historical interest. W. B.

INDEX TO VOLUME XXVII.*

* This Index contains the general heads, BOTANY, CHEMISTRY (incl. chem. physics), GEOLOGY, MINERALS, OBITUARY, ROCKS, ZOÖLOGY, and under each the titles of Articles referring thereto are mentioned.

Photomicrographs.

  a Artificial diopside. Etch pits on 110 produced by action of hot com-
mercial HF for 40 seconds.   Magnification 200 diameters.
  b Artificial diopside.   Etch pits on 1$\bar{1}$0.   Exposed to hot commercial HF
40 seconds. Magnification 230 diameters.
  c Etch pits on 1$\bar{1}$0 of crystal MgSiO₃ 50 per cent, CaSiO₃ 50 per cent.
Time of exposure 40 seconds in hot commercial HF.   Magnification 220
diameters.
  d Etch pits on 1$\bar{1}$0 of crystal MgSiO₃ 55 per cent, CaSiO₃ 45 per cent. Time
of exposure in hot commercial HF, 40 seconds.   Magnification 440 diameters.
  e Etch pits on 110 Mg-pyroxene (β-MgSiO₃).   Exposed 50 seconds in hot
commercial HF.   Magnification 1065 diameters.
  f Etch pits on 110 of crystal MgSiO₃ 75 per cent, CaSiO₃ 25 per cent.
Exposed 40 seconds in hot commercial HF.   Magnification 230 diameters.
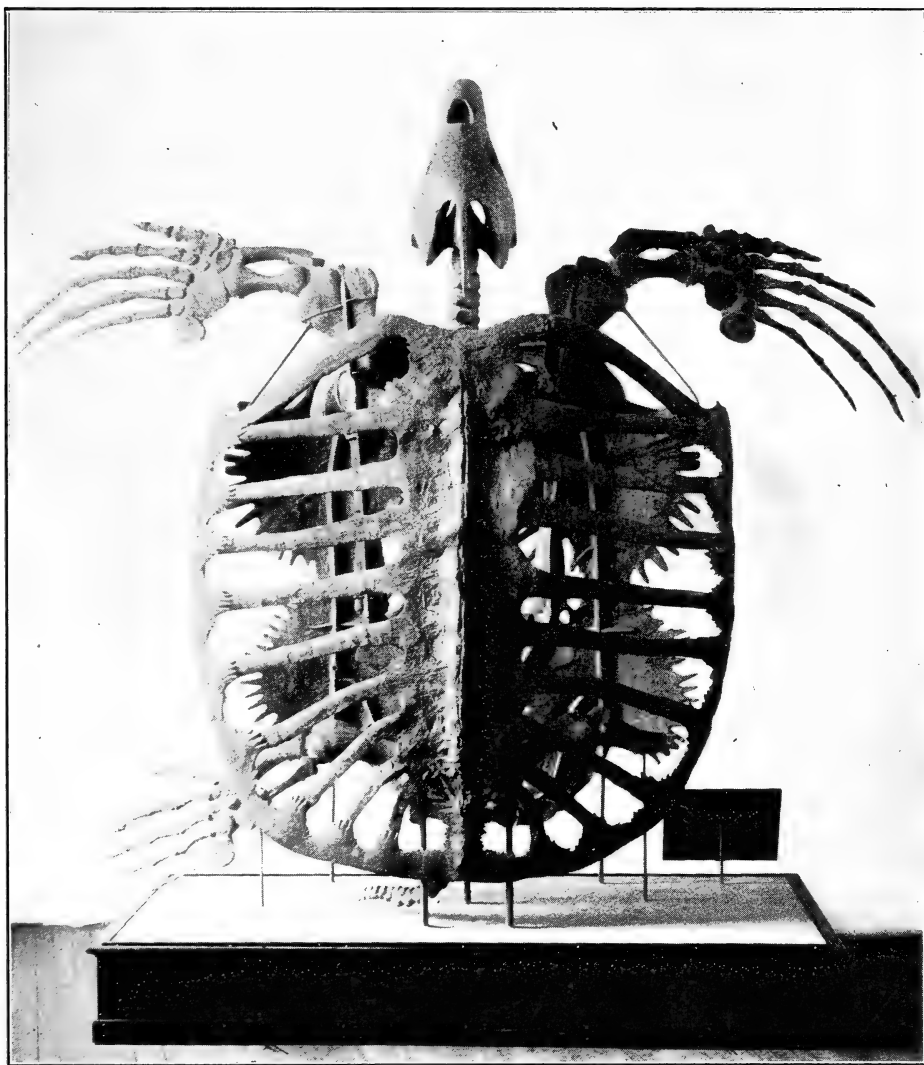
Archelon ischyros Wieland.—Photograph of dorsal view of the type as mounted in the Yale University Museum. (Compare with text figure 7.—The right flipper was bitten away just above the heel early in life by some predaceous enemy, either a shark, a fish or a mosasaur.)
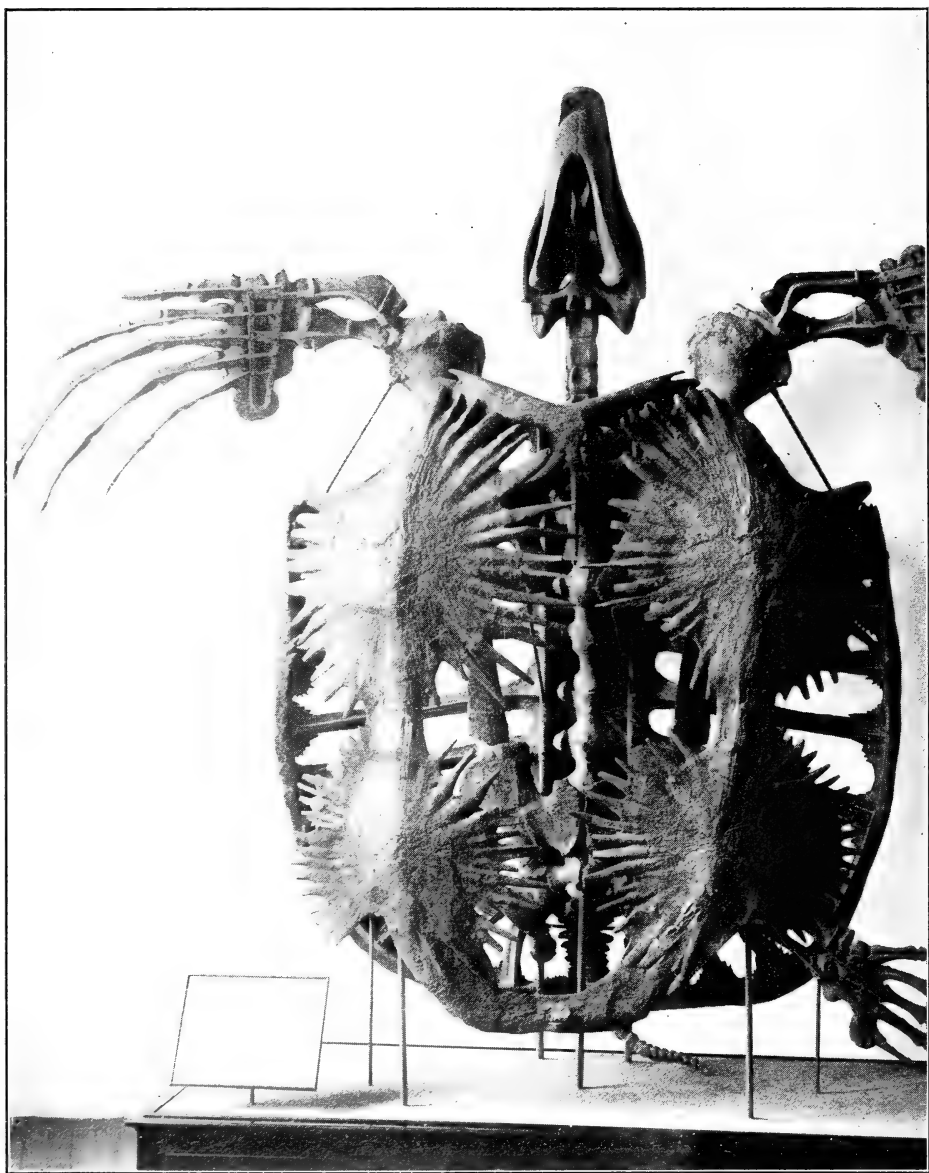
Archelon ischyros Wieland.—Photograph of ventral view of the type as now on exhibition in the Yale University Museum.   (Cf. text figure 8, and compare with the preceding plate.)
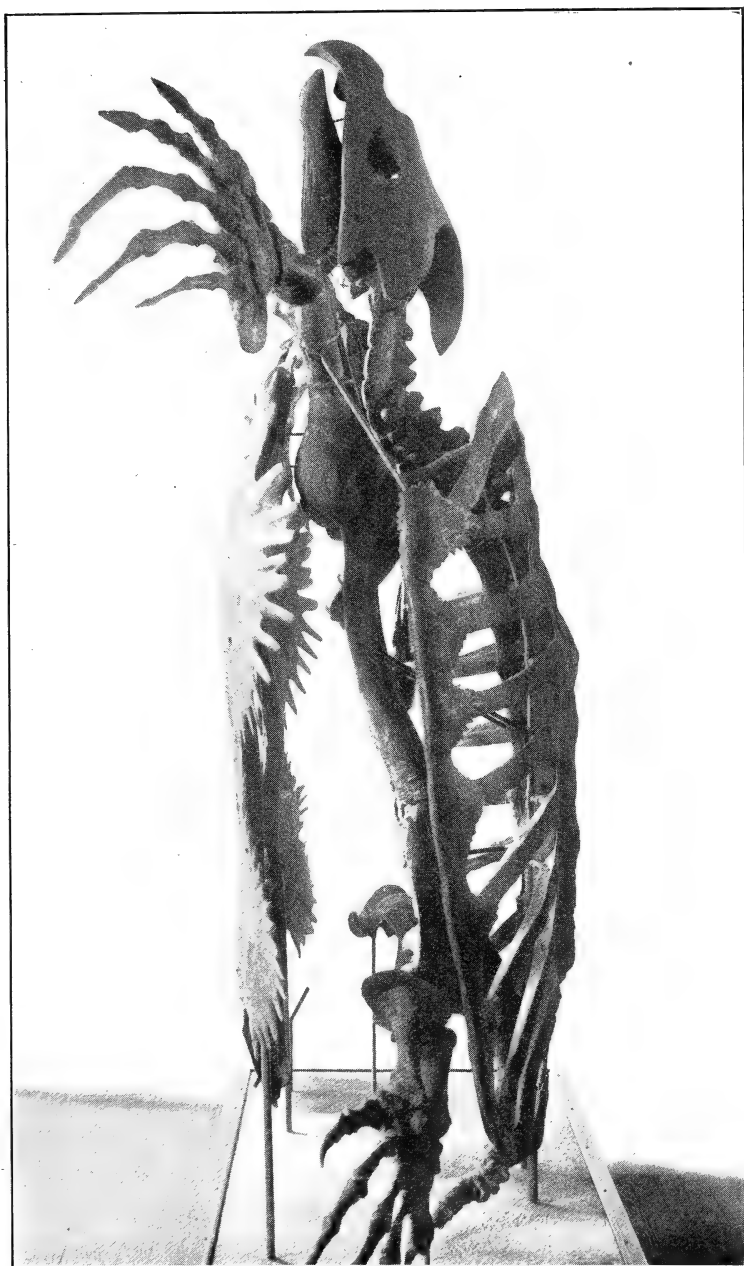
Archelon ischyros Wieland.—Photograph of lateral view of the type as now mounted in the Yale University Museum.   [Plastron in approximate position.]

New Circulars.

84: **Eighth Mineral List:** A descriptive list of new arrivals, rare and showy minerals.

85: **Minerals for Sale by Weight:** Price list of minerals for blowpipe and laboratory work.

86: **Minerals and Rocks for Working Collections:** List of common minerals and rocks for study specimens; prices from 1½ cents up.

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