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VOL. XXII—[WHOLE NUMBER, CLXXII.]

WITH 2 PLATES.

NEW HAVEN, CONNECTICUT.

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VOL. XXII—[WHOLE NUMBER, CLXXII.]

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WITH PLATE I.

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[FOURTH SERIES.]

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ART. I.—*The Relative Proportion of Radium and Uranium in Radio-Active Minerals ;* by E. RUTHERFORD and B. B. BOLTWOOD.

IN the July number for last year of this Journal, the writers gave an account[*] of measurements which had been made to determine the amount of radium present per gram of uranium in a natural mineral. Since previous experiments had shown that the amount of radium in a mineral was always proportional to its content of uranium, it was pointed out that the weight of radium present per gram of uranium was a constant of considerable practical and theoretical importance. The method adopted depended on the preparation of a standard solution of radium bromide and the amount of radium emanation formed in it was compared with that formed in a radio-active mineral containing a known quantity of uranium. Since the electrical comparison of the relative amounts of radium emanation can be made with considerable precision, the accuracy of the results obtained by the determination mainly depended on the exactness with which the solution of radium taken as the standard had been prepared.

The standard solution was prepared by Rutherford and Eve. A crystal of radium bromide was taken from a stock which previous experiments had shown to emit heat at the rate of 110 gram-calories per hour per gram and was consequently probably nearly pure. The amount of radium bromide was determined by direct weighing and also by comparing its γ-ray effect with that produced by a known larger weight of the same stock of radium bromide. The crystal of radium bromide was then dissolved in distilled water and by successive dilutions solutions were prepared to contain 10^{-2}, 10^{-4} and

[*] This Journal, xx, 55, 1905.

10^{-6} milligram of radium bromide per cubic centimeter. By evaporating known quantities of these solutions and testing the a-ray activity of the residues, Eve found that the relative activities were in close agreement with their supposed content of radium. There was, therefore, every reason to assume that the standard solutions were correct. About two months after preparation, a portion of one of these solutions was transferred to another bottle and sent to Boltwood, who, assuming the accuracy of the standard, determined by experiment that the amount of radium corresponding to one gram of uranium in a mineral was $7\cdot4\times10^{-7}$ gram.

Recently, however, some experiments made by Mr. Eve in the laboratory of McGill University indicated that the solution used for the above determination was in some way defective and that the quantity of radium actually in solution was less than had been assumed to be present. It was found that a considerable proportion of the radium had been deposited on the surface of the glass vessel in which the solution had been preserved and it is probable that this action had taken place before the solution sent to Boltwood was withdrawn. A full account of Mr. Eve's experiments is given by him in a paper which accompanies this in the same number of the Journal. We desire to thank Mr. Eve for his kindness in drawing our attention to this matter and for his assistance in preparing a new radium standard.

The method employed for determining the quantity of radium present in the material from which this new standard solution was prepared is described in detail in Mr. Eve's paper. The weight of radium bromide taken was ascertained by this method to be equal to $0\cdot27$ milligram. The minute fragment of salt was removed from the small sealed vial in which it had been received and was dropped into a small beaker containing a few cubic centimeters of dilute hydrochloric acid. The liquid was heated and was then carefully examined with a glass, when absolutely no trace of any insoluble material could be detected. The vial which had contained the salt was washed several times with concentrated hydrochloric acid and water, and these washings were added to the main solution. The solution was introduced into a standard graduated flask, the volume was increased to exactly 1000^{cc} by the addition of freshly distilled water, and the whole was agitated for some time in order to insure complete mixing. Ten cubic centimeters of this solution were now withdrawn with a standard pipette and introduced into a second graduated flask. A few cubic centimeters of dilute hydrochloric acid were added and the solution was diluted to 1000^{cc} with distilled water. After thorough mixing, 10^{cc} of this second

solution was removed, introduced into a bulb of about 100^{cc} capacity and diluted to about 50^{cc} with distilled water. The contents of the bulb were boiled vigorously for about ten minutes and the tubular orifice of the bulb was then sealed by fusion.

After a period of exactly four days had passed the emanation which had accumulated in the bulb was removed by continued boiling of the solution, and was transferred to an air-tight electroscope and its activity measured. The leak due to the emanation was equal to 4·27 divisions per minute, and the calculated leak corresponding to the maximum equilibrium quantity of emanation was 8·44 divisions per minute. On the basis of 0·27^{mg} of pure radium bromide originally taken, the amount of radium contained in the solution in the bulb was 1·57 × 10^{-5} milligram.

The leak corresponding to the equilibrium quantity of radium emanation formed by the radium associated with one gram of uranium in a natural mineral was next determined. The mineral chosen was a pure North Carolina uraninite containing 68·2 per cent of uranium. The leak in the same electroscope corresponded to 206 divisions per minute per gram of uranium. From the above numbers it can readily be calculated that *the quantity of radium associated with one gram of uranium in a radio-active mineral is equal to approximately 3·8 × 10^{-7} gram.*

The value of the new number is about one-half that of the old. On the present basis the ores of uranium per ton of 2,000 pounds will carry about 0·0034 gram of radium for every per cent of uranium present. A ton of 60 per cent uranium ore will therefore carry about 0·20 gram of radium equivalent to 0·35 gram of radium bromide. These numbers are more nearly in accord with the quantities of radium extracted from the ores in actual practice than were those derived on the basis of the former standard.

April, 1906.

Art. II.—*The Measurement of Radium in Minerals by the γ-Radiation;* by A. S. Eve.

The usual method of determining the amount of radium in a mineral is by measuring the maximum activity of the emanation obtained from a solution. Good results have been obtained in this way by Strutt, and by Boltwood. Again, the quantity of uranium present is usually found by chemical analysis; and a measure of the active matter in a sample of pitchblende can be found by observing the *a*-radiation from a fine powder constituting an average sample of the mineral.

In the present paper, an account will be given of another method capable of giving equally accurate results. It was due to a suggestion by Professor Rutherford that it would be interesting to ascertain if radium E emitted γ-rays. This was to be expected because he had already proved that radium E gave rise to β-rays, and in all known cases these are accompanied by γ-rays, and are probably their immediate cause. In a newly prepared sample of radium bromide, there has not been sufficient time for the growth of the slow transformation products, so that very little radium E is present. But uraninite, which emits but a small fraction of its emanation, must necessarily contain radium E almost in an equilibrium amount.

The results of some preliminary experiments have been published in a recent number of the Philosophical Magazine.* The writer proved that the γ-radiations from radium, thorium and radio-thorium were practically identical in character, being very penetrating and absorbed to an equal degree by lead. On the other hand, the γ-rays from uranium and actinium were feeble and readily absorbed. It is, therefore, possible to cut off the γ-rays arising from uranium or actinium in a substance, and yet to have a strong γ-radiation, due to radium or thorium, penetrating the screen. In this way it is easy to measure the amount of radium or of thorium present in any ore, or in a solution, and the active substance need not be powdered, or dissolved, or removed from bottle or test tube. It is only necessary to place the substance under a lead screen about one centimeter thick and to observe the fall of the gold leaf of the electroscope. Then a standard of known magnitude, consisting of radium or thorium, is similarly placed, and the fall of potential is again observed for the same period as before. The saturation-currents in the two cases are proportional to the quantities of radium or of thorium present. This method of determining the amount of radium or of thorium

* A. S. Eve, Phil. Mag., April, 1906.

present applies to ores which contain only uranium or only thorium. If the ore consists of a mixture of these two elements, the method cannot be applied except to obtain their joint amount. With these limitations, the method is capable of giving exact results, but when the amount of substance employed is large, a correction may be necessary for the absorption of the rays in the substance itself.

Specimens of uraninite from Joachimstahl were obtained, weighing a kilogram, and it was found that radium E, assuming it to be present, either does not emit γ-rays, or, more probably, it emits γ-rays which, like those of uranium, are of a feeble penetrating nature. The very penetrating radiation from pitchblende can therefore be wholly attributed to the presence of radium C.

In the course of this work the amount of radium present in the kilogram of uraninite was found to be of the order of the amount contained in a quarter of a milligram of pure radium bromide. Consequently it was possible to estimate the amount of uranium contained in the ore, using as a basis of calculation the result of Rutherford and Boltwood that 1 gram of uranium contains $7·4 \times 10^{-7}$ grams of radium. The amount of uranium thus determined was surprisingly small, and in consequence part of the pitchblende was sent to Dr. Boltwood at New Haven in order to check the results in the two laboratories, and to get at the bottom of the divergence in results.

Dr. Boltwood found that the radium present was about twice as great as in the determination by the writer at Montreal. As both Dr. Boltwood and myself were confident of the accuracy of our measurements, and as both methods appeared to be above suspicion, an examination was made of the standards on which the measurements depended.

It is, therefore, necessary to give some account of the standard solutions employed by Dr. Boltwood. In March, 1905, a crystal of radium bromide was taken from a supply which Professor Rutherford found gave a heating effect of 110 gram-calories per hour per gram, and which was presumably pure. This was compared by Professor Rutherford, using the γ-ray test, with a larger known quantity of radium bromide, and it was also weighed carefully by the writer. The results were in excellent agreement, and the weight determined was· $·95^{mg}$. The crystal was placed in 95^{cc} of distilled water, and fractions of the solution were then drawn off, and water was again added so that three glass flasks were filled, containing 10^{-2}, 10^{-4}, $10^{-6\ mg}$ of radium bromide per c.c. of water. Portions of these were evaporated to dryness in small zinc trays, the resulting activities were measured and their ratios were found to be satisfactory. The standards were sealed and put aside

for permanent use. Unfortunately, no acid was added to the solution, and, in the light of subsequent events, this omission was serious, although the step did not appear necessary at the time. Some time later, Professor Rutherford supplied part of the medium (10^{-4} mg per c.c.) solution to Dr. Boltwood, and on this standard their joint results depended. The advantage of using this standard was obvious, as it would presumably place in agreement the results obtained at Montreal and New Haven.

In January, 1906, when the discrepancy before mentioned, concerning the amount of radium in uraninite, was discovered, the writer examined the standard solutions which had been prepared ten months previously. On drawing off one-half of the strongest solution, placing it in a clean bottle, sealing it, and testing it when in equilibrium, it was found that the activity in the new bottle was only about one-half that remaining in the old. It was proved beyond doubt that the total amount of radium in the bottle was correct, but that the radium was not all in solution, the water containing only fifty per cent of the total radium present.

As soon as it was ascertained that the standards were no longer correct, Dr. Levin and the writer weighed, with different weights and balances, $3·69$mg of radium bromide, from the supply which Professor Rutherford found gave a heating effect of 110 gram-calories per gram per hour. The results of the two weighings were in excellent agreement, and the crystals were then sealed in a test tube in the solid state to serve as a standard for future use. A smaller crystal was also sealed in a phial and compared with the new standard by the γ-ray test. The activity rose slightly during the ensuing month, and was finally found to be that due to $·27$mg of radium bromide. This was verified with various electroscopes, and under diverse conditions as regards screens and distances. It was now possible to redetermine the amount of radium in the kilogram of pitchblende, and the correct value was equivalent to $·32$mg of radium bromide per kilogram of uraninite.

On receipt of the small crystal Dr. Boltwood found that his original solution was one hundred per cent too weak, and on redetermining the amount of radium present in the pitchblende his result, using the emanation method, was $·31$mg of radium bromide per kilogram of the sample of uraninite tested. The results obtained by these two distinct methods are thus in close agreement.

From first to last, the methods used and the measurements made by all concerned appear to be correct, but errors arose because the radium bromide in the original solutions was in some way deposited on the sides and bottom of the vessels

containing the solutions. This precipitation would probably have been avoided if some hydrochloric acid had been added in the first instance.

The preparation of standards is a difficult matter. Radium is costly; small quantities only are available; it is difficult to insure purity, while the weighing of small quantities is troublesome. It appears desirable to keep two radium standards, one in the state of solution and the other in the solid state. The two standards can be compared together by their γ-ray effects from time to time.

Summary.

1. Radium E, which Rutherford proved to give β-rays, appears to give no γ-rays. More probably the γ-rays are present, but like those of uranium they are weak and readily absorbed. The very penetrating radiation from Joachimsthal uraninite can be entirely attributed to radium C.

2. Standard solutions of radium bromide, unless some acid such as HCl is present, attack or adhere to the glass of the vessel in which they are contained, and become unreliable.

3. It appears desirable to control the standard solutions by a standard of solid radium bromide sealed in a test tube.

4. Measurements of the radium present either in an ore, in a solution or in any other form, whether made by the emanation method or by the γ-ray test, are capable of giving concordant results.

5. A correction is necessary to the determination by Rutherford and Boltwood of the ratio of the weight of radium to that of uranium in radio-active minerals. The error in their determination resulted from the radium standard altering in an unexpected manner.

McGill University, Montreal, April, 1906.

ART. III.—*On the Absorption of the a-Rays from Polonium ;*
by M. LEVIN.

[Communicated by Professor E. Rutherford, F.R.S.]

IN their well known investigations on the absorption of
a-particles emitted by radium, Bragg* and Bragg and Kleeman†
have shown that the a-particles move in a rectilinear course,
spending their energy in ionization, until their velocity becomes
so small that they cease ionizing. They have further shown, that
the a-rays possess the power of ionizing a gas only within a
limited distance from the source and that this distance is very
sharply defined. The investigation of the a-ray products of
radium has shown that each of the four a-ray products emits
a-rays of the same range in air and the same initial velocity,
and that these ranges and velocities are different for the dif-
ferent products. This was confirmed by experiments of Ruth-
erford,‡ who has shown that the photographic and phosphor-
escent action of the a-rays from radium C ends abruptly at a
definite distance, and that the range found by these methods
agrees closely with the value determined by Bragg and Klee-
man by the electric method. The hypothesis of Bragg and
Kleeman that the a-particles from each product are initially
projected at exactly the same velocity, and that this velocity is
cut down by a definite amount by passing through different
thicknesses of matter, has been completely confirmed by
direct experiment by Rutherford.

Since the a-particles emitted by a thick layer of radio-active
matter of one kind come from different depths, the particles
which escape into the air move at different velocities. For this rea-
son it is advisable to work with very thin films of radio-active
matter. As the active deposits from radio-active emanations are
deposited on bodies in infinitely thin layers, they represent ideal
sources of rays for this kind of experiment. Thus the range of
radium C was measured by McClung§ by using as a source
of a-rays a wire which had been exposed to the radium emana-
tion, and in the same way Hahn‖ has recently found the ranges
of thorium B and thorium C. Bragg pointed out in his
first paper that polonium, for the same reason, should be a
very convenient source of a-rays, as it can be obtained in a very
thin layer on a bismuth plate.

The object of the present experiments was to determine
accurately the range in air of the ionization of the particles
from polonium. As the a-rays emitted by each a-ray product
have each a definite and distinct range in air, the range of the

a-particles, like the period of transformation, is a characteristic constant of each product, and the accurate knowledge of these ranges seems to be of importance at the present state of our knowledge of radio-active transformations. It was also of interest to examine the ionization due to the a-rays of polonium at different distances from the source in order to see if it emitted only one type of a-rays. A similar examination of the active deposit of thorium by Hahn* had disclosed the unexpected fact that two different a-ray products were present instead of one, as was previously supposed.

For the experiments a bismuth rod, coated with a thin film of polonium (radio-tellurium), obtained from Sthamer of Hamburg, was used.

Measurements by the Scintillation Method.

First the range in air of the a-particles was measured by the scintillation method in the usual way. The active rod was placed beneath a zinc-sulphide screen, and the distance at which the scintillations just disappeared was measured. Several layers of aluminium foil, each of about the thickness of ·0003^{cm}, were placed above the rod and the range again measured. The results of one series of experiments are given in Table I.

TABLE I.

Number of aluminium foils.	Distance between rod and screen in centimeters.	Centimeters of air corresponding to one layer of foil.
0	3·78	
1	3·29	·47
2	2·78	·50
3	2·30	·49
4	1·84	·48
5	1·35	·49
6	·82	·40
7	·32	·50

Mean ·49

Thus the range of the a-particles in air is 3·78^{cm}. By plotting the numbers of layers as abscissæ and the ranges as ordinates, one obtains approximately a straight line. This line meets the axis of ordinates a little higher than the value obtained by experiment, if no aluminium foil is used, the value found in this way being 3·82. In another series of experiments, using other samples of aluminium foil, each corresponding in stopping power to about ·53^{cm} of air, the values found for the range in air were 3·76 and 3·79^{cms}. Adams has given an account of similar measurements with several gases before the

* L. c.

meeting of the American Physical Society in December, 1905. A short abstract of his results appeared in the Physical Review, but no numbers were given.

Measurements by the Electrical Method.

The apparatus used* for these experiments was quite similar to that used by Bragg and Kleeman. A metal box contained the ionization chamber and the polonium rod.   The chamber consisted of two insulated plates about ·50^{cm} apart, the upper plate being connected with the electrometer and the lower

1

Ionization.
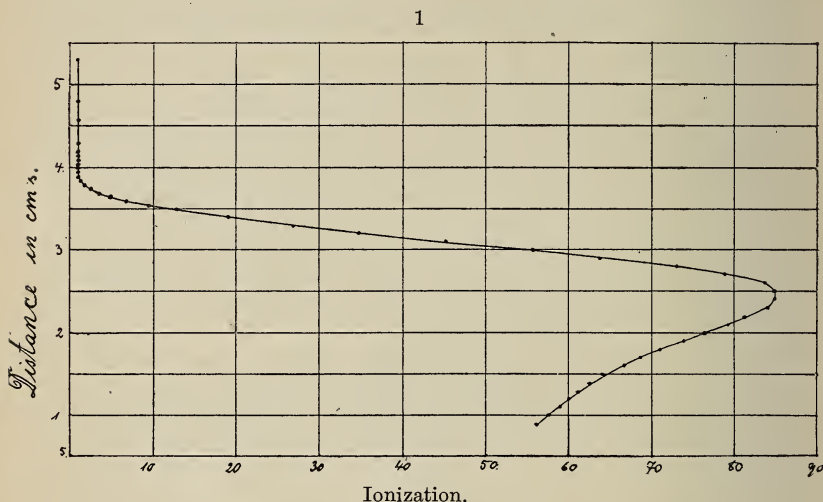
plate of wire gauze with the battery.   The polonium rod was placed in a little groove made in a lead block and was covered with a lead plate about ·6^{cm} thick having a circular hole of ·4^{cm} diameter passing vertically through it.   The lead block was placed inside the vessel on an upright support, which could be moved vertically.   The cone of rays issuing from the opening in the lead plate was sufficiently narrow so that its cross-section never covered the whole surface of the ionization chamber. The saturation-current produced in the ionization chamber was measured for different distances between the polonium rod and the wire gauze.

The ionization of the rays in air at different distances from the source was first investigated.   The results are shown in figure 1, where the ordinates represent the distance from the upper surface of the rod to the gauze in centimeters, the abscissæ the ionization measured in arbitrary units.

* I am indebted to Dr. Hahn for his kindness in allowing me to use the experimental arrangement which he had previously employed in his deter-minations of the range of the a-rays from the products of thorium and actinium.

.The shape of the curve is very similar to that obtained by Bragg and Kleeman for the a-rays from a thin film of radium and by McClung for a thin film of radium C. The ionizing power of the a-particle steadily increases with the distance, passes through a well-marked maximum and then rapidly falls off. In the experiments the ionization chamber had a depth of 5^{mm} as stated above, and the cone of rays was not very narrow. The ionization per centimeter of path consequently appears to fall off more slowly than would be observed with a shallower ionization chamber and a very narrow cone of rays.
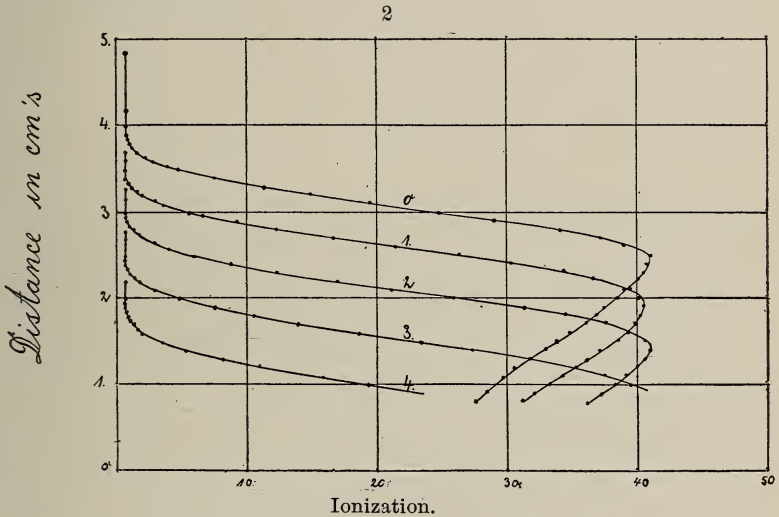
Figure 2 shows the curves obtained when the rod was covered with different layers of aluminium foil, the numbers of the curves giving in each case the number of layers of aluminium foil employed.

It is seen from the curves that the interposition of a sheet of aluminium foil does not at all alter the general shape of the curve, but that the effect of the screen is to lower the ionization curve by a definite distance corresponding to the equivalent in air of the stopping power of the aluminium screen. The amount of the maximum ionization is not affected by the absorption of the a-rays in the aluminium foil, thus agreeing with the view of Bragg, that the a-rays are not absorbed according to an exponential law, but that the whole number of a-particles' passes the aluminium sheet, their velocity all being diminished by a definite amount.

In Tables II and III, the distances between the rod and the lower plate of the ionization chamber are given, for which the a-particle begins ionizing.

TABLE II.

Number of aluminium foils.	Distance in centimeters.	Distance in air corresponding to one aluminium foil.
0	3·87	
1	3·37	·50
2	2·84	·51
3	2·33	·51
4	1·83	·51
		Mean ·51

TABLE III.

Number of aluminium foils.	Distance in centimeters.	Distance in air corresponding to one aluminium foil.
0	3·85	
1	3·36	·49
2	2·86	·48
3	2·35	·50
4	1·82	·50
		Mean ·49

The break in each of the curves is very sharply marked, so that the point where the ionization begins could be obtained from the curves with an error of about ·2^{mm}. There is, however, a little uncertainty about the actual values, because the gauze could not be obtained quite plane. The mean of these experiments gives the range of the a-particles of polonium to be 3·86^{cm}. The average, from the scintillation measurements, is 3·77, and from the extrapolated values 3·81.

Wigger[*] found that the ionization due to the a-rays of polonium extended in air to a distance of about 4^{cm}. He used, however, a large plane surface of polonium as a source of rays and did not obtain the ionization-distance curve, for which, as we have seen, a definite narrow cone of rays must be employed.

Using the a-rays of radium as a source, Bragg has shown, that the stopping power of the a-particle, passing through an atom, is proportional to the square root of the atomic weight. Adams (loc. cit.) states that he has verified the law with the a-rays of polonium, using the scintillation method. As the scintillation and electrical method give probably identical results, there was no object to be gained in determining by the electrical method the range of the a-rays of polonium in other gases besides air.

The results of this investigation have shown, that polonium is a homogeneous source of a-rays, and that the a-particles are initially projected with the same velocity. The range in air of the a-particles is 3·86^{cm}, which is slightly greater than the range of the a-particles (3·50^{cm}) of radium itself, but much less than that for the a-particles from radium C (range 7·06^{cm}).

I wish to express my best thanks to Professor Rutherford for the kind interest he took in this work, and for the advice received from him.

McDonald Physics Building, McGill University,
Montreal, 20 May, 1906.

Art. IV.—*The Thermal Constants of Acetylene;* by W. G.
Mixter.

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

Some years ago the writer observed* that the thermal con-
stants of acetylene found by different observers varied widely,
and that his result for the heat of dissociation of the gas was
considerably higher than the calculated value. It was evident
that a complete investigation of the matter involved a study of
the components of acetylene. Accordingly the heat of com-
bustion of hydrogen was determined.† The results of Thomsen,
Schuller and Wartha, Than, and the writer gave a value with
probably a small error. The heat found on burning acetylene
carbon‡ was about two per cent higher than that of the ordinary
forms of amorphous carbon. The thermal constant of this
allotrope of carbon is essential in calculating the heat of disso-
ciation of acetylene.

For the thermal work on carbon acetylene carbon was pre-
pared with care, and at the same time new determinations of
the heat of dissociation of acetylene were made. The bomb
used was similar to the one described in the paper on carbon
but with electrodes in the upper end of the stem. Both bombs
were alike in external volume and surface. One bomb was
filled with pure hydrogen and exhausted and counterpoised by
the other bomb and the needed weights. Then it was filled
with dry acetylene from carbide and at a pressure of ten or
twelve atmospheres. Next 100^{cc} of the gas in the bomb were
passed into a eudiometer and the acetylene determined by
means of ammoniacal cuprous chloride. It varied in the different
experiments from 98·6 to 99 per cent. Finally the weight was
noted. The water equivalent of the calorimeter was found as
described in the paper on carbon.

Experiment 1.—Acetylene, 6·3162 grams; water, 3160·0
grams; water equivalent of calorimeter, 285·2 grams; water
equivalent of hydrogen and carbon formed, 2·1 grams. Total,
3447·3 grams.

Minutes.	Temperature.	Temperature interval.
0	18·204	
1	18·207	
2	18·210	$21·995 - 18·21 + 0·01 = 3·775°$
3	21·8	
4	21·9	Heat observed, $3447·3 \times 3·775 = 13014^c$
5	31·97	
6	21·977	For 1 gram of acetylene 2060^c
7	21·975	
8	21·973	
9	21·970	
10	21·966	
11	21·962	

* This Journal, xii, 347, 1901.   † Ibid., xvi, 214.   ‡ Ibid., xix, 434.

Experiment 2.—Acetylene, 6·4419 grams; water and water equivalent, 3482·2 grams.

Minutes.	Temperature.	Temperature interval.
0	18·201	
1	18·203	
2	18·206	$22·039 - 18·209 + 0·011 = 3·841°$
3	18·209	
4	21·6	Heat observed, $3482·2 \times 3·841 = 13375^c$
5	22·0	
6	22·044	For 1 gram of acetylene 2076^c
7	22·042	
8	22·039	
9	22·036	
10	22·034	
11	22·031	
12	22·028	

Experiment 3.—Acetylene, 6·1254 grams; water and water equivalent, 3484·9 grams.

Minutes.	Temperature.	Temperature interval.
0	18·333	
1	18·337	
2	18·340	$21·982 - 18·34 + 0·008 = 3·65°$
3	21·8	
4	21·9	Heat observed, $3484·9 \times 3·65 = 12720^c$
5	21·984	
6	21·984	For 1 gram of acetylene 2077^c
7	21·982	
8	21·980	
9	21·978	
10	21·976	
11	21·974	

The mean temperature in these experiments was 20·12°. The average of the results, 2060, 2076 and 2077, is 2071 for the heat of dissociation of one gram of acetylene at 20° and in terms of the water calorie at this temperature. For the gram molecule, 26·016, it is 53879. This figure is one per cent higher than that found in the earlier experiments and carries a greater weight on account of somewhat improved apparatus.

Heat of Combustion of Acetylene.

The acetylene used was made from carbide and collected over water containing ferrous hydroxide to absorb oxygen. The bomb was filled and the percentage of acetylene in the gas determined as already described, and the usual precautions were taken for finding the volume, temperature, and pressure of the gas. The density of acetylene adopted, 0·0011687, was derived from the molecular weight, 26·016, and the density of

hydrogen at the latitude of New Haven. The oxygen used was free from water, hydrogen, and carbon compounds, containing, however, about one per cent of nitrogen. After each of the calorimetric tests the silver dissolved as nitrate was precipitated as chloride. The amount, however, was so slight that no correction was made for the oxidation of nitrogen.

To Professor H. A. Bumstead the writer is indebted for the following method of reducing the results.

The general formula for reducing the heat of combination, found under the condition of constant volume, and between the temperatures t_1 and t, to that found at $0°$ and under constant pressure, is easily obtained by imagining the mixed gases to be carried through two different processes from the same initial state to the same final state, and equating the losses of energy in the two processes.

First Process. —M grams of mixed gases at $p_1 V_1 t_1°$ are cooled and compressed or expanded to $p_0 V_0 0°$. By Joule's law energy given out is $MC_v t_1$ where C_v is the sp. ht. (const.-vol.) *of the mixed gases*. It is then burned at constant pressure, p_0, giving out Q calories, its volume simultaneously diminishes by $\frac{3}{7} V_0$, and work is done upon it equal to $\frac{3}{7} \frac{p_0 V_0}{J}$ calories.

$$\therefore \text{ Loss of energy} = Q + MC_v t_1 - \frac{3}{7} \frac{p_0 V_0}{J}$$

Final state is $(p_0, \frac{4}{7} V_0, 0)$.

Second Process.—M grams are burned at const. vol. V_1, temperature rising from t_1 to t giving out Q' calories; we have now to reduce the mixture of CO_2, water and water vapor, to $p_0, \frac{4}{7} V_0, 0°$ to bring it to the same final state as by the previous process. No matter what the details of the process, the energy given out by the CO_2 in this operation will be (Joule's law) $mc_v t$; where m and c_v are the mass and specific heat of CO_2. We may therefore consider the water vapor separately. Suppose it first compressed at constant temperature t until it is wholly condensed; the work done on the vapor will be

$$\frac{\pi_t V_1}{J} \text{ calories}$$

when π_t is the pressure of water vapor at $t°$. The latent heat given out will be $\sigma_t L_t V_1$ where σ_t and L_t are the density and latent heat per unit mass at t. Let the water now be cooled to 0 degrees; the heat given out is $m_w t$, where m_w is the mass of the water formed.

Total energy given out is

$$Q' + mc_v t + V_1\left(\sigma_t L_t - \frac{\pi_t}{J}\right) + m_w t.$$

Hence

$$Q + MC_v t_1 - \frac{3}{7}\frac{p_0 V_0}{J} = Q' + mc_v t + V_1\left(\sigma_t L_t - \frac{\pi_t}{J}\right)$$

$$Q = Q' - MC_v t_1 + \frac{3}{7}\frac{p_0 V_0}{J} + mc_v t + V_1\left(\sigma_t L_t - \frac{\pi_t}{J}\right) + m_w t.$$

For reducing from $0°$ to $18°$ at constant pressure we have

$$Q'' = Q + MC_p t - mc_p t - mwt.$$
$$Q'' = Q - 178.$$

The specific heats of the gases used in the calculations were the following: Acetylene, 0·3 p. c., 0·2 v. c.; carbon dioxide, 0·2 p. c., 0·15 v. c.; oxygen, 0·21 p. c., 0·15 v. c. The specific heat of acetylene has not been determined, and it is assumed to be the same as that of benzol vapor.

Experiment 4.—Gas, 569·3^{cc} at 20·6° and 756·2^{mm} pressure; gas, 98·95 per cent acetylene; weight of acetylene, 0·6091 gram; water and water equivalent of calorimeter, 3249·3 grams; oxygen, 3·3 grams.

Minutes.	Temperature.	Temperature interval.
0	18·304	
1	18·308	$20·552 - 18·312 = 2·24°$
2	18·312	
3	20·5	Observed heat, $3249·3 \times 2·24 = 7278·5^c$
4	20·54	
5	20·547	
6	20·550	
7	20·552	
8	20·552	
9	20·551	
10	20·553	
11	20·553	

$$Q' = \frac{7278·5 \times 26·016}{0·6091} = 310880$$

$$MC_v t \qquad = -315$$

$$\frac{3}{7}\frac{p_0 V_0}{J} \qquad = 810$$

$$mc_v t \qquad = 271$$

$$V_t\left(\sigma_t L_t - \frac{\pi t}{J}\right) \qquad = 253$$

$$m_w t \qquad = 370$$

$$Q \qquad = 312269^c$$

Experiment 5.—Gas, 569·3^{cc} at 20·9° and 760·8^{mm} pressure ; gas, 98·1 per cent acetylene ; weight of acetylene, 0·6069 gram ; water and water equivalent of calorimeter, 3113·1 grams ; oxygen, 3·1 grams.

Minutes.	Temperature.	Temperature interval.
0	20·372	
1	20 373	
2	22·5	$22·701 - 20·273 + 0·006 = 2·334°$
3	22·6	
4	22·701	Observed heat, $3113·1 \times 2·334 = 7266^c$
5	22·701	
6	22·701	From these data we have for the
7	22·699	value of Q=312895^c.
8	22·698	
9	22·696	
10	22·695	

Experiment 6.—Gas, 569·6^{cc} at 20·5° and 757·8^{mm} pressure ; gas, 98·5 per cent acetylene ; weight of acetylene, 0·6084 gram ; water and water equivalent of calorimeter, 3231·3 grams ; oxygen, 3·4 grams.

Minutes.	Temperature.	Temperature interval.
0	19·348	
1	19·349	
2	19·350	$21·597 - 19·35 + 0·01 = 2·257°$
3	21·5	
4	21·57	Observed heat, $3231·3 \times 2·257 = 7293^c$
5	21·599	
6	21·599	
7	21·597	$Q = 313401^c$
8	21·593	
9	21·591	
10	21·588	
11	21·587	
12	21·585	
13	21·583	

The results are as follows :

No. of Exp.	Calories
4	312269
5	312895
6	313401
Average	312855

This is for the heat of combustion of 26·016 grams of acetylene at constant pressure at 0°, and at 18° it is 312677. The results of the earlier work reduced by Professor Bumstead's

equation gave an average of 312990. Little significance is, however, attached to the latter figure as the experiments from which it is derived showed differences as great as 1·6 per cent.

Comparing the heat of combustion of acetylene with that of its components plus the heat of dissociation we have:

			Calories
Heat of combustion of 2·016 grams of hydrogen,			68440
" " 24 " acetylene carbon,			189456
" dissociation 26·016 " acetylene,			53879
			311775
Heat of combustion of 26·016 grams of acetylene,			312677
Difference,			902

Since the explosions of acetylene under pressure and of mixtures of this gas and oxygen are among the most violent chemical changes known, producing a temperature of 2700° or higher, the question arises, Is there any atomic disintegration by which radio-active gases are produced? The calorimetric results do not indicate that any thermal effect is due to such change. The products of explosions were therefore tested in an electroscope similar to the one described by Professor Boltwood.* The fall of the gold leaf was observed with a microscope. The experiments were as follows: Acetylene gas collected over unboiled tap water caused a slightly greater leak than air, as might be expected, since the waters of this locality contain a radio-gas†. Accordingly gas from carbide was collected over water which had been boiled an hour or two. Acetylene containing a trace of phosphoretted hydrogen caused no greater leak than air. The hydrogen resulting from an explosion of such gas under pressure contained a phosphorus compound and gave rather more leak than air. When, however, the acetylene was free from phosphoretted hydrogen the hydrogen it yielded gave the normal leak. Repeated tests made with the gas remaining after the explosion of a mixture of acetylene and oxygen gave negative results. Freshly prepared acetylene carbon produced in two experiments more than the normal leak but the effect was slight. This may have been due to ionization of the air caused by chemical change such as the oxidation of the hydrocyanic acid adhering to the carbon.

In conclusion it may be stated that no indication was found of atomic disintegration or energy resulting except from ordinary change.

* This Journal, xviii, 97.   † Bumstead, Ibid., xvii, 97.

Art. V.—*A Modification of the Lasaulx Method for Observ-
ing Interference Figures under the Microscope;* by Fred
Eugene Wright.

Of the many plans which have been proposed for adapting
the microscope to observations in convergent polarized light
the method of Lasaulx is probably the best and is in general
use by petrologists at the present time. His mode of pro-
cedure consists in observing the image of the interference
figure directly, as it is brought to focus by the high power
objective alone, without the aid of ocular and compensating
lens. The interference figures thus produced, when compared
with those obtained by other methods, are smaller but more
distinct and brighter and therefore better suited to general
work. The weak point of the method is the time lost in
removing and replacing the ocular for each observation and
the annoyance caused thereby.

The following device has been
constructed to obviate this difficulty
by reflecting the light rays to one
side of the ocular, as shown in the
diagram (fig. 1), and has been found
in practice to answer the purpose
well. In the writer's microscope the
small reflecting apparatus fits in a
narrow slot in the microscope tube
between the base of the ocular in
position and the iris diaphragm and,
like the upper nicol prism, can be
inserted or drawn out at will. The
mechanical construction of the device
is so simple that a good mechanic
can make it without trouble. It has
been observed that the loss of light
on reflection is not sufficient to
decrease the brilliancy of the inter-
ference phenomena appreciably.

With this appliance attached to the
microscope the passage from plane
parallel to convergent polarized light
is easily effected by inserting the re-
flecting apparatus and observing then
the interference phenomena at one
side of the ocular. The ocular re-
mains thereby in place and practically
no time is wasted during the operation.

Vertical section of upper
part of microscope tube show-
ing position of reflecting when
inserted. O, ocular; R. A.,
reflecting apparatus; B. L.,
position for Bertrand lens;
I. D., iris diaphragm.

Sliding Stop Diaphragms as Substitutes for the Iris Diaphragms in Petrographic Microscopes.

In microscopic work it has been found by petrologists that
many optical phenomena are rendered more apparent by the

use of diaphragms both below and above the condenser and objective lens systems of the microscope; that, by closing gradually the lower iris diaphragm not only is the definition improved but also methods based on the relative refractive indices of adjacent mineral sections, as the Becke line method, are materially bettered; and that, by closing the upper diaphragm in like manner, interference figures in convergent polarized light can be observed from minute mineral plates which would be otherwise totally obscured by surrounding minerals. Ordinary petrographic microscopes, however, are not fitted with such iris diaphragms and the observations suffer accordingly.

The following sliding-stop diaphragms have been used as substitutes for the iris diaphragms and are of such nature that anyone with mechanical ability can construct similar ones for any given instrument. The upper stop diaphragm (fig. 2) is made of brass similar in general outline to that of the Bertrand lens,—the observations in convergent polarized light being made after the Lasaulx method, either by removing the ocular or by use
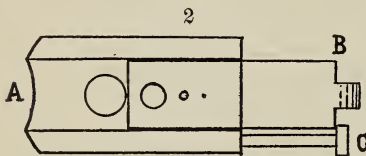
Sliding-stop diaphragm—a substitute for the upper iris diaphragm of a petrographic microscope.

of the reflecting apparatus described above. The stop diaphragm consists of two parts; A, the body, which is so constructed that, when inserted, the drilled hole occupies the center of the field and provides thereby one stop; and B, a thin strip of brass which fits in wedge-shaped grooves milled in A and into which the remaining stops are drilled. A short screw C provides a simple handle by which to grasp the apparatus. In actual practice the mineral section to be tested should first be sharply focussed and centered, the stop diaphragm then inserted and by means of an appropriate aperture the light from all other minerals in the section shut off, after which the observations in convergent polarized light can be made.

The lower stop diaphragm is of still simpler construction and consists of a strip of brass with variable sized stops not unlike those of the above apparatus. The strip is fitted into, and guided by two wedge-shaped pieces of brass screwed to the lower end of the cylinder containing the lower nicol. The lower stop diaphragm has been found particularly useful in the application of the refractive liquid method to mineral fragments.[*]

Geophysical Laboratory,
  Carnegie Institute, Washington, D. C.

* Compare Tschermak's Miner. petr. Mitteil., 1901, xx, pp. 239 and 251. Strips of thin cardboard with appropriate perforations can be used as temporary substitutes for both iris and sliding stop diaphragms.

Art. VI.—*Datolite from Westfield, Massachusetts;* by E. H.
Kraus and C. W. Cook.

Several months since, the Mineralogical Laboratory of the
University of Michigan purchased from Ward's Natural
Science Establishment of Rochester, N. Y., an excellent suite
of datolite crystals from Westfield, Mass. At that time,
crystals of datolite from this locality had not been described,
and it was therefore decided to carry out a chemical and
crystallographical investigation of the same. Recently, how-
ever, Whitlock* described several datolites from this locality.
Whitlock confined himself to a crystallographic study of these
interesting crystals, and since our investigations not only cor-
roborate many of his observations, but also give some additional
facts, we have thought it wise to present the same in detail.

Crystallography.—The original purchase consisted of six-
teen crystals varying from an half to an inch and an half in
diameter. Subsequently fifteen others were added, so that
thirty-one crystals from this locality are now in the possession
of this laboratory. However, through the kindness of Ward's
Natural Science Establishment, all of the material in their
possession was placed at our disposal, so that, in all, forty-seven
crystals were examined.

According to Mr. R. F. Jones, by whom the crystals were
collected, the datolite occurs in the cracks and crevices of Lane's
Trap Quarry, Westfield, Mass., half way between Springfield
and Westfield.† Most of the specimens seem to have been col-
lected during the past two years. All the crystals are exceed-
ingly clear and transparent and of such sizes as to make
accurate goniometric observations possible. Four distinct types
of development were noted.

Even though datolite has from time to time been studied
crystallographically, there is still considerable difference of
opinion as to the selection of the a and c axes. Although
Hess‡ and Schroeder§ had previously shown that datolite crys-
tallizes in the monoclinic system instead of orthorhombic as
assumed by Lévy,‖ Haüy,¶ and Miller,** it remained for
Dauber†† to positively establish the fact. The elements of
crystallization obtained by Dauber are:

$$a : b : c = 1.26574 : 1 : 0.63446 \quad \beta = 90°\ 9'.$$

In so doing the form m_x (fig. 1) was assumed as the unit

* N. Y. State Museum, Bull. 98, 19.
† Compare Whitlock, N. Y. State Museum, Bull. 98, 19.
‡ Pogg. Annalen, xciii, 380, 1854.
§ Ibid., xciv, 235, 1855; also xcviii, 34, 1856.
‖ Description d'une collection de mineraux, etc., pp. 179 and 182, 1838.
¶ Dana, System of Mineralogy, 6th ed., 1892, 505.
** Mineralogy, 1852, 408.
†† Pogg. Annalen, ciii, 116, 1858.

prism.   Rammelsberg,[*] in establishing the isomorphism be-
tween datolite, gadolinite, and euclase, accepted the position
proposed by Dauber but made g (fig. 1) the unit prism, whereby
the ratio was reduced to

$$0{\cdot}6329 : 1 : 0{\cdot}6345.$$

Groth,[†] Liweh,[‡] Goldschmidt,[§] and others have accepted
these values.   Hintze[||] accepts the statement of Lüdecke[¶] that
this position is the more natural and gives the simpler indices.
Lüdecke's argument, moreover, loses its force when we con-

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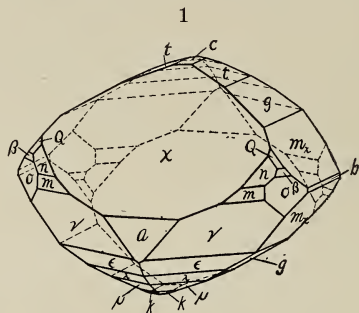
sider that seventeen of the thirty new forms described by
him were afterwards shown by Goldschmidt[**] to belong to
anglesite and not to datolite.   Dana,[††] however, does not accept
the above position, but follows Lévy[‡‡] and interchanges the
a and c axes.   In so doing the values obtained by Dauber are
taken, so that the ratio adopted by Dana is :

$$a : b : c = 0{\cdot}63446 : 1 : 1{\cdot}26574.$$

We agree with Dana that this position permits of a more
natural interpretation of the crystals and also affords the
simpler indices.   This position is, therefore, the one accepted
by us.   As indicated by Dana,[§§] the isomorphism existing
between datolite, gadolinite, and euclase can be shown by this
position just as well as by the one adopted by Rammelsberg.

The four types of development already referred to may be
described briefly as follows :

Type one (fig. 1), as noted by Whitlock, is the predomina-
ting habit.   Thirty-four crystals were found to possess this

[*] Zeitschr. der Deutsch. Geol. Ges. xxi, 807.
[†] Tabellarische Uebersicht der Mineralien, 1898, 116.
[‡] Zeitschr. für Krystallographie u. s. w., vii, 569, 1883.
[§] Index der Krystallformen der Mineralien, 1886, I, 485.
[||] Handbuch der Mineralogie, II, 164.
[¶] Zeitschr. für Naturwissenschaft, lxi, 235-404, 1888.
[**] Zeitchr. für Krystallographie, xviii, 280, 1890.
[††] System of Mineralogy, 6th edition, 1892, 504 and 505.
[‡‡] Loc. cit.   [§§] Loc. cit.

development, which may be characterized as the pyramidal habit. The following forms were observed on this type:

$a\{100\}$, $b\{010\}$, $c\{001\}$, $m\{110\}$, $r\{230\}$, $o\{120\}$, $l\{130\}$, $x\{102\}$, $v\{103\}$, $u\{104\}$, $m_x\{011\}$, $g\{012\}$, $t\{013\}$, $m_y\{067\}$ (new), $m_z\{0{\cdot}1{\cdot}10\}$ (new), $n\{111\}$, $\beta\{121\}$, $Q\{122\}$, $\nu\{\bar{1}11\}$, $\mathfrak{d}\{\bar{2}23\}$, $\epsilon\{\bar{1}12\}$, $\lambda\{\bar{1}13\}$, $\mu\{\bar{1}14\}$, $\kappa\{\bar{1}15\}$, $n_z\{\bar{1}{\cdot}1{\cdot}10\}$ (new), $M\{\bar{1}22\}$, $i\{\bar{1}23\}$, $a\{\bar{1}24\}$, $\pi\{\bar{2}31\}$, $\epsilon'\{\bar{1}48\}$, $\mu'\{1{\cdot}4{\cdot}10\}$.

The pinacoid $a\{010\}$ is always present as a brilliant face. The form $b\{010\}$ occurs on about fifty per cent of the crystals of this type. When present, it appears as a narrow edge giving good reflections. $c\{001\}$ is generally very small, often giving no image whatever. The prism $m\{110\}$ is usually to be observed as a thin edge and is always present. $o\{120\}$, which is frequently present, possesses two characteristic outlines (figs. 1 and 4). In some instances it shows natural etching. It then appears as a very dull face giving poor reflections. $r\{230\}$ (fig. 2) was noted on several crystals, giving very good readings. $l\{130\}$ was observed on but one crystal, beveling the edge between the faces $\nu(11\bar{1})$ and $m_x(011)$.
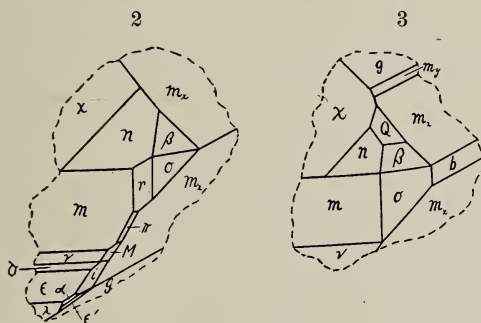
The negative hemi-orthodome $x\{102\}$ is the predominating form of this type and aids materially in orientating the crystals. The faces are often broken and the surfaces are more or less uneven, and hence give poor reflections. $v\{103\}$ and $u\{104\}$ were observed but once as very small, narrow edges. Of the clino-domes $m_x\{011\}$, $g\{012\}$, and $t\{113\}$ are always present. Of these forms, $m_x\{011\}$ is always large. $m_y\{067\}$ (fig. 3) and $m_z\{0{\cdot}1{\cdot}10\}$ are new to datolite. Even though they were observed on only two crystals, the observed and calculated angles, nevertheless, leave no doubt as to their identity.

		Observed.	Calculated.
$m_y : m_y =$ (067) : (06̄7)		94° 39′	94° 46′
$m_z : m_z =$ (0·1·10) : (0·1̄·10)		14 38	14 25

Of the pyramids, $n\{111\}$, $\beta\{121\}$, $\nu\{\bar{1}11\}$, $\epsilon\{112\}$, $\lambda\{\bar{1}13\}$, $\mu\{114\}$ are generally present,—$\nu\{\bar{1}11\}$ usually predominating.

Q$\{122\}$ is frequently present,—often as a dull face giving no reflection.

ꝺ$\{\bar{2}23\}$, sometimes quite large, is among the commonly observed forms.

M$\{\bar{1}22\}$, $i\{\bar{1}23\}$, and $a\{\bar{1}24\}$ are also among the forms frequently observed. The new forms $\epsilon'\{\bar{1}48\}$ and $\mu'\{\bar{1}\cdot4\cdot10\}$, noted first by Whitlock, were observed on several crystals. $\mu'\{\bar{1}\cdot4\cdot10\}$ gave very good readings, but $\epsilon'\{\bar{1}48\}$ was identified by zonal relationship. The location of these forms is shown

4   5
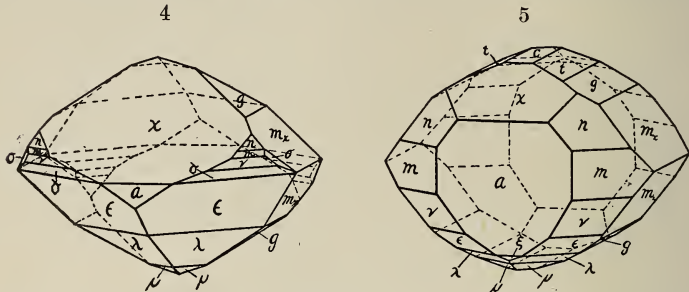
in figure 2. $n_z\{\bar{1}\cdot1\cdot10\}$ is also new to the species. This form may be considered well established, as shown by the following angles :

			Observed.	Calculated.
m	: n_z	$= (110)$: $(\bar{1}\cdot1\cdot10)$	$76°\ 49'$	$76°\ 52'$

Type two (fig. 4) also possesses a pyramidal habitus. It is distinguished from type one chiefly by the absence of the basal and clino-pinacoids. This type was observed seven times, possessing the following forms :

$a\{100\}$, $x\{102\}$, $m_x\{011\}$, $g\{012\}$, $m\{110\}$, $o\{120\}$, $n\{111\}$, ꝺ$\{223\}$, $\epsilon\{\bar{1}12\}$, $\lambda\{\bar{1}13\}$, $\mu\{\bar{1}14\}$ $\nu\{\bar{1}11\}$.

The pinacoid $a\{100\}$ occurs as a small triangular face giving excellent reflections. As in type one, the hemi-orthodome $x\{102\}$ is the predominating form. The prisms $m\{110\}$, and $o\{120\}$ are always present though generally small,—$o\{120\}$ beveling the edge between the faces $\nu(11\bar{1})$ and $m_x(011)$. Of the pyramids, $\epsilon\{\bar{1}12\}$ and $\lambda\{\bar{1}13\}$ present large, uneven faces. ꝺ$\{\bar{2}23\}$ is usually dull. The other pyramids appear as very small faces.

Type three (fig. 5) was observed on four crystals. It may be characterized as possessing a prismatic habitus. All forms are well developed,—the following being noted :

$a\{100\}$, $b\{010\}$, $c\{001\}$, $x\{102\}$, $\xi\{\bar{1}02\}$, $m_x\{011\}$, $g\{012\}$, $t\{013\}$, $m\{110\}$, $n\{111\}$, $\nu\{\bar{1}11\}$, $\epsilon\{\bar{1}12\}$, $\lambda\{\bar{1}13\}$, $\mu\{\bar{1}14\}$.

The pinacoid $a\{100\}$ is the predominating form, the others being quite equally developed. All faces except the positive

hemi-pyramid $\nu\{\bar{1}11\}$ and the ~~positive~~ *negative* hemi-orthodome $\xi\{\bar{1}02\}$ are brilliant, giving good reflections. $\nu\{\bar{1}11\}$ appears as a dull face in each instance. $\xi\{\bar{1}02\}$ in addition to being dull was so small that it could only be identified by zonal relationship. The three types thus far considered show a marked resemblance to the Bergen Hill* dalolites. Type three also simulates crystals from Toggiana.†

Type four (fig. 6), which was observed on two well developed crystals, possesses a tabular habitus. In some respects it resem-

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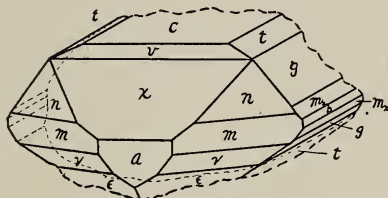
bles datolite crystals from the Lake Superior region described by Osann.‡ The following forms were noted:

$a\{100\}$, $b\{010\}$, $c\{001\}$, $m\{110\}$, $m_x\{011\}$, $g\{012\}$, $t\{013\}$, $x\{102\}$, $v\{103\}$, $n\{111\}$, $\nu\{\bar{1}11\}$, $\epsilon\{\bar{1}12\}$.

As may be seen from figure 6, the basal pinacoid $c\{001\}$ is especially prominent in this type. Of the clinodomes, $g\{012\}$ predominates,—$m_x\{011\}$ and $t\{013\}$ being comparatively narrow faces. The orthodomes $x\{102\}$ and $v\{103\}$ are both dull faces.

In all thirty-two forms were observed. They are as follows:

Pinacoids $a\{100\}$, $b\{010\}$, $c\{001\}$.
Prisms $m\{1\emptyset0\}$, $r\{230\}$, $o\{120\}$, $l\{130\}$. /
Clinodomes $m_x\{011\}$, $g\{012\}$, $m_y\{067\}$,
       $t\{013\}$, $m_z\{0\cdot1\cdot10\}$.
Orthodomes $x\{102\}$, $v\{\bar{1}03\}$, $u\{104\}$, $\xi\{\bar{1}02\}$.
Pyramids $n\{111\}$, $\beta\{121\}$, $Q\{122\}$,
      $\nu\{\bar{1}11\}$, $\mathfrak{d}\{\bar{2}23\}$, $\epsilon\{\bar{1}12\}$, $\lambda\{\bar{1}13\}$,
      $\mu\{\bar{1}14\}$, $\kappa\{\bar{1}15\}$, $n_z\{\bar{1}\cdot1\cdot10\}$, $M\{\bar{1}22\}$,
      $i\{\bar{1}23\}$, $a\{\bar{1}24\}$, $\pi\{\bar{2}31\}$, $\epsilon\{\bar{1}48\}$,
      $\mu'\{\bar{1}\cdot4\cdot10\}$.

Of these $m_y\{067\}$, $m_z\{0\cdot1\cdot10\}$, and $n_z\{\bar{1}\cdot1\cdot10\}$ are new for datolite.

On account of the excellence of the various faces, the observed angles agree very closely with the calculated. The elements

* E. S. Dana, this Journal (3), iv, 416, 1872.
† Dana's System of Mineralogy.
‡ Zeitschr. für Krystallographie, xxiv, 543, 1895.

of crystallization for these crystals differ but slightly from those usually accepted, as is shown by the following:

Westfield ..... $a : b : c = 0\cdot63482 : 1 : 1\cdot26567$ $\beta = 90° \ 9'$
Dana† -------- $a : b : c = 0\cdot63446 : 1 : 1.26574$ $\beta = 90° \ 8\tfrac{2}{3}'$

The measurements give the following results:

						Observed.			Calculated.		
m	:	m'''	$=$	(110)	: $(1\bar{1}0)$	$=$	$64°$	$49'$*	--------		
m_x	:	m'_x	$=$	(011)	: $(0\bar{1}1)$		103	22	$30''$*	--------	
a	:	c	$=$	(100)	: (001)		89	51	*	--------	
l	:	l'	$=$	(130)	: $(\bar{1}30)$		55	19		$55°$	$24'$	$30'$
o	:	o	$=$	(120)	: $(\bar{1}20)$		76	25		76	29
r	:	r'''	$=$	(230)	: $(2\bar{3}0)$		87	13		87	11
m_z	:	m'_z	$=$	(0110)	: $(0\bar{1}10)$		14	38		14	25
t	:	t'	$=$	(013)	: $(0\bar{1}3)$		45	42	30	45	45
g	:	g	$=$	(012)	: $(0\bar{1}2)$		64	45	15	64	38	30
m_y	:	m_y	$=$	(067)	: $(0\bar{6}7)$		94	39		94	46
a	:	m_x	$=$	(100)	: (011)		89	56		89	54	30
a	:	n	$=$	(100)	: (111)		38	57		38	56
a	:	β	$=$	(100)	: (121)		53	44		53	44
a	:	Q	$=$	(100)	: (122)		58	12		58	15	30
a'	:	ν	$=$	$(\bar{1}00)$	: $(\bar{1}11)$		39	0	30	38	59
a'	:	ϵ	$=$	$(\bar{1}00)$	: $(\bar{1}12)$		49	59		49	57
a'	:	λ	$=$	(100)	: $(\bar{1}13)$		58	34	45	58	32	30
a'	:	μ	$=$	$(\bar{1}00)$	: $(\bar{1}14)$		64	47		64	41
a'	:	k	$=$	$(\bar{1}00)$	: $(\bar{1}15)$		69	2		68	44
a	:	x	$=$	$(\bar{1}00)$	: (102)		45	1		45	
a'	:	M	$=$	$(\bar{1}00)$	: $(\bar{1}22)$		57	24		57	49
c	:	v	$=$	(001)	: (103)		33	36		33	35
c	:	u	$=$	(001)	: (104)		26	35		26	29
m	:	x	$=$	(100)	: (102)		53	21		53	15
m	:	n	$=$	(110)	: (111)		22	57	30	22	54
m'	:	ν	$=$	$(\bar{1}10)$	: $(\bar{1}11)$		22	58	30	22	57
m'	:	$\mathfrak{d}$	$=$	$(\bar{1}10)$	: $(\bar{2}23)$		32	28	45	32	35
m'	:	ϵ	$=$	$(\bar{1}10)$	: $(\bar{1}12)$		40	19		40	13
m'	:	λ	$=$	$(\bar{1}10)$	: $(\bar{1}13)$		51	56		51	49
m'	:	μ	$=$	$(\bar{1}10)$	: $(\bar{1}14)$		59	20		59	15
m'	:	n_z	$=$	$(\bar{1}10)$	: $(\bar{1}\cdot1\cdot10)$		76	49		76	52
m	:	β	$=$	$(\bar{1}10)$	: (121)		25	41		25	38
m	:	m_x	$=$	(110)	: (011)		65	9		65	7	30
o	:	x	$=$	(120)	: (102)		63	59		64	3
o	:	n	$=$	(120)	: (111)		29	40		29	38
o	:	β	$=$	(120)	: (121)		17	14		17	7	30
o'	:	M	$=$	$(\bar{1}20)$	: $(\bar{1}22)$		31	45		31	43
o'	:	u'	$=$	$(\bar{1}20)$	: $(\bar{1}23)$		42	50		42	32
o'	:	a	$=$	$(\bar{1}20)$	: $(\bar{1}24)$		51	1		51	5
o	:	m_x	$=$	(120)	: (011)		51	57		51	57
o	:	π	$=$	$(\bar{1}20)$	: $(\bar{2}31)$		13	13		13	13
r	:	π	$=$	$(\bar{2}30)$	: $(\bar{2}31)$		10	9		10	15
g	:	μ	$=$	(012)	: $(\bar{1}14)$		29	16		29	13
g	:	μ'	$=$	(012)	: $(\bar{1}\cdot4\cdot10)$		11	17		11	19

† These values of Dauber, modified as indicated on page 22, are also accepted by Groth, Goldschmidt and others.

Natural etching is quite common, especially on the pyramids $\lambda\{\bar{1}13\}$, $\mu\{\bar{1}14\}$ and $\kappa\{\bar{1}15\}$ as noted by Whitlock.[*] This phenomenon is also frequently observed on the prism $o\{120\}$ and the pyramid $\beta\{121\}$. In no case, however, were the figures of sufficient size to permit an accurate determination of their outline.

Chemical Analysis. — For the chemical analysis one of the clearest crystals weighing about ten grams was selected. It was perfectly transparent and free from all inclusions. Concerning the methods which were employed, it should be stated that the boron trioxide was determined by the Gooch[†] method. Water was estimated as loss on ignition. The other determinations were made according to the methods recommended by Hillebrand.[‡] Two analysis were made, which show very close agreement.

The results are :

	I	II	Average
SiO_2	37·60%	37·58%	37·59%
Fe_2O_3	·10	·10	·10
Al_2O_3	·14	·16	·15
CaO	34·64	34·74	34·69
MgO	·32	·31	·315
B_2O_3	21·76	21.94	21·85
H_2O	5·67	5·76	5·715
Total	100·23%	100·59%	100·41%

The average of the above analyses agrees very closely with that required for the accepted formula $HCaBSiO_5$. This was to be expected because of the unusual clearness and purity of the crystals. It is also to be noted that this analysis is very similar to Bodewig's[§] of the datolite from Bergen Hill, N. J., as is shown by the following comparison :

	Theoretical	Westfield	Bergen Hill
SiO_2	37·63	37·59	37·48
Fe_2O_3	—	·10	·12
Al_2O_3	—	·15	—
CaO	34·95	34·69	35·42
MgO	—	·31	—
B_2O_3	21·81	21·85	21·14
H_2O	5·61	5·72	5·71
Total	100·00	100·41	99·87

[*] N. Y. State Museum, Bull. 98, 12.
[†] F. A. Gooch, Am. Chem. Jour., ix, 23, 1887. F. A. Gooch and L. C. Jones, this Journal, vii, 34, 1899.
[‡] Bulletins 148 and 176 U. S. Geol. Survey.
[§] C. Bodewig, Zeitschr. für Krys., viii, 211, 1884.

This similarity in the composition of the datolites from these two localities becomes more pronounced when we consider that the value given by Bodewig for boron trioxide is the mean of three determinations, one of which is 21·6 per cent. This agrees very closely with the values obtained by us.

Specific Gravity.—For the determination of the specific gravity four clear crystals of convenient size were used. The determinations were made by means of the hydrostatic balance at a room temperature of 19·5° C., the water being 21·5° C., with the following results:

$$
\begin{array}{ll}
\text{I} & 3\cdot 0005 \\
\text{II} & 2\cdot 9998 \\
\text{III} & 3\cdot 0065 \\
\text{IV} & 3\cdot 0165 \\
\hline
\text{Average} & 3\cdot 0058
\end{array}
$$

The values for the specific gravity are usually given in the various standard text-books[*] as varying from 2·9 to 3. Bauer,[†] however, gives 2·9–3·6. We have been unable to find any records whatever of datolites possessing a specific gravity as high as 3·6, and on account of the fact that the figures obtained by us on very pure material are much lower, we would question the correctness of the larger value given by Bauer.

In conclusion, we wish to express our indebtedness to Prof. E. D. Campbell, Director of the Chemical Laboratory of this University, for advice and suggestions relating to the chemical portion of this paper.

Mineralogical Laboratory, University
    of Michigan, Ann Arbor, Mich.
        March 30, 1906.

[*] Dana, System of Mineralogy, 1892, 504 ; Hintze, Handbuch der Mineralogie, II, 167 ; Miers, Mineralogy, 1902, 588 ; Naumann-Zirkel, Elemente der Mineralogie, 14te Auflage 1901, 629.

[†] Bauer, Lehrbuch der Mineralogie, 2te Auflage, 1904, 762.

ART. VII.—*The Russian Carboniferous and Permian compared with those of India and America. A Review and Discussion;* by CHARLES SCHUCHERT. (With Plate I.)

CONTENTS :

PART I. THE WORK OF TSCHERNYSCHEW.

Die Obercarbonischen Brachiopoden des Ural und des Timan. Von Th. Tschernyschew. Mem. du Comité Géol., vol. xvi, 1902 [1903], pp. i–viii, 1–749, and 63 plates.

THIS large and exceedingly valuable monograph describes the brachiopods collected by the author and others during eight years in the Ural and two years in the Timan districts of European Russia. The great number of 213 species are described, and two new genera—*Keyserlingina* and *Spiriferella.*

In the present review of this monograph, the author's general conclusions regarding the occurrence of these forms in the various horizons and their significance in correlation only will be taken into account. In fact, Tschernyschew's correlations are of the first importance, and will be fully presented here.

In the introduction the author states : —

" It is my opinion that the exceptional richness of the fauna of the Upper Paleozoic sediments of Russia and the positive succession of the various horizons give us the right to regard eastern and northern [European] Russia as the starting point for the correlation of similar deposits in other countries. . . . Not infrequently my views differ from those of my colleagues in western Europe and America, and in recording these conclusions in the final chapter of my work my chief object has been to present the views of one geologist who in the course of many years has studied the upper Paleozoic deposits in the vast territory of Russia. It is very probable that some of my freely-stated assertions will be strongly criticized by geologists both at home and in foreign countries, and I shall be the first to greet such criticisms with pleasure " (pp. vi, vii).

Of the 213 species of brachiopods known in the " Upper Carboniferous " of Russia, 61 pass into the Artinsk zone and but 10 into the typical Permian. The latter are *Dielasma elongatum, Rhynchopora nikitini, R. variabilis, Camarophoria crumena, C. superstes, C. globulina, Athyris pectinifera, A. roissyi, Spiriferina cristata,* and *Productus* aff. *leplayi.*

These make it clear that this is not the normal marine fauna that continues the Paleozoic sequence into the Mesozoic.   This point, however, will be discussed on a later page (see " Conclusions," paragraph 2).

In regard to the Russian faunas the author states :—

" I wish to call attention to the decided differences which make their appearance in the fauna of the Omphalotrochus horizon when contrasted with the type of that of Miatschkowo [near Moscow; also see the following table for stratigraphic position], and on the other hand the great resemblance of the brachiopod fauna of the Schwagerina zone to that of the higher lying Permo-Carbon (the Artinsk deposits CPg and the Limestone-dolomite CPc).   In the lower Permian fauna of Russia we have already noted a decided reduction in Brachipoda, if not in quantity, at least in variety of species; and in the still higher horizons of the Russian Permian, the total number of Brachiopoda is not more than 40 species [this number has reference to all areas correlated with the typical Perm area].   Entire groups of forms . . . that give a decided aspect to the fauna of the Upper Carboniferous Artinsk, and the Limestone-dolomite beds, are completely unknown in the Permian sediments of Russia and west Europe.   Some of these groups therefore attract our attention because they are foreign to the Permian deposits, yet in the Mesozoic (Trias and Jura) they attain an extended development.   On the other hand, others belong to such original types as the Lyttoniidæ, *Tegulifera*, and *Orthotichia*, forms that give a decided character to the upper Paleozoic, and, so far as our knowledge goes, completely disappear with the Permian epoch [of western Europe]. From a biological standpoint there can be no doubt that our Upper Carboniferous brachiopod fauna has the facies of a younger type than the Permian, and that in its entirety it has a more decided Mesozoic impress than that of the [Russian] Permian following, which when compared with the other shows atavistic trends [see note 6].   As it is my opinion that this atavism finds its proper explanation in the physico-geographic conditions of the Permian sea, I hold that it is not superfluous to direct special attention to this fact, and thereby to moderate the tendency of some geologists, who in their determination of the age of this or that fauna depend mainly upon the biological peculiarities and not infrequently leave out of consideration the possible explanation that the biological differences between two synchronous or at least closely adjoining faunas are partially due to facies and chorological causes" (pp. 663–4).

" Although the data presented regarding the distribution of Upper Carboniferous deposits in the region of European

Russia show that we can not fix with certainty the exact shore-lines of the sea of this epoch, still from the general distribution and the nature of the sediments of this time, when compared with those of the Middle Carboniferous epoch, we may conclude that there was a retreat of the sea in the west. In the north the Upper Carboniferous sea had great extension and communicated freely with the far-reaching Polar sea. In the east it was limited by the Ural barrier, behind which in Siberia lay a series of more or less extensive basins of brackish or fresh water " (p. 679).

For the sake of completeness, the reviewer will here introduce a somewhat detailed generalized section of the Permian and Carboniferous of Russia, compiled from various recent sources :[*]

Brackish ? Permian or ? Triassic, Tartarian (PT).

Red grits, argillaceous sands, and intercalations of clay and marl of the same color ; rarely green or bright blue.

Red colored marls and variegated clays, with intercalations of grayish grits and sands of the same tints.

These two groups have brackish-water genera, as *Unio*, *Anthracosia*, *Najadites*, and *Palæomutela*.

Permian (P) of Samara and Oufa (the Permian sensu-stricto of Murchison).

Brown grits, marls, and limestone.

Has some pelecypods, as *Allorisma elegans*, etc.

Gray slaty limestones, with intercalated marls and friable grits.

Has *Murchisonia subangulata*, *Turbonilla altenburgensis*, *Macrodon kingianum*, *Osteodesma kutorgana*, *Modiolopsis pallasi*, *Leda speluncaria*, etc. Of Crustacea, *Bairdia*, *Estheria*. *Lingula orientalis*. Of fishes, *Palæoniscus*, *Acrolepis*.

Grits and gray limestone, more or less copper-bearing.

Rich in brachiopods: *Spirifer regulatus*, *Spiriferina cristata*, *Athyris pectinifera*, *Dielasma elongata*, *Productus cancrini*, *P. hemisphæricus*, *Strophalosia horescens*. Some bivalves and corals.

Red argillaceous grits, with intercalations of clay and gray, brown, and reddish marls.

Fossiliferous only in the higher beds: *Productus cancrini*, *Athyris pectinifera*, *Dielasma elongata*, *Allorisma elegans*, *Macrodon kingianum*, etc.

[*] The Permian and Moscowian section is taken from Nikitin—" De Moscou à Oufa (via Miatschkowo, Riazan, Penza, Syzran, Samara)," Guide des Excursions, VII, Congrès Géol. Internat., 1897, Pt. II ; the Uralian, from Tschernyschew's great brachiopod work here reviewed ; the Viséian and Artinsk, from Tschernyschew, Mém. du Comité Géol., III, No. 4, 1889.

Argillaceous limestones and marls of variegated tints.   No fossils.

Gypsiferous group of limestone, gypsum, and clay.   No fossils.

Permo-Carboniferous, or Artinskian (Lower Permian of many authors).

Horizon CPc, or dolomitic-limestone zone.   A gray or yellowish gray cavernous limestone passing often into dolomite, brecciated or conglomeratic in composition, with intercalated beds of oolite and occasionally shale.

Has a fauna smaller than, and almost identical with, that of horizon CPg. *Cladodus, Dielasma hastata, D. elongata, Spiriferina cristata, Rhynchopora nikitini, Chonetes variolaris, C. verneuiliana, Productus purdoni, P. cora, Marginifera typica, Fusulina verneuili*, and *Bradyina nautiliformis.*

Horizon CPg, or Artinskian *sensu stricto.* " Peppery " sandstone, with intercalations of shales.   In places conglomerates, limestone, shales, and slates.

Has *Phillipsia gruenewaldti, Pronorites præpermicus, Agathiceras uralicum, Medlicottia artiensia, Gastrioceras, Popanoceras, Parapronerites.* Of Upper Carboniferous brachiopods, 61 species pass into this zone. Among the more prominent fossils of the zone are the following: *Dielasma elongata, Spirifer fasciger, S. alatus, Spiriferina cristata, Spiriferella saranæ, Rhynchopora nikitini, Camarophoria plicata, Streptorhynchus pelargonatus, Productus spiralis, P. lineatus, Marginifera typica, Fusulina verneuili.*

Upper Carboniferous, or Uralian.

Schwagerina zone (C$\frac{3}{3}$), about 60 meters thick in Timan.

Abounds in *Schwagerina princeps.*   Other Foraminifera are *Fusulina verneuili, F. longissima.* Of corals, there are many species, mostly of the compound type. Of Bryozoa, the most striking is *Archimedes.* This is the horizon *par excellence* for brachiopods, Tschernyschew recording 194 forms.   *Dielasma* in greatest abundance, with 13 species; *Hemiptychina* 4, none below; *Notothyris* 3; *Aulacothyris* 2; *Keyserlingina* 2, none below; *Terebratuloidea* 2, none below; *Pugnax* 8; *Camarophoria* 14; *Spiriferina* 8; *Spiriferella* 4; *Spirifer* 21; *Martiniopsis* 7, none below; *Martinia* 13; *Reticularia* 4; *Meekella* 2; *Orthotichia* 1, none below; *Chonetes* 11; *Aulosteges* 1; *Productus* 40; *Proboscidella* 3 (these are not of the type of the Lower Carboniferous, having had another

origin); *Marginifera* 8. Pelecypods also common and of the ordinary Upper Carboniferous types. Of cephalopods, *Agathiceras uralicum, Pronorites cyclolobus uralensis, P. postcarbonarius.* Trilobites, *Griffithides roemeri* and *G. gruenewaldti.*

Productus cora zone (C_3^2), about 70 meters thick in Timan and 100 in southern Ural. The most abundant fossil is *P. cora.* Other brachiopods are *Dielasma,* 4 species (*bovidens*); *Camarophoria* 4; *Spiriferina* 2; *Spiriferella saranæ, Spirifer cameratus, S. condor, S. fasciger, S. marcoui* (goes no higher), *Derbyia regularis, D. crassa, Meekella striaticostata* and 3 other species; *Chonetes mesoloba, C. granulifera, C. flemingi, C. variolata, Aulosteges, Productus boliviensis* and 21 other forms, *Marginifera uralica* and 4 other forms. Corals are rare, especially the compound forms so common both above and below. *Archimedes* rare. Large *Fusulina verneuili. Griffithides scitula.*

Omphalotrochus zone (C_3^1b). This zone and the one below have a united thickness of about 70 meters. Most abundant fossil *Omphalotrochus whitneyi.* Of brachiopods there are *Dielasma itaitubense, Camarophoria* 3, *Spirifer marcoui, Derbya crassa, D. regularis, Meekella striaticostata, Aulosteges, Productus nebrascensis, P. cora, P.* 10 species, *Marginifera uralica.* Corals very abundant; this zone in the Urals is 12 meters thick.

Spirifer marcoui zone (C_3^1a).

Has an abundance of *S. marcoui* and corals.

Middle Carboniferous, or Moscowian (C_2), about Miatschkowo.

1. Greenish white fragmental limestone, ·3 meter thick.
2. Greenish compact argillaceous limestone, ·7 meter thick.
3. Yellow dolomitic limestone, $2\frac{1}{2}$ to 3 meters thick.
   Abounds in fish teeth and plates of *Cladodus, Dactylodus, Deltodus, Ostinaspis, Pœcilodus, Polyrhizodus, Psephodus, Psammodus,* and *Solenodus.* Also *Productus semireticulatus.*
4. Grayish compact limestone, $1\frac{1}{2}$ to 2 meters thick.
5. White granular soft flaggy limestone, 2 to 3 meters thick.
   Has a normal marine fauna. Those preceded by 1 are the characteristic species. Has many of the fishes found in 3, and *Cymatodus, Helodus, Orodus, Petalodus,* and *Tomodus.* Also *Nautilus mosquensis, Euomphalus pentangulatus, E. marginatus, Macrocheilus ampullaceous, Allorisma regulare, Conocardium uralicum, Productus cora (riparius), P. lineatus,* 1 *P. semireticulatus,*

P. longispinus, P. punctatus, 1 *Enteletes lamarcki, Meekella eximia,* 1 *Spirifer mosquensis,* 1 *S. strangwaaysi, S. fasciger,* and 1 *Seminula ambigua.* In the clay bands this is also the horizon for crinoids *Cromyocrinus, Hydriocrinus, Phialocrinus, Poteriocrinus, Stemmatocrinus,* etc. Also *Archiocidaris rossica, Lepidesthes,* and *Culliastes.* Several species each of *Fenestella* and *Polypora.* Of corals, *Bothrophyllum conicum, Petalaxis* and 1 *Chætetes radians.* Also *Fusulina cylindrica,* but not readily seen.

6. Fusulina limestone made up of Foraminifera and crinoidal matter, 1 meter thick.

Has some of the fishes also found above, *Nautilus* 6 species, *Productus semireticulatus, P. punctatus, Meekella eximia, Enteletes lamarcki, Spirifer mosquensis, Archiocidaris rossica, Chætetes radians, Syringopora parallela, Bothrophyllum conicum, Axophyllum rossophyllum, Fusulina cylindrica, Bradyina, Endothyra, Fusulinella, Cribrostomum,* and *Tetrataxis.*

7. Yellowish white hard compact limestone, $1\frac{1}{2}$ to 2 meters thick.

8. Dirty white limestone.

Lower (?) Carboniferous, or Viséian.

Upper limestone ($C\frac{2}{1}$).

Has *Allorisma regularis, Rhynchonella pleurodon, Seminula ambigua, S. subtilita, Schizophoria resupinata, Productus longispinus, P. corrugatus, P. pustulosus, Fusulina verneuili, Fusulinella sphæroidea,* etc.

Lower limestone ($C\frac{1}{1}$).

Has an abundance of corals, *Syringopora gracilis, Lithostrotion affine, L. cæspitosum, L. irregulare,* and brachiopods, *Productus giganteus* and *Chonetes papilionacea.* Also *P. striatus, Athyris squamigera, A. expansa, Martinia glabra, Phymatifer pugilis, Phanerotinus serpula, Phillipsia globiceps,* etc.

Devonian.

Correlations with India.

Tschernyschew regards it as " highly desirable to discuss in detail the section of the Salt Range, which, as far as the sequence of the horizons and their paleontological characteristics are concerned, is described more completely than is any other region of Asia. This area is at present not only the starting-point for the correlation of other Asiatic regions, but for the Austrian Paleozoic as well ; hence I hold that my view regarding this profile will not be unacceptable" (p. 715).

Of the many Indian species of Brachiopoda, the author finds that 31 are also known in the Ural-Timan region. To these he has added 13 other species not common to both areas, but which clearly have related forms. He then discusses the distribution of these various species in the beds of India and the Ural-Timan region, and concludes:—

" Of great significance is the occurrence of the family Lyttoniidæ in the Schwagerina horizon of the Ural and the Virgal beds of India. This occurrence is of great moment and significance in the history of the upper Paleozoic of Russia " (see " Conclusion," paragraph 5).

" Through a comparison of the brachiopod fauna of the Upper Carboniferous deposits of the Ural and Timan with those of the various subdivisions of the Productus-limestone of the Salt Range, we clearly see that the lower Productus-limestone, or the Amb beds [see tables on pp. 32, 37], is more properly correlated with the Ural-Timan horizon having *Spirifer marcoui* and *Omphalotrochus whitneyi*, and that in our Schwagerina horizon we more naturally may discern the greater part of the Middle Productus-limestone, while the homotaxial sediments of the Cora horizon we have to seek in the upper layers of the Amb beds and probably also in the lower horizons of the Middle Productus-limestone, or in the Virgal group (according to Noetling's nomenclature). In this parallelism the Kalabagh beds [upper division of the Middle Productus-limestone] and the Upper Productus-limestone (in any event, the major part) well represent the Artinsk deposits and their equivalents of the Ural."

" This result is in the main at variance with the prevailing views as to the age of the various subdivisions of the Productus-limestone of the Salt Range, and approaches decidedly the original conclusion that the age of these beds is Carboniferous. I foresee that against my deductions the objection will be raised that they are based on a comparison of the brachiopods alone, but I can also defend them through other classes of the animal world. Moreover, I wish to say a few words in regard to the Cephalopoda, especially the ammonites." He then discusses the ammonites of Russia and Sicily, as described by Karpinsky and Gemmellaro, and lays particular stress upon the conclusion of the former, which he quotes as follows : " That the Sicilian fauna is somewhat earlier in origin than that of the Urals, although they, as I will again assert, approach closely the Artinsk. On the other hand, it is possible that the differences mentioned are due to chorological causes. The complicated Arcestidæ, for instance, can only belong to the southern regions " (pp. 719--20).

Because of the wide distribution of the remarkable fish *Helicoprion* in North America,* Japan, India, and Australia, and of the fact that in the Ural all the specimens of this genus are from the Artinsk horizon, Tschernyschew holds that these data should be given great weight, since so peculiarly constructed an animal " must have had a very restricted duration " (p. 722).

" According to my judgment all that has been said is strictly against the conclusion of Waagen and his adherents, who see in the Productus-limestone the entire Permian series of Russia. In the general chronological scheme the Productus-limestone has to take a deeper position than that assigned to it by Waagen, Noetling, and others" (p. 725).

Regarding Noetling's statement that the Productus-limestone passes without break into the Ceratite-bearing beds of the Triassic, Tschernyschew admits it to be " a very serious argument in favor of the intimate stratigraphic connection between the Trias and the Permian in the Salt Range, and the entire question relative to the discordance or transgressive nature of the beds appears to him [Noetling] impossible in such close association. " Tschernyschew answers that the total dissimilarities in the faunas of the Productus-limestone and the Ceratite beds of the Triassic, which are separated by only a few meters (in fact not a single species passing from one into the other, according to Waagen), cannot be accounted for, as Noetling thinks, by the changeable nature of the sediments at this level. " Such a sharp paleontological boundary is, rather, testimony for a transgressive superposition of the Trias on the Paleozoic of the Salt Range. "   He then states that numerous Paleozoic and Mesozoic examples of supposed continuity, with very similar lithologic deposits, were later shown by the Russian geologists to be discontinuous and transgressive, with great chronologic differences.   " With this I shall allow the matter to rest, adding the further statement that I believe the evidence cited by Noetling not to have the strength of sound proof in favor of a gradual replacement of the Permian sea in the Salt Range by the Trias, the sharp paleontologic boundary between these deposits indicating, rather, a transgressive superposition of the Scythian stage upon the Productus-limestone " (pp. 726–27).

As the Otoceras beds of the Himalaya, supposed to be transitional between the Productus-limestone and the Ceratites beds of the Salt Range, enter largely into the question whether the latter are not transgressive upon the former, Tschernyschew discusses the matter as follows :—

" What relation the zone with *Otoceras woodwardi* and *Ophioceras tibeticum* in the Himalaya bears to the section of

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* This genus is unknown in North America, and the author probably has reference to the related type *Campyloprion lecontei* occurring in Nevada. See Eastman, Amer. Nat., June, 1905, pp. 405–409.

the Salt Range is a problem that still needs a final solution. Paralleling it with the upper horizon of the Upper Productus-limestone, the correlation is primarily based on the identity of *Medlicottia wynnei* Waag. of the Salt Range with *M. dalailamæ* Diener, which Krafft (A. v. Krafft, Ueber d. perm. Alter d. Otoceras-stufe des Himalaya. Centralbl. f. Min., Geol. u. Pal., 1901, pp. 275–279) says represent but one species. However, as Waagen's original specimen is, according to Krafft, very badly preserved, this stated identity requires better material for its proof. It is all the more necessary to be careful, because in the Artinsk beds of Russia were found Medlicottias that much remind one of *M. wynnei* Waagen. In any event, before the correlations of Noetling (Neues Jahrb., Beil.—Bd. XIV, table facing p. 468) can be accepted it is necessary to prove an uninterrupted paleontological connection from the zone with *Cyclolobus oldhami* and *Hemiaspis carbonarius* to the beds with *Otoceras woodwardi*" (p. 727. See Noetling's recent work on the Otoceras beds of the Himalaya here reviewed).

Tschernyschew states that until the entire Permo-Carboniferous fauna of Russia is worked out, no positive correlation can be made, but for the present the equivalent as presented in the following table is the most probable (p. 728):—

	Salt Range		Ural and Timan
Upper Productus-limestone	Chideru beds Jabi beds Khund-Ghat beds	} Chideru of Noetling	Lower Permian of European Russia
			Limestone-dolomite horizon CPc and Artinsk beds CPg
Middle Productus-limestone	Kalabagh beds Virgal beds Katta beds	} Virgal of Noetling	Schwagerina zone, 50 to 60 meters
Lower Productus-limestone	Amb beds of Waagen and Noetling		Cora zone, 70 to 100 meters
			Omphalotrochus zone } 60 to 70 Spirifer marcoui zone } meters
	Warcha beds (Speckled sand and Lavender clay) Dandote beds Talchir bed (Bowlder clay)	} Pendschat of Noetling	Middle Carbon with *Spirifer mosquensis* of the east slope of Urals
			Conglomerate and breccia of east slope of Urals

Correlation with America.

Tschernyschew regards the McCloud limestone of the Shasta, California, region as the homotaxial equivalent of the Omphalotrochus horizon of the Ural and Timan. Further, he agrees with Professor Smith that this limestone is to be referred to the Lower Coal Measures. The fossils of the lower beds of the Pitt formation "remind one mostly of the Cora horizon of the Ural and Timan." "As to the analogues of the Schwagerina horizon it is difficult to state anything positively, although the extensive Pitt shales (about 2000 feet) may in part represent these beds of the Ural and Timan" (p. 700). Concerning the Robinson beds of Diller he states that "their age is near that of the Ural-Timan Cora zone."

Regarding Cummins's Texas section, this author says: "With some probability the Canyon and Strawn beds may be considered as analogous to our Ural-Timan Cora horizon, the Cisco and Albany beds to the Schwagerina zone. This is seen in the interesting paleontologic data obtained by Cummins and White in the Wichita and Clear Fork beds which overlie the Albany formation. The fauna gathered in the upper portion of the Wichita and in the lower part of the Clear Fork according to its development may be regarded as near that of the Artinsk of east and north Russia" (p. 702).

According to Prosser's work, Tschernyschew correlates the Kansas sections as follows: "The Wabaunsee and Cottonwood beds I have seen while on an excursion in Kansas in 1891, the former in the railroad quarry at the station Manhattan, and the latter in the Ulrich quarry in the same village. I should prefer to correlate both with the Cora horizon of east and north Russia. The Neosho beds and probably also the lower portion of the Chase series appear to be analogous with the Schwagerina horizon of Russia, and the remainder of this as well as the Marion beds must be regarded as homotaxial with the Russian Permo-carbon and the lower Permian. Finally, the Wellington and Cimarron beds may represent the lower red colored Permian series of east and north Russia" (p. 703).

"In Missouri and Iowa the character of the Upper Carboniferous sediments approaches the type developed in the Donetz basin,* and as in this region of Russia so in these states the Coal Measures were deposited in a relatively great sea closed toward the east, north, and south, that had connection only in

* For a detailed exposition of the Lower (C_1), Middle (C_2) and Upper (C_3) Carboniferous lithological and biological sequence, see Tschernyschew and Loutonguin, in Le Bassin du Donetz (Guide des Excursions, VII, Congrès Géol. Internat., 1897, Pt. XVI).

the west and southwest with that of the widely extended Upper Carboniferous sea of western North America." The Mississippian series "represents the entire lower and in all probability also a portion of the Middle Carboniferous divisions of Russia. . . . As has been stated above, the Wabaunsee beds are to be regarded as near the Cora horizon; we can not therefore ascribe a younger age to the Des Moines series, and they are in all probability at least in part equivalent to the Omphalotrochus horizon " (pp. 704–5).

"The Donetz type of sedimentation is still more typical in the profiles of the states Illinois, Ohio, and Kentucky. . . . At present one can only point out that a portion of the Upper Coal Measures of these States in all probability represents the beds of the Donetz basin, which on the basis of the latest researches may be regarded as the analogues of the Artinsk deposits of the Urals."

Tschernyschew then sums up his conclusions in the following table :—

Ural and Timan	California, Nevada, Utah, and Colorado	Texas and Arkansas	Kansas, Nebraska, Iowa, Missouri
Artinsk deposits	Shale and shaly limestone of the Wasatch Mountains and their pelecypod fauna	Wichita and Clear Fork beds	Marion beds
			Chase beds
Schwagerina horizon	Light colored limestone of the Upper Carboniferous	Albany and Cisco beds	Neosho beds
Cora horizon	Lower portion of Pitt shale series. Robinson beds. ? Weber quartzite		Missouri series and Cottonwood beds of Kansas and Nebraska Wabaunsee beds Oread limestone and Osage shales of Kansas
Omphalotrochus horizon	McCloud limestone Upper portion of Wasatch limestone	Canyon and Strawn beds	The series from Garnet to Oswego limestones of Kansas / Des Moines beds of Missouri

In this connection, it may not be amiss to give the opinion of one who has now devoted ten years to a study of American Carboniferous faunas, and who has had the great advantages of the U. S. Geological Survey,—Dr. George H. Girty.

"Tschernyschew also correlates the Russian section with that of the Mississippi Valley. His correlation may be correct, but the Pennsylvanian faunas of the latter area are so widely different from those of our Western States which the Russian ones most closely resemble, that, in the opinion of one who has had some acquaintance with both types, a precise correlation is, in our present knowledge, impossible. The beds placed in alignment by Tschernyschew contain faunas so widely dissimilar that it seems an act of temerity to group them together. The evidence for so doing consists in part of the occurrence of certain American species in the Russian faunas, but the identifications, if one may judge by the figures given, in some cases are questionable and in others consist of such long-ranged types that in view of the really small percentage which these forms bear to the entire fauna, the evidence appears of diminishing significance the more critically it is examined " (3, p. 24).

Part II.   The Work of Noetling.

1. *Ueber das Verhältniss zwischen Productuskalk und Ceratitenschichten in der Saltrange, Indien.* Von Fritz Noetling.   Centralblatt für Min., Geol. und Pal., 1904, pp. 321–327.

2. *Ueber Medlicottia Waag. und Episageceras n. g.,* etc.   Von Fritz Noetling.   Neues Jahrb., Beil.-Band XIX, 1904, pp. 334–376.

3. *Ueber das Alter der Otoceras-Schichten von Rimkin Paiar (Painkhanda) in Himalaya.* Von Fritz Noetling.   Neues Jahrb., Beil.-Band XVIII, 1904, pp. 528–555.

The first of these papers is a short summary of an earlier, very important and extensive discussion by the same author (4. *Beiträge zur Geologie der Salt Range,* etc., Neues Jahrb., Beil.-Band XIV, 1901, pp. 369–471), describing the sequence of the horizons closing the Paleozoic and their unbroken succession into the well-developed Lower Triassic of India.   Noetling's work has been assailed by one of the foremost geologists of Europe, and as the proper correlation of the Productus-limestone with European horizons affects the various formations composing the Permian system, it is well for Americans to become acquainted with these latest works, especially since Asiatic faunas are now known in southwestern Texas, California, and Alaska.

Noetling states : " Upon the Cambrian beds of the Salt Range there lies discordantly a sedimentary complex, followed by a series that Koken has established as of Jurassic age, in which there is no evidence of discontinuity, although during its deposition at various times very different physical conditions must have occurred.

" On the basis of origin, one can separate this sedimentary complex into three divisions of varying thickness, namely :

" An upper, pure marine ⎞
" A middle, glacio-marine ⎬ division.
" A lower, glacial ⎠

" . . . This arrangement is intended only to express the relative participation of ice and sea-water in these deposits. Nowhere do we see a stratigraphic break or discordance; through local intercalations of drift horizons, the lower glacial deposits, the stratified beds, and the Conularia layer are closely united with the glacio-marine division (Olive-sandstone and Lavender-clay), and from the latter there occurs a very gradual transition into the pure marine division.

" Again, three very unequal faunal divisions may be distinguished, namely:

" An upper division: characterized by an abundance of Ceratites.

" A middle division: characterized by an abundance of Paleozoic brachiopods and sparingly of Ammonites.

" A lower division: thus far without such fossils.

" These three faunistic divisions do not wholly agree with the three genetic sections. The lower division without fossils is of course in harmony with the glacial division, but the middle section embraces the glacio-marine and the lower portion of the marine divisions, while the upper member includes the upper part of the marine section. The following table will make this clear:—

" Genetic divisions	Faunistic divisions		Stratigraphic divisions
Pure marine beds	Characterized by the absence of Paleozoic brachiopods and the appearance of a great abundance of Ceratites	Paleozoic brachiopods absent. Ceratites occurring in abundance	Ceratite beds
	Characterized by the retreat of the Ceratites and the appearance of an abundance of Paleozoic brachiopods	Paleozoic brachiopods abundant. Ceratites rare	Productus limestone
Glacio-marine beds		Paleozoic brachiopods unknown Conularia fauna	Lavender-clay ⟋ Olive-sandstone
Glacial beds	Without fossils	Without fossils	Bowlder clay "

"The stratigraphic divisions represent the four or five great natural groups into which the Permian system of the Salt-Range is readily divisible, on the basis of the paleontological, lithological, and genetic characteristics."

"Naturally of greatest importance are the two groups of the upper marine division—the Ceratite beds and the Productus-limestone—for if the age of either of them can be satisfactorily determined, it follows that the age of the other is also fixed. In a general way, the age of these two groups is already established: The Productus-limestone, with its very remarkable abundance of Paleozoic Brachiopoda, must belong in the Paleozoic, while the Ceratite beds having the Ammonites characterized by Ceratite suture lines must be referred to the Triassic. However, the Productus-limestone was regarded as Carboniferous until the detailed description of the fauna by Waagen taught that this view must be decidedly modified. On my first trip to the Salt Range I noticed the gradual transition from the Productus-limestone into the Ceratite beds at Chideru; later I was able to extend this observation through the profile in the Chuas ravine, near Virgal; here can be plainly seen the individual lithologic members of the Productus-limestone and the Ceratite beds in most intimate succession. . . . Because of the indisputable succession at these two places I argued as follows: Such an intimate connection of Paleozoic and Triassic can only exist near the dividing line between the Permian and Triassic; if the Ceratite beds belong in the Triassic, then the underlying Productus-limestone must fall into the Permian, and accordingly, on account of the individuality of its fauna, it must represent but a single division of the Permian, but can not at the same time be the equivalent of both the Zechstein and the Rothliegendes."

The author then makes comparisons with other Indian Triassic regions, and also discusses the possibility that the Productus-limestone may be Upper Carboniferous. He concludes that if the Ceratite beds of the Salt Range are not Triassic, then the entire lower Trias is absent in the Himalaya. He maintains that the possibility of the Triassic being transgressive upon the Upper Carboniferous is excluded, because the transgression would then fall in the middle of an undisturbed sequence, i. e., in the Upper Productus-limestone. Further, if these deductions are not correct, then no reliance can be placed on the development of the suture lines of ammonites for the determination of geologic age (see below for his conclusions resulting from his studies on *Medlicottia*).

Noetling holds that there was a faunal transgression from the Urals, but that the time of its spreading was at about the middle of the Permian. "While this fauna was expanding radially, one can readily believe that the peripheral parts of

the transgression were younger than those of the pivotal region. In transgressions, one has to calculate not only with two dimensions, but also with a third, because a species may occur in geologically older beds near the center than at the periphery, where it may be found unchanged in younger deposits. . . . . It may be assumed that at the time of the Upper Carboniferous in the region of the present Urals, there existed an extended ocean, whose boundary was pushed toward the south and southeast (Uralic transgression). This transgression was not of a catastrophic or sudden nature, but was slow and continuous through a long period of time. The fauna spreading with the transgression passed, at least in part, unchanged into younger deposits ; while in the outermost boundaries of the transgression, in the Salt Range and in the Himalaya, there occurs a series of forms in beds that are younger than the same species found in the central region. This crudely stated hypothesis naturally collides, of course, with the theory of guide-fossils (Leitfossilien), but my long-continued studies in India, namely, in respect to the Tertiary fauna, have more and more convinced me that the rigid theory of guide-fossils, valuable as it is within restricted areas, always proves disappointing when applied to greater, more widely extended regions."

In the author's larger work of 1901, cited above (4), he fully presents his views regarding the sequence of the Indian Permian and Triassic sections and their correlation with that of Europe. Noetling, however, recognizes that the difficulties are great, for he states : " If the Permo-Triassic formations of the Salt Range had first been studied, it would never have occurred to anyone to draw a line in this unbroken series and to apply to the divisions two names. One would have regarded the series as a unit, which it is. . . . . If from these formations one had proceeded to seek the European equivalents, they would have been hard to force into the scheme framed for the Salt Range. Speculation of every sort would probably have been resorted to. I now find myself in an analogous position in forcing into the European scheme the Permo-Triassic series of the Salt Range, and if it is to be employed in this case then one must make a purely artificial separation " (4, p. 458).

From this work, the table of Plate I is compiled, giving the sequence of the formations, their terminology, thickness, and correlations with European standards ; the Himalayan section is added from Noetling's paper here numbered 3.

The second of these papers cited deals with the very important Permian ammonite *Medlicottia*. The genus is here studied in considerable detail and comparisons are made between the European and Indian species. The American forms are

not discussed, these being left to Prof. James Perrin Smith. In regard to the stratigraphic and evolutional conclusions attained by the author, he states:

" The views here presented are proved partly by ontogenetic, partly by phylogenetic examinations and observations, and therefore they may to a certain extent be depended upon. I must, however, note the assumption on my part that the Sicilian Fusulina-limestone is older than the Artinsk [= Permo-Carb. of the Russians] horizon, and again that the latter is older than the Productus-limestone of the Salt Range. By following out this assumption and comparing the various suture lines with one another, I obtained positive results which were proved by the development of the suture lines of *M. orbignyana.* This especially applies to the divisions of the external saddles " (p. 354).

" In this connection I would [first] like to point to an observation, which in spite of its scantiness permits of wholly unsurmised deductions regarding the climatic conditions at the close of Paleozoic and the beginning of Mesozoic time. In an earlier work I had the opportunity of propounding the question—Is the abundant appearance of *Productus* possibly connected with a cooler temperature of the sea-water?" [In Neues Jahrbuch, 1896, II, p. 86, this problem is stated as follows: "In India at least, but more particularly in the Salt Range, there was a glacial period at the beginning of Permian time. It would be interesting to examine the evidence to see if the great abundance of *Productus* has any connection with the cooler temperature of the sea-water."]

" A greater knowledge of the Paleozoic deposits of the Salt Range has given undoubted evidence of the existence of a Glacial Period at the beginning of Permian time, which deposits locally were laid down in the sea. [For a full bibliography and a good description of the late Paleozoic glaciation of India, see Noetling, Neues Jahrb., 1896, II, pp. 61–86.] In other words, this sea must have been one with a low temperature. Subsequently, in this sea was deposited the Productus-limestone, and the conclusion is not probable that the temperature of the water rose during the melting of the glaciers and the introduction of the *Productus*-fauna. In the Salt Range, therefore, this fauna is to be regarded as an arctic one.

" The studies of *Medlicottia* have shown that *M. primas* Waag. is in all probability to be regarded as a descendant of *M. orbignyanus* Vern. sp. of the Artinsk horizon. One can picture to himself the condition whereby the Medlicottias migrated from north to south (more correctly from northwest to southeast) at the same time that they passed into higher beds.

" If this conclusion is correct, i. e., the fact that a migration of the Ammonite world from north to south took place toward the end of the Permian, then, I ask, is it not conceivable that the *Productus*-fauna accustomed to a cold sea was, in consequence of the raising of the general temperature of the water, driven from its original northern habitat toward the south, where shortly before the disappearance of the Permian ice period it found the required normal temperature? Is it not further conceivable that, with a continued increase in the temperature of the sea, which under some circumstances may have occurred very rapidly, the Brachiopod fauna, also, may here have been suddenly exterminated, while the Ammonites, apparently better adapted to warmer water, developed in a most remarkable manner? Is it not, moreover, conceivable that the end of Paleozoic time was characterized by a probable rapid increase in temperature which spread itself from north to south? If this hypothesis is correct, we must then assume that the dividing line between Paleozoic and Mesozoic time is marked by a change of temperature which spread from the northern hemisphere, thus forcing the Paleozoic Brachiopoda southward, where for a short time in a suitable medium,—a sea cooled by the Permian glaciers, they attain a wonderful development, and then die out when the average temperature exceeded that beneficial to them " (pp. 375–6).

These suggestions of Noetling's are of the greatest interest. However, as *Medlicottia* occurs in Texas in association with an undoubted Upper Carboniferous fauna of the type so well known in the Mississippi valley, the question arises—Are not these the oldest Medlicottias? If so, then the further question is raised—Was not the migration east and west through the great mediterranean Thetys instead of from north to south? In 1901, Noetling (4, p. 457) explains this change of fauna on the basis of change in the depth of the sea. He states: " The Brachiopoda of the deeper waters died out and are replaced by the Ammonites, lovers of shallow waters and flat coasts."

It is the impression of the reviewer that, until more is known in regard to the extremely interesting Productus-limestone fauna of the El Paso, Texas, region and similar or Artinsk faunas from California and Alaska, no safe deductions as to paths of migration can be made.

From the third paper by Noetling, on the Otoceras horizon, is gleaned the following :—

" In a treatise on the divisions of the pelagic Trias, Mojsisovics, Waagen, and Diener, supported by the statements of Waagen that there exists a hiatus in the Salt Range between the uppermost Permian and the lowest Trias, have denied the

existence of the Otoceras beds or their equivalents in this part of the Trias sea.

" I had serious doubts about this conclusion, for on my visit to Chideru in the Salt Range I was convinced that there is here a gradual transition from the Upper Productus-limestone (Permian) to the Ceratites beds (Trias).

" This observation is not new, for at different times Wynne has pointed out the gradual passage in the sequence of the beds from the Productus-limestone to the Ceratites beds, but his statements have unfortunately received too little attention " (p. 529).

On this visit Noetling looked for the Otoceras beds at the base of the Ceratites zone below the Ceratites-limestone, but did not find this diagnostic fossil. To his great surprise he did find what he took to be an *Otoceras* in the Ceratites-shale, i. e., above the Ceratites-limestone. On his return to the museum at Calcutta, however, the fossil proved not to belong to this genus. After a further dissection of the Himalaya section he states : " In the Himalaya the Otoceras beds lie immediately below the Hedenstroemia beds. Accordingly, in the Salt Range, either the Otoceras beds or their equivalents must be looked for immediately beneath the Ceratites beds. As, however, in the Salt Range, immediately beneath these beds lies the Permian (Upper Productus-limestone = Chideru group) it follows that we have to seek for the equivalents of the Otoceras beds in the Salt Range in the Upper Productus-limestone, probably in my *Euphemus indicus* zone, but over the zone with *Episageceras wynnei*." In spite of careful collecting none were found, and he concludes : " According to our experience we almost doubt the occurrence of *Otoceras* in the region of the Salt Range." The two regions have a different stratigraphic sequence with somewhat different faunas, and it may be that they were separated from one another by a submerged barrier (a rising anticline) not wholly preventive of intermigration.

Then follows a long discussion of the apparently complete transition zone in the Himalaya, between the Productus-limestone and the Ceratites beds, and considerable detail regarding the included fauna as well. This discussion is entirely too long and too detailed to be summarized here, but Noetling's views are clearly presented in two correlation tables, one of which has been added to the table given on Plate I.

<div align="center">[To be continued.]</div>

PLATE 1
Horizons and Zonal Names

				Salt Range			Himalaya	
				Discordance			Region of Spiti	Region of Niti
Triassic	Buntsandstein	Scythian stage	Upper	Upper Ceratite limestone	Zone of *Stephanites superbus*	Maximum thickness	Not known as yet	Dark limestone of Byans
			Lower Middle	Ceratite sandstone	Zone of *Flemingitrs flemingianus*		Hedenstroemia beds	Hedenstroemia beds
				Ceratite clay	Zone of *Koninckites volutus*	220'		
					Zone of *Prionolobus rotundatus*			
				Lower Ceratite limestone	Zone of *Celtites* (?) sp.		Zone of *Meekoceras litangense*	Zone of *Prionolobus noettlingi*
Permian	Marine Neozóyas	Zechstein	Thuringian stage	Chideru group or Upper Productus-limestone Brown earthy limestone	Zone of *Euphemus indicus*		Zone of *Ophiceras tibeticum*	Zone of *Ophiceras tibeticum*
					Zone of *Episageceras wynnei* 50'		Zone of *Otoceras woodwardi*	Zone of *Episageceras dalailamæ*
								Zone of *Otoceras woodwardi*
					Zone of *Bellerophon impressus*	300'		
					Zone of *Cyclolobus oldhami* 180'		Dark Productus slates with *Cyclolobus oldhami*	Dark Productus slates with *Productus abichi*
					Zone of *Derbya hemisphaerica*			
					Zone of *Productus lineatus* 70'			
	Marine Palaeozóyas			Virgal group or Middle Productus-limestone Light colored flinty limestone	Zone of *Xenodiscus carbonarius* 20'			
					Zone of *Lyttonia nobilis* 130'	300'		
					Zone of *Fusulina kattaensis* 50'			
					No *Fusulina* occur higher than this stage			
				Amb group or Lower Productus-limestone Dark, sandy limestone	Zone of *Spirifer marcoui* and *Fusulina* 200'			
	Glacial Palaeozóyas	Rothliegendes	Pandschabian stage	Warcha group	Lavender clay Speckled sandstone	250'		
				Dandote group	Olive sandstone Zone of *Conularia laevigata* In shale Zone of *Eurydesma globosum* Olive sandstone	200'		
				Talchir group	Bowlder-clay	150'		

Discordance
Cambrian

Art. VIII.—*Note on two interesting Pseudomorphs in the McGill University Mineral Collection;* by R. P. D. Graham, B.A.

1. *Pseudomorphs of Orthoclase after Laumontite from Templeton, Ottawa County, Quebec.*

The specimens described below were collected some years ago by Dr. B. J. Harrington in the apatite region of Templeton, and had been labelled by him as pseudomorphs after laumontite, although they were not further examined at the time. They consist chiefly of flesh-red to almost white crystals, measuring up to about half an inch in length for the most part, and having a very fresh appearance. the edges being quite sharp and the faces smooth with a dull and somewhat waxy lustre, although in some cases they are somewhat weathered on the surface. They are of the usual laumontite habit (fig. 1) showing a combination of monoclinic prism with basal plane. The faces do not directly yield reflections owing to their dull lustre, but by placing a drop of alcohol on each in succession, after adjustment on the reflecting goniometer, and taking readings at the moment when the drop is just about to disappear (as suggested by H. T. Whitlock*), the angles can be measured with a fair degree of accuracy, and they were found to correspond with those of laumontite. The crystals are implanted in irregular groupings in a compact material of a rather paler tint, but possessing the same general characters, and this in turn encrusts the dark green pyroxene and brownish phlogopite which are characteristic of the Templeton locality. The pyroxene is in the form of large prismatic crystals, an inch or so in diameter, and both this mineral and the phlogopite are more or less completely coated with a layer a quarter of an inch thick of the pale-colored massive material from which the pseudomorphous crystals spring; there are also dispersed through it fragments of a pale green apatite, and in one of the specimens, a crystal of zircon. The prism faces of the crystals are usually striated vertically and sometimes exhibit a step-like structure along the directions of the original laumontite cleavages, which, however, are now entirely lacking. The fracture is fairly even, and the crystals are solid and homogeneous throughout; in physical characters they correspond exactly with the feldspar: $H = 6$, Sp. G. $= 2.56$. Thin splinters fuse B. B., the pink color fading to white; and
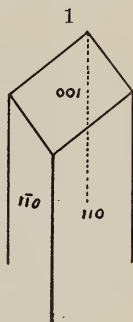
* N. Y. State Museum Publication, 1905.

only a slight trace of water is given off on heating in a closed tube. The finely powdered mineral is insoluble in acids, and a preliminary examination of the solution obtained after fusion with a mixture of sodium and potassium carbonates showed that it contained no fluorine or chlorine. An analysis was made of material selected from some of the freshest crystals with the following result (column I):

	Templeton. I.	Weissig. II.	Orthoclase. III.
SiO_2	63·12	65·00	64·7
Al_2O_3	19·83	19·54	18·4
Fe_2O_3	0·67	——	
CaO	—·—	0·19	
MgO	0·24	1·61	
K_2O	15·13	12·69	16·9
Na_2O } Li_2O }	0·52	0·56	
Ign.	0·89	0·35	
	100·40	99·94	100·0

The sodium and lithium, which are present in only very small amount, were not separately determined, but the presence of both was shown by a spectroscopic examination of a solution in hydrofluoric acid. In containing a small percentage of lithium, this occurrence resembles the original weissigite from Dresden, the result of an analysis of which by Jenzsch is given above for comparison (column II).

The crystals are therefore pseudomorphs of orthoclase after laumontite and the compact material in which they are embedded doubtless had a like origin.

Although such pseudomorphs have not been described before from a Canadian locality they have been found in several other districts, and the following account of some of these occurrences is taken mainly from Blum's treatise on pseudomorphs.*

In 1853, Jenzsch† examined a mineral which occurs at Weissig, near Dresden, and which he found to have the composition of an orthoclase with a content of about one-half a per cent of lithia (see his analysis quoted above) as well as the general characters of a feldspar, the hardness being 6 and the specific gravity 2·55: these facts, together with the characteristic form of the crystals, combinations of monoclinic prism with basal plane, led Jenzsch to regard the mineral as a distinct species, to which he gave the name *weissigite* in reference to the locality at which it occurs. Weissigite, however,

* Die Pseudomorphosen, II, 20; III, 60.
† N. Jahrb. f. Min., 396, 1853; 405, 1854; 800, 1855.

is found in a porphyritic amygdaloid, associated with quartz and chalcedony, conditions under which a feldspar had never been known to occur up till that time; this, and the similarity of the form and habit of the crystals to laumontite subsequently convinced Jenzsch that the orthoclase was not a primary mineral in the amygdules, but that weissigite is in reality a pseudomorph of orthoclase after laumontite, which was the view held by Blum.

Similar pseudomorphs are mentioned by Blum as occurring at Niederscheld, near Dillenburg in Nassau. Flesh-red crystals of the common laumontite habit are dispersed through the greenstone, associated with quartz, which often completely envelops them; calcite and prehnite are also present in small quantity. The prism faces of the crystals are striated vertically, and the crystals are often more or less split along the directions of cleavage of the original laumontite: the alteration to orthoclase is seldom complete. Specimens of the same kind are also found at Schelder Eisenwerk, and at Oberscheld, where crystals an inch in length occur in a druse.

At Beilstein whole druses of pseudomorphs of orthoclase after laumontite occur in an altered diabase; the crystals, which are sometimes more than an inch long, have their original form well preserved, and show the usual striæ and cracks along the prism faces; and their pseudomorphous nature is also evident from the hollowness of many of the crystals. There is an almost identical occurrence at Conradsreuth, between Münchberg and Hof in Fichtelgebirge.

Laumontite is among the minerals found in the Lake Superior mining region of Michigan, where it occurs in clefts, coated, often completely, by calcite, and sometimes also by native copper. The laumontite is weathered and shows various stages of alteration, and has been analyzed by Lewinstein[*] with the following results; I refers to a brownish laumontite which readily crumbles, breaking along the cleavage directions, whilst II is of a more weathered material which has become firm and hard, and no longer possesses cleavage.

	I.	II.	Laumontite.
SiO_2	57·92	55·21	51·1
Al_2O_3	10·19	22·58	21·7
Fe_2O_3	1·19	2·55	
CaO	4·59	0·98	11·9
MgO	1·13	1·31	
K_2O	2·58	3·41	
Na_2O	1·14	3·45	
H_2O	21·26	10·51	15·3
	100·00	100·00	100·0

[*] Zeitschr. f. Chem. u. Pharm., iii Jahrg., 1860, p. 11.

These analyses were made by dissolving as much as possible of a weighed quantity of the mineral in acid, and calculating the results up to 100 per cent after deducting the weight of the insoluble residue. Hence they do not show the actual composition of the material taken, although they serve to indicate that the percentage of lime falls off more and more as the alteration proceeds, as also does that of the water once the hardening of the material has commenced, whilst the alkalis make their appearance in increasing quantities, rendering probable the assumption that the crystals are partial pseudomorphs of feldspar after laumontite. Sharp, well formed crystals of adularia, exhibiting the forms $\{110\}$, $\{001\}$, are also found at Lake Superior, situated on calcite and native copper, and these have also been regarded as probably due to the alteration of laumontite. On the other hand, J. D. Whitney[*] has called attention to the very common occurrence of orthoclase in all the mines of this region; he describes the crystals as being rarely more than a few hundredths of an inch in length, of a reddish color, arranged in bunches and geodes, and accompanied by native copper and the zeolites, the usual vein minerals of the region. From a consideration of the relative manner in which these minerals are associated with one another, Whitney concluded that in this case the orthoclase was formed contemporaneously with the accompanying minerals, and that it is not a pseudomorphous product of the zeolites; from which it would appear that orthoclase does occur in the veins at Lake Superior as a primary mineral, associated with the zeolites, etc., although, at the same time, the adularia crystals referred to above may have had a different and secondary origin, as Blum has suggested.

It is doubtful whether orthoclase has ever been found replacing laumontite at any of the well known Scotch localities for that mineral, notwithstanding the fact that such pseudomorphs have been described or referred to by several authors. In 1848, Haidinger[†] examined a number of altered zeolites from Allan's collection in Edinburgh, among which were some flesh-red crystals having the angles of laumontite but the hardness (6) and the specific gravity (2·5 to 2·8) of feldspar; the crystals had drusy surfaces and were ill-defined, and in addition were frequently hollow or else filled with a dark green stony material. These specimens were found in the trap rock, associated with quartz, at the Kilpatrick Hills, near Dumbarton, and also at Calton Hill, Edinburgh. Haidinger described them as pseudomorphs of feldspar after laumontite, apparently relying on qualitative tests in their determination, since he

[*] This Journal, xxviii, 16, 1859.   [†] Sitz. Akad. Wien, iii, 95, 1848.

gives no quantitative analysis of the material in the paper referred to. It is quite possible, however, that they were pseudomorphs of albite, and not orthoclase, after laumontite; and Greg and Lettsom quote an analysis by Heddle of such pseudomorphs from Kilpatrick, which have the composition of a soda feldspar containing about one per cent of potash. Hintze, however, under *orthoclase*, mentions pseudomorphs after laumontite as occurring at Kilpatrick, and in the same paragraph refers to an analysis by Bischof which he appears to suggest was made on material from this locality. The same analysis is given by Blum, although that author does not expressly state where Bischof obtained his specimens, and on referring to Bischof's original paper* I find the same uncertainty exists even there, as it is not at all clear where the material he analyzed came from. The additional fact that Greg and Lettsom make no mention of pseudomorphs of orthoclase after laumontite in their *Mineralogy of Scotland* which appeared in 1858, several years after these observations of both Haidinger and Bischof, lends considerable probability to the view that such pseudomorphs had not at that time been found in Scotland, but that in all the observed cases the replacing mineral had been albite; nor are pseudomorphs of orthoclase after laumontite included in the list of *British Pseudomorphs* published by Prof. Miers† in 1896. However, a variety of orthoclase does occur at Kilpatrick, which was named *erythrite* by Thomson‡ in allusion to the flesh-red color; this he described as a compact feldspar, which he never observed in crystals, but there is nothing in his description to suggest that this was of a pseudomorphous nature.

It will be seen from the foregoing that pseudomorphs of orthoclase after laumontite are of fairly wide occurrence, although in the specimens from many of the localities the alteration seems to be incomplete, and the crystals often more or less hollow; but in the case of the specimens from Templeton described in this note, the crystals are invariably quite solid and compact, and, except in the form, show no trace whatever of a former existence as laumontite material. In this complete alteration to orthoclase, and, further in the small content of lithium, the mineral resembles the original *weissigite*.

The reverse change, from orthoclase to laumontite, has been observed from at least one locality, the Höllenstein-Klamm, Florenthals, Tyrol, where more or less altered adularia crystals, usually coated with chlorite, are found.

* N. Jahrb. f. Min., 43, 1850.   † Min. Mag., xi, p. 263.
‡ Phil. Mag., xxii, p. 188, 1843.

2. *Pseudomorph after corundum from Perth, Ontario.*

The specimen here described is an unusually large and well developed crystal of which a photograph is reproduced (fig. 2); it is about 5 inches in length and the prism has a diameter of 2 inches. At first sight it somewhat resembles a crystal of

2 3
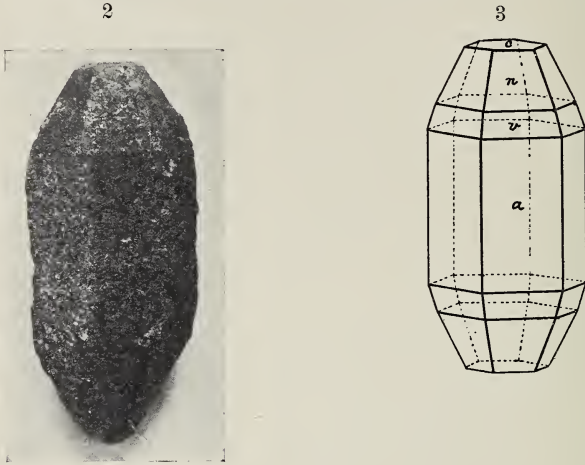
black quartz with rough surfaces, the predominant forms being the hexagonal prism and bipyramid, but it is terminated at one end by a fairly flat basal plane. It is also found, on closer inspection, that the edges between the prism and pyramid are truncated by faces belonging to a steeper pyramid, although these can scarcely be distinguished in the photograph; the lower end of the crystal presents a somewhat blunted appearance. The various angles were measured by means of the hand goniometer, and were found to be those of a corundum crystal, the forms present being:—a $\{11\bar{2}0\}$, n $\{22\bar{4}3\}$, c $\{0001\}$, and v $\{44\bar{8}3\}$ (fig. 3).

The crystal is almost entirely coated with black tourmaline, usually as a compact granular layer forming a fairly smooth surface; but sometimes the grains are more distinct and have bright facets, by which the mineral can be identified, as well as by the strong pleochroism under the microscope. On one side of the specimen (the left hand of fig. 2), however, the crust consists of rounded grains of a soft, pale apple-green mineral, associated with some pink calcite. From the low specific gravity of the crystal ($G = 2 \cdot 6$ about) it was evident that very little, if any, of the original corundum remained unaltered in the interior, and the specimen was accordingly

sawn in half at right angles to the prism; it was found that the tourmaline forms a thin outer shell (except on one face, as noted above) whose thickness is very uniform and seldom exceeds 1^{mm}, and that no visible trace of the original corundum exists. The interior is filled with a pale green material, having a greasy feel and a hardness between 2 and 3, which is, in fact, identical with that which forms the outer surface on one side of the crystal; dispersed through this are a few patches of white to pink calcite, and numerous minute scales of pennine and of a silvery white mica (damourite); there are also one or two small patches of the granular black tourmaline. For the most part, the green material appears quite compact on the smooth surfaces obtained by cutting through the crystal, but on a broken surface it has a more definite prismatic structure, with a pair of fair cleavages inclined at about 90°. The cleavage angle of these prisms could only be determined approximately by maximum illumination measurements owing to its irregularity and the dull lustre. Thin flakes are translucent but exhibit no definite optical characters under the microscope. The specific gravity is about 2·6 and the streak white. The mineral fuses easily and quickly in the Bunsen flame to a white glass, and gives off water when heated in a closed tube; it is insoluble in acids. Owing to the intimate mixture with calcite, and especially to the presence of the small pennine and damourite flakes, it is difficult to select a pure sample for analysis, and the material used may possibly have contained small amounts of these minerals. A single analysis gave the following:

$$
\begin{array}{lr}
SiO_2 & 43\cdot05 \\
Al_2O_3 & 30\cdot28 \\
Fe_2O_3 & 3\cdot30 \\
MnO & 0\cdot49 \\
CaO & 1\cdot85 \\
MgO & 6\cdot70 \\
K_2O & 3\cdot68 \\
Na_2O & 0\cdot92 \\
Ignition & 10\cdot70 \\
\hline
& 100\cdot97
\end{array}
$$

The above analysis serves at least to show the approximate composition of the pale green material which constitutes the main portion of the interior of the crystal, so far as can be judged from the surface exposed by sawing through the specimen. This appears to be a mineral of indefinite composition belonging to the pinite group. In view of its (probable) rectangular cleavages, it may be noted that this mineral

approaches in chemical composition to wilsonite and other pseudomorphs after scapolite, which it further resembles in having a low fusibility and a density of about 2·6; indicating that the pinite may here also be an alteration product of scapolite. The presence of calcite dispersed in patches throughout the mass would be well in accord with such a replacement.

It would seem, then, that the original crystal of corundum was first coated with a thin layer of granular black tourmaline; that the corundum kernel subsequently underwent a pseudomorphous change to some mineral having cleavages at 90° or nearly 90,° such as scapolite, and that this in turn became altered to pinite. I have not, however, been able to find any description of, or reference to, pseudomorphs of scapolite after corundum.

The exact locality of the specimen is not known, but it comes from the apatite region of Perth, Ontario, and it is interesting that a cavity in one of the prism faces contains a little transparent apatite of a pale greenish yellow color.

The pseudomorph is especially remarkable on account of the size, and the sharp outline and regularity of the crystal, in which respects it differs much from the majority of corundum crystals from Canadian localities, these being usually much smaller and not so well developed.

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Art. IX.—*The Estacado Aërolite ;* Description by Kenneth
S. Howard ; Analysis by John M. Davison.

I

The aërolite from Texas recently obtained by Ward's Nat-
ural Science Establishment, as noted in the February issue of
this Journal, has been brought to Rochester, sliced, and
analyzed chemically and petrographically.

What is known concerning the fall of this meteorite is told
by a resident of Hale Center, Texas : " The best history I can
give of the meteorite is as follows : It was found twelve miles
south of Hale Center, which is located in the center of Hale
County, Texas, in the spring of 1902, or rather that is when it
was taken home by R. A. McWhorter, who has been the owner
of it all the time. In the year of 1882 a bright meteor was
seen one night by the people of a Quaker colony called Esta-
cado. This place is about fifteen miles southeast of where the
meteor was found. The meteor was seen to pass to the west
and fall northwest from them. At that time this Quaker col-
ony was the only settlement on the whole Staked Plains, and
the only people outside of them were a few scattering cowmen.
In the following year of 1883 a few cowboys, in rounding up the
range, saw this meteor and the Estacado people felt certain
that this was what they saw fall the year before, and we have
all considered it so." As the region is a stoneless one, the
attention of the people of the vicinity were naturally attracted
to this remarkable mass. The name of the settlement, Esta-
cado, seems most appropriate for the aërolite.

The weight of the meteorite before sawing was about two
hundred ninety kilograms, it thus being among the largest of
known aërolites. Its form was trapezoidal, as shown by the
photographs. Its longest diameter was 58·5^{cm}, while its other
two diameters measured 45·7^{cm} and 44·4^{cm}. It was cut in half
parallel to its longest and shortest diameters. Several slabs
were taken off at the same time, one of them being shown in
photograph 3. The greatest vertical diameter of this slab is
about 18^{cm} back of what was apparently the "nose" of the
meteorite.

The exterior of the mass is rusty brown in color, probably
due to terrestrial oxidation. The sawed slices of the stone
show a tendency to rust rapidly. Hardly any of the coating
of the meteorite approaches in appearance the black of an
original crust. On some of the sides the oxidation has been
considerable, a scale knocked off of one side being 3 to 4^{mm}
thick. As shown by the photographs (figs. 1, 2), the mass has

FIGURE 1.

FIGURE 2.
The Estacado Aërolite.

eight well-marked sides, one of which (F in photograph 3) looks like an old fracture surface. The oxidation on this side is less than elsewhere and there is no apparent variation in structure as the edge is approached, such as there is on the other sides. The sides are quite flat, some of them even slightly concave, the edges between adjoining sides being, for an aërolite, fairly angular.

Side A has a smoothed appearance and may have been the "nose" of the mass in flight. The surface markings on this
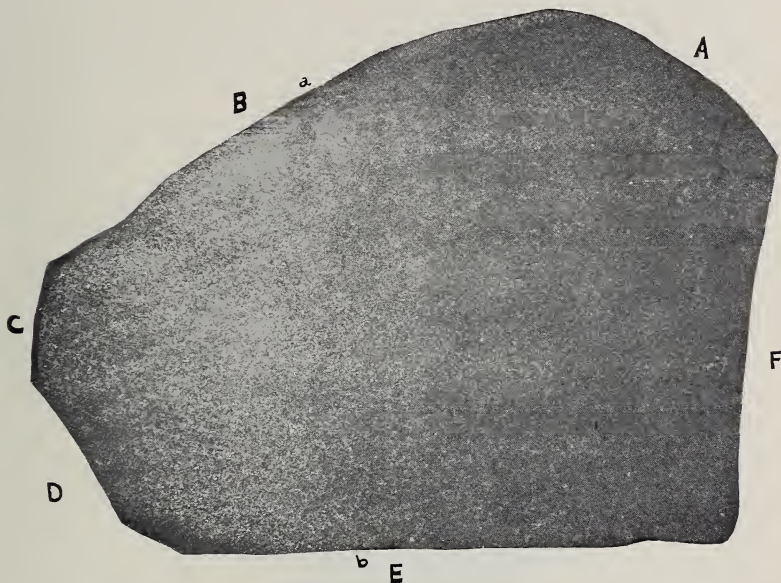
FIGURE 3.   Longitudinal slice of Aërolite.

side are not deep, while on sides D and E, which are opposite A, there are well defined pittings.

The stone is a crystalline chondrite, its structure being very similar to the Pipe Creek aërolite, which is also from Texas. In Brezina's classification Pipe Creek is placed in group Cka.

The slab shown in the photograph is 53.4^{cm} in length and 40.6^{cm} in height. The polished surface shows a dull black ground mass thickly permeated with irregular particles of nickel iron. Roundish enstatite chondrules of a more shiny black are scattered through the stone. Here and there are green olivine chondrules, some of which are larger than any of the black chondrules. The largest of the green ones, which is in the center of the slice shown in the photograph (fig. 3), measures about 1^{cm} in length.

The slice also shows some other interesting markings. Some five centimeters from the center toward the smaller end a straight dark line (ab) runs across the meteorite at an inclination of about 15° from the vertical. It passes just to one side of one of the olivine chondrules shown in the photograph. Parallel to, and 15^{cm} from, side A is an irregular and somewhat broken line composed of the metallic particles. This line runs from the edge of side F nearly to the edge of side B.

The line also shows on some of the other slabs, and on one of them, just before it reaches the edge of side B, it turns and runs parallel with the edge for a couple of centimeters. On the various slabs the metallic lines are at different distances
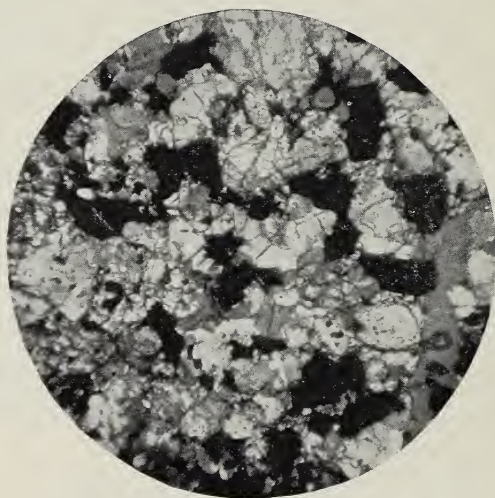
FIGURE 4. Micro-section. ×40.

from side A, indicating that a seam of this material passes through the meteorite obliquely to the cut surface. From the edge of side F, which shows comparatively slight oxidation, three indistinct veins run into the meteorite. They are black, indefinite in outline, and somewhat branching.

A petrological analysis by W. Harold Tomlinson of Germantown, Pa. shows that the mineral constituents are olivine and enstatite. Some pyrrhotite was also found. Mr. Tomlinson remarks : " The olivine and enstatite occur both as grains and as chondri. The grains of olivine contain frequent inclusions of smaller grains and of iron, and occasionally have gase-

ous inclusions. The inclusions in the enstatite are generally parallel to the cleavage." He found the specific gravity to be 3·60. The microphotograph (fig. 4) was made between cross nicol prisms, the magnification being about forty diameters.

II

Chemical Analysis by John M. Davison.

The specific gravity of the Estacado aërolite is 3·63. The metallic part was separated with a magnet, and the slight amount of adhering stony matter determined and deducted.

The stony part was separated by hydrochloric acid into a soluble and an insoluble portion. The insoluble portion was digested with a solution of Na_2CO_3 and the dissolved SiO_2 added to that dissolved by HCl. This analysis gave

Metallic		16·41	per cent.
Stony	Soluble in HCl	41·09	"
	Insoluble in HCl	42·50	"

100

Analyses of these, omitting minor constituents and calculated to 100, gave

Metallic.		Soluble in HCl.		Insoluble in HCl.	
Fe	89·45	SiO_2	32·00	SiO_2	63·57
Ni	9·99	MgO	32·02	MgO	23·45
Co	0·56	FeO	31·60	FeO	9·54
		CaO	4·38	CaO	3·44
	100		100		100

The stony part appears to be mainly olivine and enstatite. The analysis of the entire mass gave the following percentages:

Fe	14·68	Al_2O_3	3·60
Ni	1·60	Na_2O	2·07
Co	0·08	K_2O	0·32
Cu	trace	TiO_2 found but not determined	
C found but not determined		Cr_2O_3 " " " "	
S	1·37	MnO " " " "	
P	0·15		
SiO_2	35·82		100·95
FeO	15·53	Less O for S	·68
MgO	22·74		
CaO	2·99		100·27

Of the S found 0·82 per cent came from the metallic and the portion soluble in HCl, and 0·55 per cent from the insoluble portion fused with Na_2CO_3. In this fusion the crucible was screened by a close fitting asbestos board, and a blank experiment showed that there was no contamination from the gas flame. This distribution of the S would indicate that nearly half of the troilite was embedded in the enstatite protected from action of acids.

From 3·9597 grams of the aërolite 0·025 gm. of chromite was separated by repeated treatment with HFl and other acids. With the chromite were a few minute particles of a transparent colorless mineral that had survived this usage, though evidently attacked.

Search was made for ZrO_2, with negative result.

Art. X.—*On Stibiotantalite;* by S. L. Penfield and W. E. Ford.

Historical.—Stibiotantalite was first described by G. A. Goyder[*] in 1892 and more minutely in 1893, as occurring in rounded water-worn fragments in the tin-bearing sands of Greenbushes, West Australia. No crystals were observed, but it was evident from the cleavage of the material and its action on polarized light that it possessed a crystalline structure, and it was assumed that it belonged to the orthorhombic system, though no convincing evidence was brought forth. An analysis, which is quoted later in this article, indicated that the mineral is essentially a combination of oxides of antimony and tantalum, with some niobium and a very little bismuth, but no formula was suggested. The physical properties were given as follows:—Hardness, 5 to 5·5. Specific gravity, 7·37. Luster, adamantine to resinous. Color, pale reddish-yellow to greenish-yellow. Fracture, subconchoidal to granular. Within the past few years a considerable quantity of this material has become available to collectors through the agency of several mineral dealers.

Crystals from Mesa Grande, San Diego County, California, a New Locality.

The material from Mesa Grande was brought to the attention of the present writers by Mr. Ernest Schernikow of New York. It was observed by him as occurring very sparingly with the wonderful tourmaline crystals found at the locality and described by Sterrett,[†] and great pains were taken to have every crystal and fragment carefully saved. In all, some twenty-five crystals have been found, representing several years savings from a vast amount of material, so it may be considered a rare mineral at the locality. Associated with it, besides the tourmaline already referred to, are large and wonderfully beautiful crystals of pink beryl of unusual habit, fine crystals of quartz, orthoclase and lepidolite, and, as a great rarity, cassiterite. The orthoclase is generally kaolinized to a considerable extent. Several crystals of stibiotantalite were observed grown on to, or over, pink tourmaline; one group has attached to it a little feldspar and lepidolite; the others are all detached crystals and some of them are doubly terminated. None of the detached crystals show fresh fractures, and they evidently were found loose in the deposit. Stibiotantalite appears to be

[*] Proceedings Chem. Soc., 1892, 9, p. 184. Journal Chem. Soc., 1893, lxiii, p. 1076.
[†] This Journal (4), xvii, p. 459, 1904.

of later origin than the tourmaline and lepidolite, though undoubtedly it was one of the primary minerals of the deposit.

The crystals are mostly of a rich dark-brown color, with resinous to adamantine luster. Fragments look exactly like the resinous variety of sphalerite, and a few pieces were found of light brown color, transparent, and so closely resembling the well known sphalerite from Picos de Europa, Spain, that by appearances the two can not be told apart.
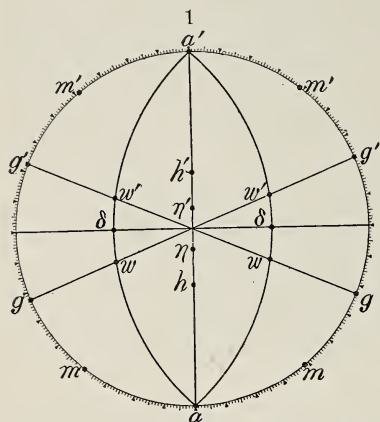
Stibiotantalite crystallizes in the orthorhombic system and is hemimorphic. With few exceptions, the habit of the crystals gives no suggestion of hemimorphic development, which, according to the orientation adopted, is in the direction of the brachy- or *a*-axis. All the crystals that have been studied are polysynthetic twins, thus causing them to imitate the symmetry of the normal group. In habit they resemble columbite, and, as will be shown, the two minerals are related both in chemical composition and axial ratio. In order to bring out the crystallographic relationship, however, it has been necessary to assign rather complex symbols to some of the forms of stibiotantalite, but it is believed that it is better to do so than to give simpler symbols to the forms and refer them to other axes. The axial ratio of the two minerals are as follows:

Stibiotantalite _____ $a : b : c = 0 \cdot 7995 : 1 : 0 \cdot 8448$
Columbite _____ $a : b : c = 0 \cdot 8285 : 1 : 0 \cdot 8897$

The forms observed on stibiotantalite are shown in stereographic projection in figure 1, but, owing to polysynthetic twinning, it is impossible to state as regards some of them whether they occur both in front and behind, or intersect only one end of the brachy-axis, as demanded by hemimorphism. The symbols are as follows:

a (100)	η (209)
a' (Ī00)	η' (Ī09)
m (110) or (Ī10)?	h (203), probably also h' (Ī03)
q (130)	δ (043)
q' (Ī30)	w (4·12·9) probably also w' (Ī·12·9)

The only crystals observed which exhibit a marked hemimorphic development are represented in figures 2, 3 and 4. They are orientated according to pyroelectric deportment, the a faces to the front all developing negative electricity on cooling, as tested by the carmine-sulphur-lycopodium mixture suggested by Bürker.[*]   The crystal shown by figure 2 has at the top two ridges and a valley, but no reëntrant angle at the sides : The two ridges on cooling develop positive, and the valley negative electricity.   This crystal is a polysynthetic twin, and may be taken as a type for illustrating the structure of other crystals.   The vertical axis is the twinning axis, and the macropinacoid a the composition face.   If it is assumed as in figure 5 that a hemimorphic crystal has the prism g (130) and the dome η (209) intersecting the front end of the a-axis only, a lamella in twin position, figure 6 (as indicated by the letters underlined), would give a ridge and a valley at the top, corresponding to figure 2, but also reëntrant angles at the sides, which do not occur on the crystal shown in figure 2.   It seems therefore necessary to assume that, in addition to g to the front, there is a corresponding g' ($\bar{1}$30) behind and, as will be shown, also, an η' ($\bar{2}$09) behind, figure 7 : These forms appear in twin position as shown in figure 8, and an interspersed twin lamella, as in figure 9, may then show at the sides the prism g' corresponding in direction with g.   The prism lettered g, figure 2, is therefore to be regarded as a composite face, composed partly of g and partly of g'.   At the top of such a crystal there may be, as in figures 2 and 9, a ridge and a valley, provided that in the twin lamella there occurs in connection with g' not η' sloping to the front but η sloping behind.   As a matter of fact, only a few of the crystals

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show reentrant angles at the top, and the faces of later figures lettered η or η' must in reality be regarded as composite, made up partly of η and partly of η'.

Figures 3 and 4 both show hemimorphic character by the development of η' behind, but this face is in reality composite, composed in part of η in twin position. Figure 3 shows prominent reentrant angles at the sides, compare figure 6: none of the other crystals show these so prominently,

and as a rule reentrant angles are so small as to give the effect of fine striations parallel to the vertical axis, or a rounding of the obtuse edge between g and g', as if resulting from oscillatory combination, figure 4. The crystal represented by figure 4 is the only one showing any prominent development of a replacement of the edges between a and g; the form, however, is so striated and distorted by the development of vicinal faces that no satisfactory measurements could be obtained; it approximates to (301) respectively ($\bar{3}01$), but the symbols are
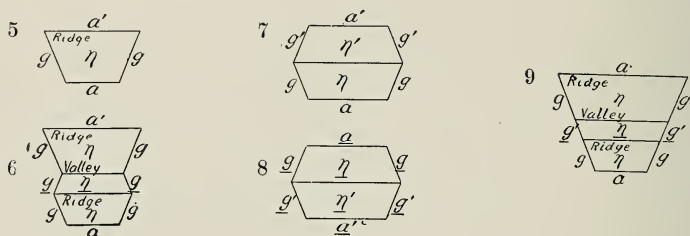
questionable. The pyramid w is developed to so slight an extent and the crystals are so complicated by polysynthetic twinning that it is impossible to state whether it occurs only in front or only behind; hence it is assumed that both forms, w (4.12.9) and w' ($\bar{4}.12.9$), are present. With the exception of the three crystals just described, the general habit is like that of the normal group of the orthorhombic system, as illustrated by figures 10 to 13, in which the forms are represented with ideal symmetry, whereas they all show vertical striations on the pinacoid and prism faces, and some rounding of the edges between g and g'. One crystal only, figure 12, is shorter in

the vertical than the horizontal direction. The largest crystal of the types illustrated is shown in about natural size in figure 13, which measured in the direction of the *a*, *b* and *c* axes, respectively, $6 \times 25 \times 30^{mm}$, while the remaining ones average
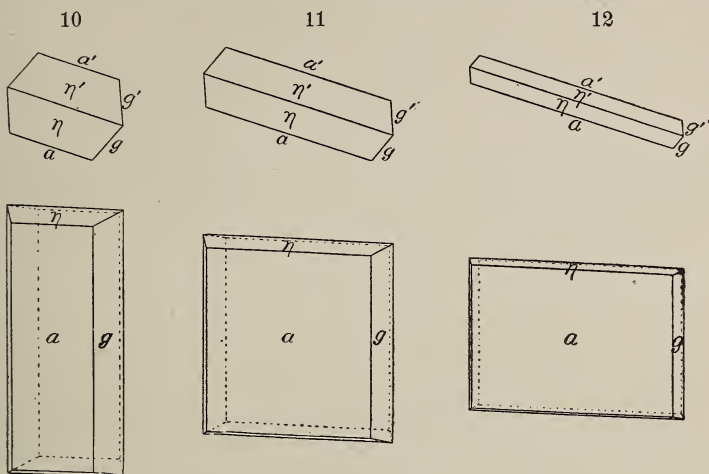
about one-fourth this size. Figure 14 shows in detail one of the corners of the crystal idealized in figure 13; it is rather unusual in showing the η and η', and w and w' faces with
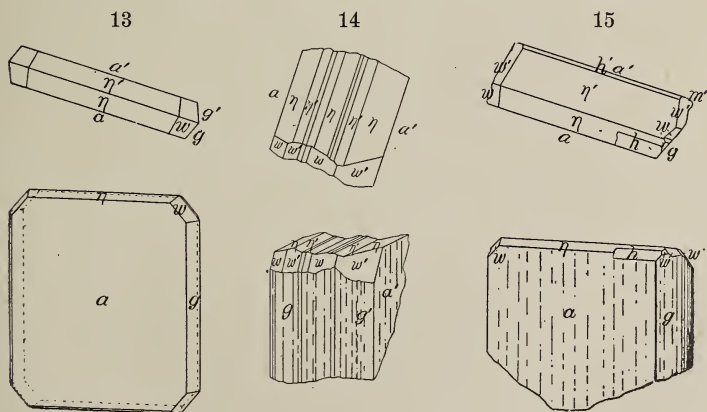
numerous reentrant and salient angles, while the *g* and *g'* faces are finely striated and round into one-another. At the opposite end of the crystal the η and *w* faces appear without reentrant angles.

The general resemblance to columbite is shown by the prominent development on both species of the macropinacoid a, parallel to which stibiotantalite has a highly perfect and columbite a distinct cleavage, while both minerals have an indistinct cleavage parallel to the brachypinacoid b (010). The prism g is always present on stibiotantalite, while on columbite it is seldom wanting and often prominent. The macrodome h occurs on both minerals but is not common, while the prominent development of rather flat macrodomes, η (209) on stibiotantalite, and k (103) and l (106), respectively (206) and (2.0.12), on columbite is a feature common to both species. The pyramid w (4.12.9), although not occurring on columbite, is in the same vertical zone as two of its prominent pyramids, s (263) and u (133), respectively, (4.12.6) and (4.12. 12). If the crystals of stibiotantalite were black and of metallic luster they certainly might be mistaken for columbite, because of similarity in appearance, habit, occurrence and association. Columbite, it should be stated, is not hemimorphic and does not exhibit pyroelectricity.

Crystals of stibiotantalite show certain peculiarities as regards the development of the forms and the character of the surfaces, as follows :—

The macropinacoids a and a', which are generally the most prominent of all the forms, have a bright luster and are usually striated vertically, the striæ being rather fine and seldom giving rise to much rounding or irregularity of the surface : on a few crystals they appear almost free from striations. Both (100) and ($\bar{1}$00) occur without any apparent difference, except when tested for pyroelectricity, and then it generally appears that the same surface develops two kinds of electricity owing to twinning and interpenetration.

The prisms g (130) and g' ($\bar{1}$30) are present on all of the crystals and are always striated vertically, due to polysynthetic twinning and in part perhaps to oscillatory combination, both causes giving rise to a rounding of the edge between g and g', or as is frequently the case, to a considerable distortion when one prism face predominates over the other, figure 14. In almost all of the crystals, however, portions of the prismatic faces are quite free from striations, so that good measurements may be had. Any modification of the edge between a and g was rarely observed. On two crystals distinct replacements, indicating the presence of a prism corresponding to m (110) or m' ($\bar{1}$10) were noted, but the faces were too poorly developed to give good measurements ; compare figure 15.

The macrodomes η (209) and η' ($\bar{2}$09) are prominent on all of the crystals as shown by the figures. A single face is generally composed of both η and n' as explained on page 58.

The domes are generally free from striations and dull in comparison with the other faces, appearing as if corroded, but on a few of the crystals they are bright and somewhat striated, not sufficiently so, however, to interfere with measurements. The domes h (203) and perhaps h' ($\bar{2}$03) occur on only a few of the crystals, two of which are shown as nearly as possible in true proportions in figures 2 and 15.   On both crystals the surfaces were so dull, seemingly etched, that on the goniometer they gave no reflections of the signal, but by placing bits of microscopic cover glass against the faces satisfactory measurements were obtained which leave no doubt as to the correctness of the symbol. Owing to the interposition of a twin lamella, the dome h, in front, shown in figure 15, extends only about one-third way across the crystal.

16

17

The pyramid w (4.12.9) appears on only a few of the crystals, is never very prominent and its development is so complicated by polysynthetic twinning, that it is difficult to state whether it occurs in front (4.12.9), or behind ($\bar{4}$.12.9), or in both positions. The pyramid faces are often striated parallel to the edge $4.12.9 \wedge \bar{4}.12.9$, as if in oscillatory combination, and frequently distinct reentrant angles occur, figures 3, 14, and 15, which indicate rather that the striations result, in part at least, from polysynthetic twin-

ning.   The pyramid faces generally have bright surfaces which yield good reflections even when the accompanying dome faces are dull.

A basal plane c and brachypinacoid b have not been observed, but occasionally owing to oscillatory combinations of $g \wedge g'$, or as a result of polysynthetic twinning, a striated surface results, approximating in position to b.

The surfaces as a whole are not the best for reflecting light, and striations gave rise to further difficulties, but it is believed that the measurements and axial ratios derived therefrom must be very nearly correct.

The crystal shown in figure 16, considerable portions of which are missing, is unique. It measures about 5^{cm} in length, 4 in height and 3 in thickness, respectively in the directions of the a, c and b axes, and weighs 150 grams (over 5 ounces), or
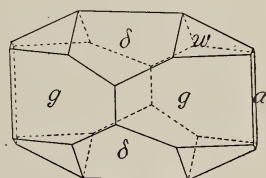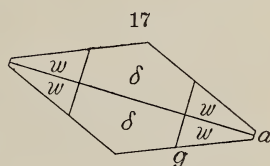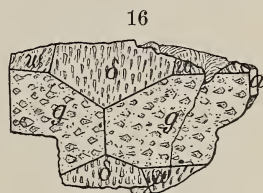
six times as much as the next largest crystal, which is of the
type shown by figure 13. It was found at a considerably later
period than the other crystals, and at a different part of the
deposit. It was picked up in two pieces, and the fracture sur-
faces do not appear fresh, as if recently broken in taking the
crystal from the matrix. Originally it must have been quite
symmetrical in development and in shape about as shown in
figure 17, which, as is also the case with figure 16, is drawn
with the a faces to the right and left, instead of front and
back, in order to show the form to best advantage. It was
attached at the lower left-hand corner to pink tourmaline, bits
of which are still adhering to it. The upper and lower edges,
and a considerable portion of the lower, right-hand corner
have been broken away. The a, a' faces to the right and left
are fresh-looking cleavage surfaces; and whether the pina-
coids a and a' were originally present, as shown in figure 17,
or whether adjacent g faces came together at the acute edges,
cannot be told.

The habit of this crystal is entirely different from that of the
others, and the peculiarities of its surface are also different.
The brachydome δ (043) has been observed only on this crys-
tal. The prism g is not striated vertically. The surfaces are
all etched, so that only measurements with a contact goni-
ometer may be had, but these all agree with those obtained
from other crystals. The best-formed etchings on the prism g
are rather deep depressions, shaped about as shown in figure 16,
though the majority are much more rounded: in places they
join one-another, giving rise to furrows running irregularly
over the surface. The etchings on the brachydome δ are long
depressions, some of them quite deep, while those on the pyra-
mid w are also long, but somewhat comma-shaped, the tails
pointing away from the edge $w \wedge \delta$. The crystal is light yel-
lowish-brown in color, more transparent than any of the others,
and has a specific gravity of 6·69.

The crystal is a polysynthetic twin, though the outward
form gives no evidence of it. The two large fragments which
make up the specimen do not of themselves exhibit pyroelec-
tricity, probably because of numerous cracks running through
the material, but a small homogeneous fragment, when tested,
exhibited alternating bands of positively and negatively excited
material, remarkably uniform and not over 2^{mm} in width.

Throughout a portion of its interior the crystal is curiously
cavernous, although the exterior is firm and consists of remark-
ably pure, transparent material. The cavity looks as though
it had been eaten out by some solvent, and is lined with some
secondary material which without endangering the specimen
could not be gotten out in sufficient quantity for a satisfactory
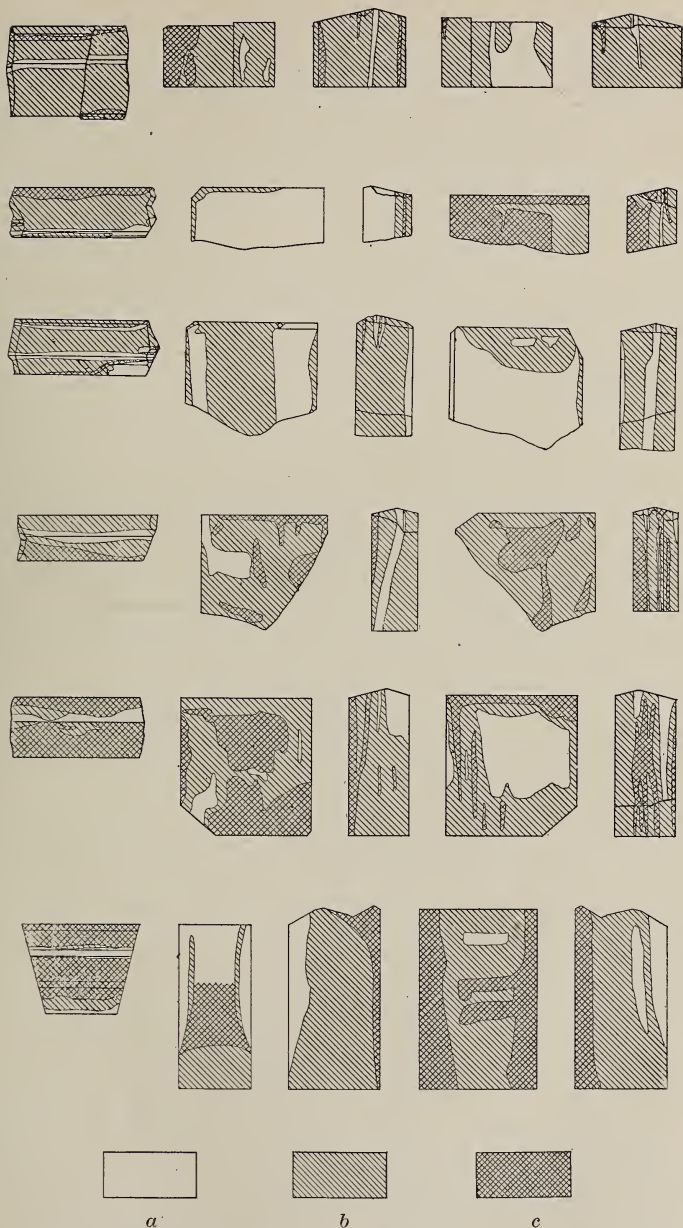
a, negatively electrified areas ; *b*, neutral areas ; *c*, positively electrified areas.

Plate showing the distribution of negatively electrified, neutral and positively electrified areas of crystals when cooled.

test.   Resting on this secondary material are a few very minute pyramids of cassiterite.

Pyroelectricity.—The pyroelectric phenomenon which is exhibited by all of the crystals is a matter of interest.   It reveals a complex polysynthetic twinning structure, as the result of which the crystals with few exceptions appear as if they possessed normal orthorhombic symmetry.   Each crystal has its own peculiar polysynthetic development, and it seems sufficient to select a few examples as types, in which the distribution of the electrically excited surfaces is indicated diagrammatically, as in the accompanying plate, page 63.   The crystals are represented, as it were, unfolded; there is given first a top view, then in turn views of the front, right-hand side, back and left-hand side.   Lower ends have not been represented because, with few exceptions, they are fracture surfaces.   As stated on page 63, the crystals were tested for pyroelectricity with a mixture of carmine, sulphur and lycopodium, with which negatively and positively electrified surfaces are coated respectively, white by lycopodium, and red by sulphur coated with carmine.   In the diagrams the negative surfaces are indicated by white (lycopodium), the positive by cross lines (red, sulphur and carmine), while the neutral, brown surface of the crystals is simply lined.   The diagrams illustrate how irregularly the lamellae are intergrown and, to a certain extent, how complex the twinning really is, but they do not do the subject full justice, for often the lamellae are very thin and red and white alternate in bands, too narrow to be represented by line drawings.

Two pebbles of the stibiotantalite from Greenbushes, Australia, belonging to the Brush Collection, were tested for pyroelectricity, but in their entirety gave no effect; when broken up, however, small homogeneous pieces gave the reaction distinctly, and it may be assumed that failure to get a response from the larger pebbles is because of the numerous cracks which permeate the material.

Crystal Measurements.—The measured and calculated angles are as follows:—

						Measured.	Calculated.
g	∧	g',	130	∧	$\bar{1}30$	= 45° 16'*	
g	∧	w,	130	∧	4.12.9	= 39 20*	
m	∧	m''',	110	∧	$1\bar{1}0$	= approximately	77° 18'
w	∧	w'	4.12.9	∧	$\bar{4}.12.9$	= 34 43	34 38
w	∧	w''',	4.12.9	∧	$4.\bar{1}\bar{2}.9$	=	91 6
η	∧	η,	209	∧	$\bar{2}09$	= 26 30	26 26
a	∧	h,	100	∧	203	= 54 30	54 50
δ	∧	δ',	043	∧	$04\bar{3}$	= approximately	96 48

From the measurements marked by an asterisk the axial ratio given on page 62 was calculated.

Orthorhombic symmetry was shown by the measurements of $q \wedge w$ in four upper octants of one crystal, which, though varying from 39° 15′ to 39° 25′, are as nearly alike as the character of the reflections warrant. The crystal on which these measurements were made is the one shown in figure 15, where the distribution of the w faces is like that of the normal group of the orthorhombic system, owing perhaps to polysynthetic twinning.

Optical Properties.—Thin sections cut parallel to the three pinacoids, when examined in polarized light, all showed extinction parallel to directions corresponding to the crystallographic axes. Some of the sections were not uniformly colored throughout, some portions being darker than others, but whether this phenomenon is due to any essential variation in chemical composition or not has not been determined. It is believed that if the difference in color indicates any variation in chemical composition, it is probably slight.

The indices of refraction vary somewhat for crystals of different specific gravity. Determinations have been made on two crystals; one having a specific gravity of 6·818, and the other of 6·299. In both cases the indices of refraction were determined from two prisms; one with a face parallel to the base and its edge parallel to the a-axis, which gave with 90° incidence the values for rays vibrating parallel to the a and b axes, respectively, β and a; the other prism with its edge parallel to the c-axis gave the value γ. The optical orientation is therefore $a = \mathfrak{b}$, $b = \mathfrak{a}$ and $c = \mathfrak{c}$. With basal sections, also, 2H acute was measured in potassium mercuric iodide solution, $n_y = 1 \cdot 7156$. The values for the two crystals are as follows:—

Specific gravity 6·818, corresponding to about 39 per cent Ta_2O_5 and 17·5 per cent Nb_2O_5.

	a	β	γ	2V, Calculated	$\gamma - a$
For Li	2·3470	2·3750	2·4275 ∴	73° 40′	·0805
" Na	2·3742	2·4039	2·4568 ∴	75 5	·0826
" Tl	2·4014	2·4342	2·4876 ∴	77 38	·0862

" Na $2Ha = 119° 10′ \therefore 2\,V = 75° 58′$

Specific gravity 6·299, corresponding to about 22·5 per cent Ta_2O_5 and 30 per cent Nb_2O_5.

	a	β	γ	2V, Calculated	$\gamma - a$
For Li	2·3686	2·3876	2·4280 ∴	70° 0′	·0594
" Na	2·3977	2·4190	2·4588 ∴	73 25	·0611
" Tl	2·4261	2·4508	2·4903 ∴	77 50	·0642

" Na $2Ha = 113° 11′ \therefore 2\,V = 72° 37′$

As may be seen from the above, the mineral is characterized by an unusually high index of refraction, the values γ for yellow, 2·4568 and 2·4588, being somewhat higher than that of diamond, 2·418, and considerably above that of sphalerite, 2·369, yet so near the latter that, both minerals being of the same color and possessing good cleavage, it is evident that fragments of the two must look exactly alike. An unusually strong dispersion, $\rho < v$, is a marked feature of the mineral, and also a high birefringence, $\gamma-a$ for yellow being for the crystal of higher specific gravity ·0826, and for the other ·0611. The character of the birefringence is positive. The plane of the optical axes is the macropinacoid (100), and the vertical axis c is the acute bisectrix.

The divergence of the optical axes, $2V$, is so great that $2E$ can not be observed ; in fact, the mean index of refraction of the mineral is so far above that of our highest refractive liquids that it was with the greatest difficulty that $2H$ could be observed : This was due in part to the fact that the sections, prepared from the same crystals from which the prisms were cut, contained some dark inclusions which interfered with the transmission of light. $2H$ therefore was measured only for sodium light, the illumination from lithium and thallium flames being too weak to yield distinct interference figures. It seems rather anomalous to have $2H$ acute as high as 119° and 113°, but this is due to the very high index of refraction of the mineral. In both crystals the agreement between the values of $2V$, as calculated from the three indices of refraction and from $2Ha$, are as satisfactory as could be expected, considering the difficulties encountered in preparing the prisms and sections, and making the measurements. As shown by the tabulated results, the substitution of Nb_2O_5 for Ta_2O_5 causes a slight increase in the values of the indices of refraction, a decrease in birefringence $(\gamma-a)$ and, except in the case of thallium, a decrease in $2V$. The dispersion is much more marked in the crystal of lower specific gravity, the differences of $2V$ for green and red being in the one about 4° and in the other about 7°.

Chemical Composition.—For chemical analysis two crystals were employed, one having a specific gravity of 6·72, and the other 5·98. The method of analysis was as follows : The mineral was dissolved, without heating, in hydrofluoric acid in a platinum dish, and the antimony and bismuth precipitated by hydrogen sulphide. The precipitate was collected on a filter and then digested with a solution of sodium sulphide in order to separate antimony from bismuth. The undissolved bismuth sulphide was collected, dissolved in warm nitric acid and, after removal of the latter, reprecipitated by hydrogen sulphide. The precipitate was then collected on asbestos,

ignited in a current of carbon dioxide and weighed as Bi_2S_3.
The antimony separated from the bismuth was reprecipi-
tated as sulphide, collected on asbestos, and, after heating
in carbon dioxide, weighed as Sb_2S_5. Preliminary experi-
ments with known amounts of bismuth and antimony proved
that the methods as given above yielded correct results. The
filtrate from the original sulphide precipitate, containing the
niobium and tantalum, was evaporated to dryness and the resi-
due decomposed by fusion with acid potassium sulphate.
The fusion was then digested with water and the insoluble
niobium and tantalum oxides were filtered, ignited and
weighed. Qualitative tests indicated that there were not
determinable quantities of other substances present. The
results of the analysis of the original stibiotantalite from
Australia by Goyder, together with those of two varieties of
the mineral from Mesa Grande, are as follows :—

	Australia.	Mesa Grande.			Mesa Grande.		
Specific gravity	7·37		6·72			5·98	
		I	II	Average	I	II	Average
$(Ta,Nb)_2O_5$	58·69	55·22	55·44	55·33	50·57	50·03	50·30
Sb_2O_3	40·23	44·31	44·21	44·26	49·07	49·49	49·28
Bi_2O_3	·82	·31	·34	·33	·53	·54	·53
NiO	·08			99·92			100·11
H_2O	·08						

99·90

The results of the analyses indicate that with decrease in
specific gravity there is an increase in antimony oxide, and a
proportional decrease in the combined acid oxides, due to the
isomorphous replacement of heavier Ta_2O_5 by lighter Nb_2O_5.
As there is no satisfactory method for separating tantalum from
niobium, the attempt has been made to determine the propor-
tions of the two oxides by taking the specific gravity of the
mixed oxides as obtained from the analyses, and comparing the
results with those of pure Ta_2O_5 and Nb_2O_5, which are quite
widely separated. This method has been tested sufficiently to
indicate that it gives fairly satisfactory results, and from the
values given below and a consideration of the ratios, which in
both analyses are almost exactly 1 : 1, it may be seen that the
percentage of the Ta_2O_5 and Nb_2O_5 must be reasonably exact :—

Sp. gr. = 6·72.		Ratio.		Sp. gr. = 5·98.		Ratio.	
Ta_2O_5	36·35	·0815		11·16	·0250		
Nb_2O_5	18·98	·0708 } ·1523	1·00	39·14	·1460 } ·1710	1·00	
Sb_2O_3	44·26	·1536		49·28	·1711		
Bi_2O_3	·33	·0007 } ·1543	1·01	·53	·0011 } ·1722	1·01	

99·92   100·11

Goyder, in his analysis of the original stibiotantalite from Australia, made no separation of the tantalum and niobium oxides, but assuming that the ratio of $(Ta,Nb)_2O_5 : (Sb,Bi)_2O_3 = 1 : 1$, the proportions of Ta_2O_5 and Nb_2O_5 were determined indirectly. Thus, considering the first of our analyses, where the per cent of $(Ta,Nb)_2O_5$ is 55·33 ; the per cent of Ta_2O_5 may be taken as x, when that of Nb_2O_5 will be $55·33 - x$: now having the molecular weights, $Ta_2O_5 = 446$, $Nb_2O_5 = 268$, $Sb_2O_3 = 288·4$ and $Bi_2O_3 = 465$, the following equation results :

$$\frac{x}{446} + \frac{55·33 - x}{268} = \frac{44·26}{288·4} + \frac{0·33}{465}, \text{ from which } x = 35·15.$$

Treating all three analyses in like manner, the results, together with the theoretical composition of the end products, are as follows :

	Theory for $(SbO)_2Ta_2O_6$				Theory for $(SbO)_2Nb_2O_6$
Sp. gr.	7·90	7·37	6·72	5·98	5·73
Ta_2O_5	60·73	51·13 (52·16)*	35·15	10·60	0·00
Nb_2O_5	0·00	7·56 (6·53)	20·18	39·70	48·17
Sb_2O_3	39·27	40·23	44·26	49·28	51·83
Bi_2O_3	----	0·82	·33	·53	----
NiO	----	0·08	----	----	----
H_2O	----	0·08	----	----	----
	100·00	99·90	99·92	100·11	100·00

The results of the indirect determination of Ta_2O_5 and Nb_2O_5 in the last two analyses show a very satisfactory agreement with the values derived from the specific gravities of the oxides, and it may be pointed out that a slight variation in the per cent of Sb_2O_3 causes about four times as great a variation in the percentages of Ta_2O_5 and Nb_2O_5, while, also, variations up to 4 per cent in Ta_2O_5 or Nb_2O_5 have little effect upon the ratio owing to the large molecular weights of the acid oxides.

The ratios in the two new analyses, being almost exactly 1 : 1, indicate that in chemical composition stibiotantalite is an isomorphous mixture of $Sb_2O_3.Ta_2O_5$ and $Sb_2O_3.Nb_2O_5$, with a little bismuth replacing the antimony. It is a curious and interesting fact that, in materials from such widely separated localities, the amounts of bismuth should be so nearly alike.

The chemical relation between stibiotantalite and columbite may perhaps be represented best by developed formulas, as follows :

$$O = Sb - O - Nb = O \qquad Fe < \begin{matrix} O - Nb = O \\ O < > O \\ O - Nb = O \end{matrix}$$
$$O = Sb - O - Nb = O$$
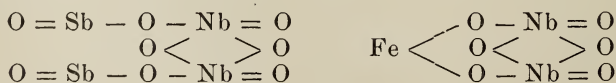
* The percentages given in parentheses result from the molecular weights made use of in this article. The figures given by Goyder vary somewhat because he used slightly different molecular weights.

What it is desired especially to bring out by the formulas is that in stibiotantalite two univalent *antimonyl* radicals (O=Sb) play the same rôle as a bivalent atom of Fe in columbite, hence, chemically, the mineral is regarded as a basic antimony tantalate, respectively, niobate. Following ordinary methods, the formulas would be written $(SbO)_2(Ta,Nb)_2O_6$ and $Fe(Ta,Nb)_2O_6$. It may be that the similarities in habit, cleavage and axial ratios between stibiotantalite and columbite, as pointed out earlier in this paper, are mere matters of accident, but, taken in connection with the chemical formulas, this does not seem at all probable. It is assumed that the antimony-oxide radical, known in chemistry as *antimonyl*, plays the part of a metal in stibiotantalite, replacing the hydrogen atoms of tantalic, respectively, niobic acid. This tendency may be noted in a number of compounds of the antimony-bismuth group, where we have basic salts containing the *antimonyl* (SbO) and *bismuthyl* (BiO) radicals. If the crystallographic relationship to columbite is disregarded, the formula of stibiotantalite may be simplified to $(SbO)(Ta,Nb)O_3$, or, looked at in another way, to $Sb(Ta,Nb)O_4$, the latter an antimony salt of normal tantalic, respectively, niobic acid. Against the latter assumption, however, it may be argued that normal salts of tantalic and niobic acid are almost unknown, and the tendency to form a basic salt containing the antimonyl radical would probably be greater than to form an antimony salt of the normal acids. Among minerals which are normal salts of tantalic and niobic acids, there are only two closely related species, fergusonite and sipylite, (Y,Er,Ce) $(Ta,Nb)O_4$ and $Er(Ta,Nb)O_4$, but these may as well be written as basic salts, for example, $(ErO)_2(Ta,Nb)_2O_6$, conforming to the columbite type of formula.

That the antimony in stibiotantalite is trivalent and not pentavalent is known by the summation of the analyses and also by the results of the following experiment:—Some powdered mineral was dissolved in hydrofluoric acid, and the precipitate thrown down by hydrogen sulphide was collected, dried and tested by heating in a closed tube. Had the antimony been pentavalent, the precipitate would have been either Sb_2S_5 or a mixture of Sb_2S_3 and sulphur, and have yielded an abundant sublimate of sulphur when tested in a closed tube; it gave, however, only a trace of sulphur, the same as stibnite, Sb_2S_3, when similarly heated.

By means of the data given in connection with the three analyses which have been made, it is possible to represent the relations between the specific gravity and chemical composition of stibiotantalite graphically, as shown in figure 18, where the specific gravities are taken as abscissas and per cents as

ordinates. Referring to page 73, the percentages of the total acid oxides, $(Nb,Ta)_2O_5$, of the three analyses have been plotted on the vertical lines corresponding to the specific gravities. The three points thus found do not fall quite on a straight line, hence a circular arc is drawn through them and continued. As given on page 74, the theoretical percentages of Nb_2O_5 and Ta_2O_5 in $(SbO)_2Nb_2O_6$ and $(SbO)_2Ta_2O_6$ are, respectively, 48·2 and 60·7; hence where the $(Nb,Ta)_2O_5$ curve intersects, horizontal lines corresponding to the above figures must determine approximately the specific gravities of the two unknown end products, namely 5·73 and 7·90. Next, the percentages of Nb_2O_5 and Ta_2O_5, as given on page 74, were plotted, and, as shown by the figure, these fall very near two circular arcs, one

18

Specific Gravities.
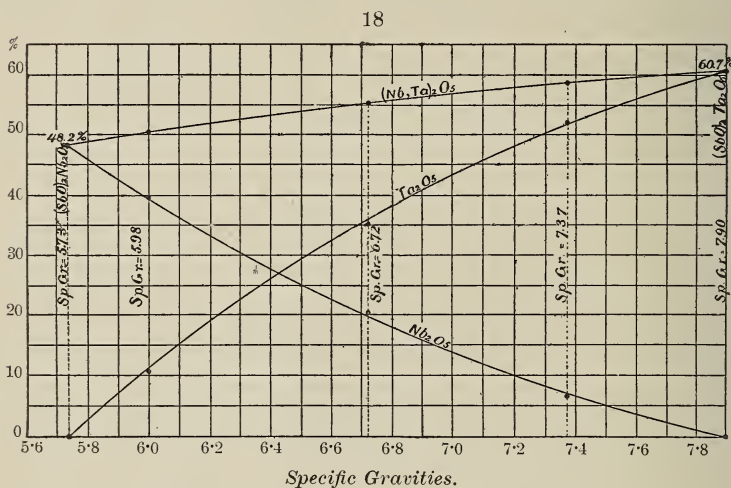
passing from 0 per cent to 48·2 per cent Nb_2O_5, the other from 0 per cent to 60·7 per cent Ta_2O_5. The greatest variation of the determinations of Nb_2O_5 and Ta_2O_5 from these curves is not over one per cent, which is well within the errors of analysis. If instead of using the values for Nb_2O_5 and Ta_2O_5 given on page 74, which were obtained indirectly from the percentages of Sb_2O_3 and Bi_2O_3 and were selected because the three analyses received like treatment, the values as given for our two analyses on page 73 are plotted on figure 18, the points fall almost exactly on the Nb_2O_5 and Ta_2O_5 curves. Certainly, considering the difficulties of the analyses, the close conformity of the determinations to the two curves is a most satisfactory confirmation of the reliability of the results obtained. It was by means of the diagram that the approximate composition of the two crystals studied optically, as

given on page 71, was determined. The majority of the crystals examined range in specific gravity from 6·6 to 6·7.

Pyrognostics.—Stibiotantalite, when heated intensely at the tip of the blue flame, is fusible at about 4 and imparts a pale bluish-green color to the flame due to volatilization of antimony. After driving off a part of the antimony there is left an infusible mass of niobium and tantalum oxides generally darkened by antimony. If the flame from the mineral is directed against a piece of charcoal a considerable coating of oxide of antimony collects on the coal.* When fused with 3 or 4 times its volume of sodium carbonate on charcoal, a coating of antimony oxides and small globules of metallic antimony are obtained. The powdered mineral is not appreciably attacked by ordinary acids, not even by boiling, concentrated sulphuric, but is readily soluble in hydrofluoric acid. Unchanged when heated in closed and open tubes and gives no characteristic reactions with the fluxes.

Summary.—Stibiotantalite is a mineral first found in rounded, water-worn pebbles in Australia and recently in well-crystallized specimens in California. In chemical composition it is an isomorphous mixture of $(SbO)_2Nb_2O_6$ and $(SbO)_2Ta_2O_6$, exhibiting a wide range in specific gravity, from 5·98 to 7·37, depending upon the proportions of Nb_2O_5 and Ta_2O_5 present. The crystals belong to the hemimorphic group of the othorhombic system, although, owing to twinning, they imitate the symmetry of the normal group. In axial ratio, development and occurrence of several forms, the mineral is related to columbite. Stibiotantalite is characterized by an unusually high index of refraction, above diamond, a high birefringence and a wonderful luster.

In closing, the writers take special pleasure in expressing their thanks to Mr. Ernest Schernikow, of New York, who has most generously placed at their disposal for study all of the crystals which the locality, so far as known, has afforded. He may well be proud that his eagerness to promote the science of mineralogy has enabled him to bring to light a mineral of such unusual beauty and scientific interest.

Mineralogical Laboratory of the
      Sheffield Scientific School of Yale University,
            New Haven, Conn., February, 1906.

* Tried in the same way as when testing for zinc ; Brush-Penfield Determinative Mineralogy and Blowpipe Analysis, p. 131.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *Properties of Liquid Nitrogen.* — Until recently it has been possible to experiment with liquid and solid nitrogen only upon a small scale, but since the gas is now a commercial article in Germany, where it comes compressed to about 100 atmospheres in a passably pure condition, H. ERDMANN has taken the opportunity to study the liquid on a large scale. He employed a copper cylinder of about $1\frac{1}{2}$ l. capacity which was provided with a manometer and had been tested to a pressure of six atmospheres. This was surrounded with liquid air and connected with the nitrogen bomb, so that the gas could be carefully introduced. The nitrogen could be condensed at an over-pressure of 0·7 atmosphere, while the condensation went on rapidly when this pressure reached 2 or $2\frac{1}{2}$ atmospheres. The liquefied nitrogen was then transferred to a Weinhold-flask by means of a siphon valve. After filtration through a dry folded paper the liquid nitrogen was found to be a very mobile, clear, perfectly colorless liquid, which is decidedly different from the bluish colored liquid air. Since liquid air, even when freshly prepared, contains 50 to .60 per cent of oxygen, its specific gravity is so high that pieces of ice float upon it. On the other hand, ice sinks in liquid nitrogen, as does also solid absolute alcohol. The latter phenomenon agrees better with the specific gravity of liquid nitrogen determined by Ramsay and Drugman (0·7914 at the boiling-point), than with the determination of Dewar (0·850). When liquid nitrogen is poured upon a bulb filled with dry oxygen at atmospheric pressure, some of the oxygen is condensed in the form of bluish drops. This does not occur when liquid air is used. It is suggested that the easily prepared liquid nitrogen will be of service to chemists in producing somewhat lower temperatures than those obtainable with liquid air.—*Berichte,* xxxix, 1207.

H. L. W.

2. *The Oxidation of Ammonia to Nitrates and Nitrites.*—The probable exhaustion in a short time of the South American nitrate beds makes it important to consider other means of producing nitrates and nitrites. The principal methods thus far suggested are the oxidation of atmospheric nitrogen and the oxidation of ammonia by the aid of contact substances. Since Germany possesses cheap water power in but few places, but has an abundant supply of ammonia from coal, the utilization of the second process appears to be of importance in that country. SCHMIDT and BÖCKER have, therefore, made some experiments with the oxidation of ammonia by atmospheric oxygen, using platinum and platinized asbestos as contact substances. They find as an average of many experiments a yield of from 75 to 76 per cent of the ammonia in the form of oxides of nitrogen, and in many cases a yield of over 80 per cent. It appears, however, that the process for producing nitrates cannot be carried out

profitably under the present condition of prices, but the production of nitrites from ammonia, by oxidizing it with air or oxygen in the presence of pyrites under certain conditions, according to a patented process of Bayer & Co., seems to be more promising.— *Berichte*, xxxix, 1366. H. L. W.

3. *The Detection and Determination of Small Quantities of Iron.*—A. MOUNEYRAT has found that the green color produced by passing hydrogen sulphide gas for about ten minutes through dilute, slightly ammoniacal solutions of iron salts is a much more delicate test than the familiar sulphocyanide reaction. It appears that the ferrous sulphide forms a colloidal solution when very little of it is present. The green color is discharged by concentrated solutions of ammonium and sodium sulphates and of sodium chloride, but many organic substances such as glycerine, sugars, tartrates, etc., increase the stability of the solutions and make it possible to obtain stronger ones. The limit of the delicacy of the reaction is about one part of iron in a million, when it is carried out in the manner just described, but the delicacy can be made greater by adding four or five milligrams of albumen to the ammoniacal solution, saturating with hydrogen sulphide as usual, then mixing with an equal volume of alcohol and allowing the liquid to stand ten or twelve hours. A green film is then found at the bottom of the vessel, due to the precipitation of a part of the albumen. It is stated that small quantities of mercury, lead, silver, chromium, nickel do not interfere with the reaction, although copper does so. The green colors obtained with amounts of iron varying from $\frac{1}{1000}$ to $\frac{1}{1000000}$ are practically proportional to the amounts, so that it is possible to make quantitative determinations in this way.— *Comptes Rendus*, cxlii, 1049.

H. L. W.

4. *Quantitative Determination of Acetone.*—ADOLPH JOLLES has devised a method for this purpose, which depends upon the combination of sodium bisulphite with acetone according to the equation

$$(CH_3)_2CO + NaHSO_3 = (CH_3)_2C \diagdown \begin{matrix} OH \\ SO_3Na \end{matrix} \cdot$$
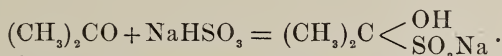
A titrated solution of bisulphite is added in such quantity that three or four times the required amount is present, and after standing 30 hours it is titrated back with iodine solution. Each molecule of bisulphite corresponds to a molecule of acetone. The reaction takes place slowly, and it was not found possible to shorten the time of standing. Test analyses gave very accurate results. They were made by mixing 25^{cc} of liquid containing about 0.05^g of acetone with 25^{cc} of $\frac{1}{5}$ normal bisulphite in a stoppered flask, then, after 30 hours, titrating back with $\frac{1}{10}$ normal iodine solution. —*Berichte*, xxxix, 1306. H. L. W.

5. *Avogadro and Dalton ; the Standing in Chemistry of their Hypotheses ;* by ANDREW N. MELDRUM ; 8vo, pp. 113. Edinburgh, 1906 (James Thin).—This is a very interesting essay dealing chiefly with the relative importance of the atomic and molecu-

lar chemical theories. The argument is in favor of the greater value of Avogadro's contribution to science, while the admirers and followers of Dalton are criticized for giving him undue credit. All who are interested in the history of chemistry will find the book instructive, even though they fail to agree entirely with its conclusions; for it is ably written and displays much knowledge of the literature of the subject.   H. L. W.

6. *Electric Discharge in Gases.*—Faraday supposed that an electric discharge occurs as soon as a determined discharge potential is reached which is sufficient to break down the dielectric. This theory takes no account of polar differences.

O. Lehman has sought to reconcile Faraday's theory with the facts by the assumption of a dark convective streaming which occurs before the discharge; and which on account of the different discharge, fitness of positive and negative air, leads to the formation of a positive air envelope at the cathode. J. J. Thomson, in an electrolytic theory, supposes that before the occurrence of the discharge a convective dark current is formed.

H. Sieveking, following the example of O. Lehman, has employed vessels of large size in studying the question of the existence of such dark currents. Lehman showed that the cathode space is much influenced by the nearness of the walls of the exhausted vessel to the cathode; he accordingly used exhausted vessels of 60 liters capacity.

Sieveking sums up his conclusions as follows :

(1) An investigation with a vessel enclosing an electroscope suitably charged showed that a dark current did not exist before the discharge. This is against the electrolytic hypothesis. Furthermore the insulation of the exhausted space below the point of discharge was perfect. A dissipation of electricity which must accompany a dark current could not be shown by an electrometer.

(2) In wide exhausted vessels the dark space is not influenced by a strong ionizing substance. This fact militates against the supposition of the electrolytic theory that this region is a poverty stricken one.

(3) The experiments indicate that the double layer which O. Lehman supposed to exist before the occurrence of the discharge does not exist.

(4) The very weak current which J. Elster and H. Geitel have shown to exist in air, and upon which Kaufmann founded the characteristics of the dark current, are not present in a space protected from ionization. The entire investigation leads one to believe in a pure disruptive discharge.

(5) The remarkable effect of the magnetic field on the electric discharge leads one to conclude with O. Lehman, from the standpoint of the electron theory, that powerful inner movements occur in the molecules which, through rotary movements, greatly influence the effect of the electric field.—*Ann. der Physik*, No. 7, pp. 209–226, 1906.   J. T.

7. *Note on the computed drop of pressure in adiabatic expansion ;* by C. BARUS.—I have hitherto expressed my results for the distribution of colloidal and other nuclei in a gas in terms of the observed fall of pressure δp in the fog chamber. If under isothermal conditions p is the pressure of the fog chamber, p' the pressure of the vacuum chamber and p_3 the common pressure after exhaustion of the former, $\delta p = p - p_3$. Recently I computed the actual fall $\Delta p = p - p_2$, where p_2 is the true isothermal pressure in the fog chamber isolated from the vacuum chamber immediately after exhaustion. The results are $\delta p - \Delta p = \cdot 225\ \delta p$, nearly.

Naturally I expected some appreciable correction in the final reduction, but I did not anticipate so large a difference. The result, however, is very interesting, for on applying it I find that the distribution curves obtained in the use of very large fog chambers now practically coincides with the curve which I deduced from the data obtained by Wilson with his small and unique apparatus. It appears furthermore that the successive improvements which I have added to my fog chamber have for some time reached a limit, and that its true efficiency is greatly in excess of my estimate.

8. *Meteorologische Optik ;* von J. M. PERNTER. Mit zahlreichen Textfiguren. III Abschnitt: Seite 213–558. Wien und Liepzig, 1906 (Wilhelm Braumüller).—The opening section of this important work was noticed in this Journal several years since (see vol. xiii, p. 472), and now the third part is issued. It discusses a very interesting series of phenomena, namely, those due to the presence of minute foreign particles in the upper atmosphere. Many different forms of halos and of coronas are described and figured as well as discussed from a theoretical standpoint ; in relation to these phenomena the varied forms of snow and ice crystals are described in detail. The subject of rainbows is very fully treated and illustrated. Altogether the work is a very important contribution to our knowledge of a peculiarly interesting but difficult subject.

9. *Leitfaden der Wetterkunde gemeinverständlich bearbeitet ;* von Dr. R. BÖRNSTEIN. Zweite umgearbeitete und vermehrte Auflage. Pp. 230, with 22 tables. Braunschweig, 1906 (Friedrich Vieweg & Sohn).—After an interval of five years, the author has brought out a second edition of his elementary work on Meteorology. This is an indication of the success that the book has had in meeting the needs of those for whom it was expressly designed. The author states, as the fundamental principle present in his mind, that any person may, if properly instructed, become his own weather prophet, and with this before him he has endeavored to treat the whole subject in such a manner as to make it as intelligible as possible. This he has accomplished with marked success, but it still remains true that the subject is one not without difficulty, and requiring much study for even superficial mastery. Some of the new points introduced into this edition concern the relation of the temperature of the

air to water and forest, the heat movement in the ground, and observations above the earth by means of balloons and other methods; the discussion of the phenomena of atmospheric electricity has been rewritten.

10. *Refraktionstafeln ;* von Dr. L. DE BALL, Direktor der v. Kuffnerschen Sternwarte. Pp. xiv, with 11 tables. Leipzig, 1906 (Wilhelm Engelmann).—The tables here included are based upon Radau's theory of refraction ; the refraction constant assumed is that of Bauschinger, namely, $60''·15$ for normal conditions of pressure in temperature and at sea-level at a latitude of 45°. There are eleven series of tables, and the special mathematical sources upon which they are based are explained in the Introduction, which is printed both in German and French.

11. *Shaft Governors ;* by W. TRINKS and C. HOUSUM. Pp. 11, 97, with 27 figures and 16 tables. Van Nostrand Science Series, No. 122. New York, 1905 (D. Van Nostrand Co.).—This recent addition to the Van Nostrand Science Series will be properly valued by those who have to do with the use of shaft governors in practical machinery.

II. GEOLOGY AND MINERALOGY.

1. *Preliminary Report of the State Earthquake Investigation Commission;* 17 pp. Berkeley, May 31.—The Governor of California, on April 21, 1906, appointed a commission to examine and report on the phenomena connected with the earthquake which occurred three days previously at San Francisco. The members of the Commission are as follows: A. C. Lawson, of the University of California ; G. K. Gilbert, of the U. S. Geological Survey; H. Fielding Reid, of Johns Hopkins University ; J. C. Branner, of Stanford University ; A. O. Leuschner and George Davidson, of the University of California ; Charles Burkhalter, of the Chabot Observatory, and William Wallace Campbell, Director of the Lick Observatory.

In the preliminary report it is stated that the plane of dislocation was along the well-known fault-line which extends in a remarkably straight line obliquely across the Coast Range from Point Arena to Mount Pinos in Ventura County, a distance of 375 miles. This physiographic line " affords every evidence of having been in past time a rift, or line of dislocation, of the earth's crust and of recurrent differential movement along the plane of rupture. The movements which have taken place along this line extend far back into the Quaternary period, as indicated by the major, well-degraded fault scarps and their associated valleys; but they have also occurred in quite recent times, as is indicated by the minor and still undegraded scarps. Probably every movement on this line produced an earthquake, the severity of which was proportionate to the amount of movement."

" The earthquake of the 18th of April, 1906, was due to one of these movements. The extent of the rift upon which the move-

ment of that date took place is at the time of writing not fully known. It is, however, known from direct field observations that it extends certainly from the mouth of Alder Creek near Point Arena to the vicinity of San Juan in San Benito County, a distance of about 185 miles. The destruction at Petrolia and Ferndale in Humboldt County indicates that the movement on the rift extended at least as far as Cape Mendocino, though whether the rift lies inland or offshore remains as yet a matter of inquiry. Adding the inferred extension of the movement to its observed extent gives us a total length of about three hundred miles. The general trend of this line is about N. 35° W., but in Sonoma and Mendocino counties it appears to have a slight con-cavity to the northeast, and if this curvature be maintained in its path beneath the waters of the Pacific it would pass very close to and possibly inside of Capes Gordo and Mendocino. Along the 185 miles of this rift where movement has actually been observed the displacement has been chiefly horizontal on a nearly vertical plane, and the country to the southwest of the rift has moved northwesterly relatively to the country on the northeast of the rift. By this it is not intended to imply that the northeast side was passive and the southwest side active in the movement. Most probably the two sides moved in opposite directions. The evidence of the rupture and of the differential movement along the line of rift is very clear and unequivocal. The surface soil presents a continuous furrow generally several feet wide with transverse cracks which show very plainly the effort of torsion within the zone of the movement. All fences, roads, stream courses, pipe lines, dams, conduits, and property lines which cross the rift are dislocated. The amount of dislocation varies. In several instances observed it does not exceed six feet. A more common measurement is eight to ten feet. In some cases as much as fifteen or sixteen feet of horizontal displacement has been observed, while in one case a roadway was found to have been differentially moved twenty feet. Probably the mean value for the amount of horizontal displacement along the rift line is about ten feet and the variations from this are due to local causes such as drag of the mantle of soil upon the rocks, or the excessive movement of soft incoherent deposits. Besides this general hori-zontal displacement of about ten feet, there is observable in Sonoma and Mendocino counties a differential vertical movement not exceeding four feet, so far as at present known, whereby the southwest side of the rift was raised relatively to the northeast side, so as to present a low scarp facing the northeast. This vertical movement diminishes to the southeast along the rift line and in San Mateo County is scarcely if at all observable. Still farther south there are suggestions that this movement may have been in the reverse direction, but this needs further field study.

" As a consequence of the movement it is probable that the lati-tudes and longitudes of all points in the Coast Ranges have been permanently changed a few feet, and that the stations occupied

by the Coast and Geodetic Survey in their triangulation work have been changed in position. . . .

"The great length of the rift upon which movement has occurred makes this earthquake unique. Such length implies great depth of rupture, and the study of the question of depth will, it is believed, contribute much to current geophysical conceptions.

"The time of the beginning of the earthquake as recorded in the Observatory at Berkeley was 5 h. 12′ 6″ A. M., Pacific standard time. The end of the shock was 5 h. 13′ 11″ A. M., the duration being 1′ 5″. Within an hour of the main shock twelve minor shocks were observed by Mr. S. Albrecht of the Observatory and their time accurately noted. Before 6 h. 52′ P. M. of the same day thirty-one shocks were noted in addition to the main disturbance. These minor shocks continued for many days after April 18, and in this respect the earthquake accords in behavior with other notable earthquakes in the past. The minor shocks which succeed the main one are interpreted generally as due to subordinate adjustments of the earth's crust in the tendency to reach equilibrium after the chief movement."

The destructive effects of the earthquake are in the main distributed with reference to the line of rift, and are evident over an area approximately 50 by 400 miles. Within this area the intensity of the shocks varied greatly in accordance with topographic position and the character of the underlying rocks. The facts indicate an "excessively destructive effect of the earth wave as transmitted by the little coherent formations of the valleys bottoms."

A discussion of the geological problems presented by the earthquake is left for a more exhaustive report.

2. *United States Geological Survey*, CHARLES D. WALCOTT, Director.—The titles of publications recently received are given in the following list (see vol. xxi, 251, March, 1896): notices of some of these follow later.

Third Annual Report of the Reclamation Service. 1903–4. (Second Edition.) F. H. NEWELL, Chief Engineer. Pp. 653, with 59 plates in separate cover.—The Act of Congress, looking forward to the reclamation of the arid lands in the Western States and Territories, was passed in June, 1902. Since then three reports of the Reclamation Service connected with the Survey have been published; the last of which, in revised form, has recently been given to the public. It gives a summary of the various extensive operations planned, and shows that when they are brought to completion the results will be of the highest importance, not only for the regions involved, but for the country at large.

TOPOGRAPHIC ATLAS.—Twenty-seven sheets.

FOLIOS: No. 130. Rico Folio : Colorado. Description of the Rico Quadrangle ; by WHITMAN CROSS and F. L. RANSOME : Geography and General Geology of the Quadrangle by WHITMAN CROSS. Pp. 20, with 5 colored maps and 6 figures.

No. 131. Needle Mountains Folio : Colorado. Description of Needle Mountains Quadrangle by WHITMAN CROSS, ERNEST HOWE, J. D. IRVING, and W. H. EMMONS. Topography and General Geology by WHITMAN CROSS and ERNEST HOWE. Pp. 13, with 4 colored maps and 11 figures.

No. 132. Muscogee Folio : Indian Territory. Description of the Muscogee Quadrangle ; by JOSEPH A. TAFF. Pp. 7, with 3 colored maps.

No. 133. Ebensburg Folio : Pennsylvania. Description of the Ebensburg Quadrangle ; by CHARLES BUTTS. Pp. 9, with 4 colored maps.

No. 135. Nepesta Folio. Colorado. Description of the Nepesta Quadrangle ; by CASSIUS A. FISHER. Pp. 5, with 3 colored maps.

No. 136. St. Mary's Folio : Maryland—Virginia. Description of the St. Mary's Quadrangle; prepared, under the supervision of WILLIAM BULLOCK CLARK, geologist-in-charge, by GEORGE BURBANK SHATTUCK. Pp. 7, with 2 colored maps.

No. 137. Dover Folio : Delaware—Maryland—New Jersey. Description of the Dover Quadrangle ; prepared under the supervision of WILLIAM BULLOCK CLARK, geologist-in-charge, by BENJAMIN LeROY MILLER. Pp. 10, with 2 colored maps.

MONOGRAPHS.—Atlas to accompany Monograph XXXII on the Geology of the Yellowstone National Park ; by ARNOLD HAGUE, Washington, 1904.

This atlas, recently published, contains twenty-three beautifully executed maps, giving in detail the topography and geology of the Yellowstone region. The text, which this atlas illustrates, was issued several years since and then noticed in this Journal. (See vol. ix, p. 297.)

PROFESSIONAL PAPERS.—No. 44. Underground Water Resources of Long Island, New York; by A. C. VEATCH, C. S. SLICHTER, ISAIAH BOWMAN, W. O. CROSBY and R. E. HORTON. Pp. 394, with 34 plates including several maps in pocket and 7 figures.

No. 45. The Geography and Geology of Alaska : A summary of Existing Knowledge; by ALFRED H. BROOKS ; with a Section on Climate, by CLEVELAND ABBE, JR.; and a Topographic Map and Description Thereof, by R. U. GOODE. Pp. 327, with 34 plates and 6 figures.

No. 47. The Tertiary and Quaternary Pectens of California ; by RALPH ARNOLD. Pp. 264, with 53 plates and 2 figures.

No. 48. Report on the Operations of the Coal-Testing Plants of the U. S. Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904. EDWARD W. PARKER, JOSEPH A. HOLMES, MARIUS R. CAMPBELL, Committee in charge. Pp. 1492, with 13 plates and 135 figures. Part I, Field Work, Classification of Coals, Chemical work. Pp. 1–300. Part II, Boiler Tests. Pp. 301–980. Part III, Producer Gas, Coking, Briquetting, and Washing Tests. Pp. 981–1492.

No. 49. Geology and Mineral Resources of Part of the Cumberland Gap Coal Field, Kentucky; by George Hall Ashley and Leonidas Chalmers Glenn, in coöperation with the State Geological Department of Kentucky, C. J. Norwood, Curator. Pp. 239, with 40 plates, 13 figures and two pocket maps.

Bulletins.—No. 269. Corundum, its Occurrence and Distribution in the United States; by Joseph Hyde Pratt. Pp. 176, with 18 plates and 26 figures. This is a revised and enlarged edition of Bulletin No. 180.

No. 274. A Dictionary of Altitudes in the United States. Fourth edition; compiled by Henry Gannett. Pp. 1072.

No. 280. The Rampart Gold Placer Region, Alaska; by L. M. Prindle and Frank L. Hess. Pp. 54, with 7 plates and 1 figure.

No. 281. Results of Spirit Leveling in the State of New York for the years 1896 to 1905 inclusive; by S. S. Gannett and D. H. Baldwin. Pp. 112.

No. 282. Oil Fields of the Texas-Louisiana Gulf Coastal Plain; by N. M. Fenneman. Pp. 146, with 11 plates and 15 figures.

No. 288. Results of Spirit Leveling in Pennsylvania for the years 1899 to 1905 inclusive; by S. S. Gannett and D. H. Baldwin. Pp. 62.

Water-Supply and Irrigation Papers.—No. 148. Geology and Water Resources of Oklahoma; by Charles Newton Gould. Pp. 178, with 22 plates and 32 figures.

No. 153. The Underflow in Arkansas Valley in Western Kansas; by Charles S. Slichter. Pp. 90, with 3 plates and 24 figures.

No. 154. The Geology and Water Resources of the Eastern Portion of the Panhandle of Texas; by Charles N. Gould. Pp. 64, with 15 plates and 4 figures.

No. 157. Underground Water in the Valleys of Utah Lake and Jordan River, Utah; by B. Richardson. Pp. 76, with 9 plates and 5 figures.

Nos. 134, 165, 166, 167, 168, 169, 171. Report of Progress of Stream Measurements for the Calendar year 1905. Prepared under the direction of F. H. Newell. Parts I–V, VII, XI.

3. *Pleistocene Geology of Mooers Quadrangle;* by J. B. Woodworth. Bulletin 83 New York State Museum, pp. 60, with Bibliography and Index. One geologic map and 25 plates. *Ancient Water Levels of the Champlain and Hudson Valleys;* by J. B. Woodworth. Bulletin 84, N. Y. State Museum, pp. 265, with Bibliography and Index. One geologic map and 28 plates. Published by the New York State Education Department, Albany, New York, 1905.—An examination of the published maps depicting late Pleistocene events will show that one of the latest phases, that of ice withdrawal from the Champlain and lower St. Lawrence valleys, has been least perfectly understood. The question of marine invasion subsequent to such with-

drawal and its relation to the glacial attitude of the land and postglacial changes of level have been inferred from rather too widely scattered data ; and the conclusions thus reached were perforce somewhat contradictory. The situation required extended and detailed investigation of the field from Manhattan to the St. Lawrence.

The distinguishing features of Prof. Woodworth's reports on this area are their clear and dispassionate discussion of the hypothesis of glacial retreat in a narrow valley and of the formation of associated marginal deposits (pp. 79–86, No. 84) ; and the interpretation of complex deposits over an extended field. In these respects the reports are justly comparable to Leverett's Monographs on the glacial history of the Great Lakes region.

To the student of glacial geology the method of work is quite as interesting as the conclusions. It is found that the form of the Hudson Valley influenced the retreat of the ice so strongly that it is possible to outline the history of glacial retreat in terms of the varying cross-section of the valley, taking into account the order and arrangement of the deposits made either by ice or tributary streams. In the Champlain region the evidence collected is chiefly from the New York side of the lake and consists of moraines, dry gorges and falls, spillways, beaches, bars, wave-cut cliffs and benches, and marine shells.

While the conclusions are based on a limited amount of field work and cannot therefore be regarded as final on account of the great extent of the field and the complexity of the details, they nevertheless have a high value because of the discriminating choice of sites critically examined for decisive evidence. ɪ. ʙ.

4. *Geology and Water Resources of Oklahoma ;* by CHARLES NEWTON GOULD. Water-Supply and Irrigation Paper No. 148. Pp. 178, with 32 plates and 32 figures. U. S. Geol. Survey. Washington, 1905.—This report is as much of a geologic nature as hydrographic and as such should be called to the attention of geologists. The Wichita mountains in the southern part of the territory consist of Archean and Lower Paleozoic formations and are completely surrounded by Permian strata. The lower of these "Red Beds" are believed to correspond chronologically with Carboniferous limestones in Kansas. Many sections are given showing the gypsum beds, and Prof. Gould believes the Permian here to be wholly marine. The Tertiary deposits of the High Plains and their relation to water supply are also discussed.

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5. *Bulletins of the Geological Survey of Virginia ;* THOMAS L. WATSON, Geologist in charge. No. II. The Clay Deposits of the Virginia Coastal Plain, by HEINRICH RIES ; with a chapter on The Geology of the Virginia Coastal Plain by WILLIAM BULLOCK CLARK and BENJAMIN LE ROY MILLER. Pp. 184, with 15 plates. Board of Agriculture and Immigration, 1906.—This is a thorough account of the clay occurrences and industry of Virginia, rendered more interesting from the introduction on the general geology of the Coastal Plain.

No. III. Hydrography of Virginia; by N. C. GROVER and R. H. BOLSTER. Pp. 234, with 10 plates and 1 text-figure. This Bulletin discusses the drainage basins of the prominent rivers of Virginia,—namely, the Potomac, the James, the Roanoke, and New River. A drainage map of the state showing gaging and rainfall stations is given, and a large amount of data are presented for the individual rivers.

6. *La Sierra de Cordoba: Constitucion geologica y Productos minerales de aplicacion ;* by W. BODENBENDER. Rep. Argentina An. d. Ministerio d. Agric. Sec. Geol., Tom. I, Num. II, 1905. 8°, 150 pp.—The Sierra de Cordoba lies between 21° and 23° S. and 63½° and 65° W. in Argentina with a general north and south direction and is composed of several ranges, some of whose peaks have altitudes from 6–8000 feet. The memoir is devoted first to a general geological description of the area, aided by a geological map. Then follows a list of occurrences of minerals, of which a large number of species are mentioned. The rocks are then treated and brief petrographic descriptions of the different kinds are given, both of the crystalline schists and igneous rocks. The sedimentary rocks are conglomerates, sandstones, etc., of Cambrian and supposedly Silurian age and of the Permian-Triassic, with argillaceous beds of the Pampas terrane. The work concludes with a brief account of the economic mineral deposits. It is illustrated by a considerable number of halftone cuts of photographs illustrating various features of interest in the mountain region. The work is more or less general and preliminary in character; yet contains in compact form a great deal that is of interest and importance concerning a little known region. L. V. P.

7. *Contributions from the Geological Department of Columbia University.* Vol. xii, Nos. 107, 108. Vol. xiii, Nos. 109–114. —These include numerous geological papers, published by gentlemen connected with Columbia University in various journals and society transactions, and now collated, in convenient form for binding, in sequence with similar volumes previously distributed.

8. *The Constitution of the Silicates.* — In a paper on the Chemical Constitution of the Feldspars, presented to the Vienna Academy in 1903, Professor TSCHERMAK undertook to throw light on the chemical composition of the feldspars, especially with reference to the particular type of silicic acid present. From the slow decomposition of the mineral by hydrochloric acid a hydrated silicic acid is separated which, when exposed to the air, rapidly loses water for a number of days, but finally passes into a condition where the further loss is very slow, except upon ignition. By determining the amount of water present at the point named, the author believes that he establishes the constitution of the silicic acid present. For anorthite, for example, the loss of water by ignition was found to be 23·41, while the acid H_2SiO_3 requires 22·98. The conclusion is reached, therefore,

that anorthite is to be regarded, not as an orthosilicate, but as a metasilicate. Later papers on the same general subject (Sitzungsberichte Akad. Wien cxiv(i), 455, 1905, cxv(i) Feb., 1906), discuss the matter in more detail. The conclusion is reached that while willemite and monticellite are to be regarded as orthosilicates, olivine is a metasilicate, and the acid present in garnet, epidote, zoisite and prehnite is $H_4Si_3O_8$; the formula of olivine would be written $(MgOMg)SiO_3$.

9. *An Introduction to Chemical Crystallography;* by P. GROTH, Authorized Translation by HUGH MARSHALL. Pp. vii, 123. New York, 1906 (John Wiley & Sons).—The Chemical Crystallography of Professor Groth was noticed about a year since when the German edition was issued (see vol. xix, p. 467). We have now an authorized English translation made by Dr. Hugh Marshall of the University of Edinburgh. This will be found very useful by the English-speaking public and will extend the sphere of usefulness of this valuable work. The translation has been prepared in coöperation with the author, who has supervised the proof-sheets. It follows the original closely and adds occasional references to original papers or abstracts which have appeared in the Journal of the Chemical Society.

10. *Geometrische Kristallographie;* by ERNST SOMMERFELDT. Pp. 139, with 31 Tafeln and 69 text-figures. Leipzig, 1906 (Wilhelm Engelmann).—Those interested in the problems of modern crystallography, handled particularly from the theoretical side, will find much of value in the present work. A series of thirty-one ingeniously constructed plates at the close of the volume present, in a novel way, the symmetry conditions and the relations of the existing forms to each other.

11. *Étude sur l'État actuel des Mines du Transvaal: Les Gîtes—Leur Valeur, Étude industrielle et financière;* by GEORGE MOREAU. Pp. 218, with 48 figures. Paris, 1906 (Librairie Polytechnique, Ch. Béranger, Editeur).—This is a useful work to those interested in the mines of South Africa, giving a description of the country and its geology with particular reference to the Witwatersrand; a full discussion of methods of exploitation adopted is added. The author speaks enthusiastically of the mineral resources of the Transvaal and its possibilities, although he recognizes some of the limitations to its development which unavoidably exist.

12. *Anleitung zum Gebrauch des Polarisationsmikroskops;* von Dr. ERNST WEINSCHENK. Pp. vi, 147, with 135 figures. Zweite, umgearbeitite und vermehrte Auflage. Freiburg im Breisgau, 1906. (Herdersche Verlagshandlung. Zweigniederlassungen in Wien, Strassburg, München, und St. Louis, Mo.)—An excellent presentation of the polarization microscope in its different parts, with the various methods of investigation applicable to it and the principles involved in their use. It is well illustrated and gives, in small compass, just the information needed by students of the subject. It should be in the hands of every one concerned with this field of investigation.

13. *Tabellen zur mikroskopischen Bestimmung der Mineralien nach ihrem Brechungsindex;* von Dr. J. L. C. SCHROEDER VAN DER KOLK.· Zweite umgearbeitete und vermehrte Auflage ; von E. H. M. BEEKMAN. Pp. vi, 68 with folded plate. Wiesbaden, 1906 (C. W. Kreidel).—The first edition of these useful tables was issued in 1900 and noticed in volume ix, p. 229, of this Journal. The tables have been rearranged and increased in size by Dr. Beekman, and in their new form will unquestionably prove still more valuable to those interested in microscopic mineralogy. The preparation of this new edition was undertaken in order to carry out the plan of the author, who died on June 17, 1905; it consequently follows the lines laid down by him.

14. *Minéralogie des Départements du Rhone et de la Loire;* par FERDINAND GONNARD. Pp. 122, with 31 text-figures. 1906. Lyon (A. Rey) and Paris (J. B. Baillière & Fils). Annales de l'Université de Lyon. Nouvelle Série : I. Sciences, Médecine, Fascicule 19.—This is an account of the mineral species which occur in two of the departments of France particularly rich in this direction. Among the most conspicuous species may be mentioned the azurites of Chessy, the zeolites of Mt. Simiouse, the calcite of Couzon and the cerussites of Pacaudière. The work is a valuable supplement to the more exhaustive treatises on mineralogy.

15. *Studien über Meteoriten, Vorgenommen auf Grund des Materials der Sammlung der Universität Berlin;* von C. KLEIN. Aus den Abhandlungen des Königl. Preuss. Akademie der Wissenschaften vom Jahre, 1906. Pp. 141, with three plates. Berlin, 1906.—The meteorite collection of the University of Berlin has always been a classical one ever since the time of Gustav Rose. For many years, however, the collection did not grow adequately, and it is only since Professor Klein took hold of the matter that it has regained its relative importance among the great collections of the world. In 1887, there were 213 localities represented, and now in 1906 the number has increased to 500. This publication is much more than a mere catalogue of the specimens represented, for it also gives a description of meteorites in general, with a special account of certain important examples. One of the most interesting of these has been earlier described by the same author, namely the leucituranolite of Schafstädt.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Plaster-plaques for Museums;* by GEORGE LINCOLN GOODALE (Communicated).—The fine finish of a properly made plaster mount renders it preferable to slate or ground glass or polished wood, for specimens which require a firm support and a good contrasting surface. The excellent mounts which have been made by the Dentons show clearly the adaptability of plaster for even the most delicate and brilliant organisms. The problem in our Museum was to provide a mount which should answer not

only for very fragile and delicate specimens, but would at the same time serve to keep in perfect position specimens of considerable weight and size. It was imperatively necessary to secure such specimens from even the slightest bending.

The Blaschka glass models of plants in flower are shipped to our Museum fastened to a firm cardboard which answers every purpose as a permanent mount for the smaller species. But even when re-enforced by strips of wood, the larger plates of cardboard have a tendency to curve, sometimes in more than two directions, and this curvature seemed likely to put the larger models in some peril of breaking.

Acting on a suggestion of Dr. Libbey of Boston, an attempt was made, about six years ago, to substitute plaster-plates for the heavy cardboard. More than a year was consumed in fruitless experimenting. The small plates were fairly strong and for the most part, satisfactory, but the larger ones, say from two feet square and upward, were untrustworthy and therefore of no use in our cases.

Fortunately, at the time when our experiments were on the eve of abandonment, there was in the service of the Museum an expert cabinet-maker who expressed a desire to undertake a continuation of the work along a different line. After a few trials which varied in success, he was able to produce plaques of high finish and great density. Tests showed that these new plaques were sufficiently strong to bear any weight to which it was likely they could ever be subjected, and moreover, they did not show the least tendency to bend. About fifty were made four years ago, and, after they had been exposed to all reasonable risks, it was found that they had not sustained any permanent injury of any sort. During the last three years, more than seven hundred plates have been successfully made, and these are now installed in the exhibition rooms of the botanical section of the Museum. They are so strong, so free from curvature and so attractive in general appearance, that they appear to answer every requirement as mounts.

The following is the method of their manufacture:

(1) The appliances. On a stout table perfectly levelled there is placed a plate of the finest plate-glass of the required size. On our tables we have used glass of a convenient size for our work, namely four by three feet, and five by four feet. Care is taken to choose only " first " plate: " seconds " are likely to have small blow-holes or slight curvatures. For each plate on the table another of equal size and of about the same thickness is placed near at hand.

In order to form a dam around the sides of the glass, to prevent the plaster from running off, we have used strips of wood of just the thickness of the desired plaque. These are simply put in place and not fastened to the glass in any way.

(2) The liquid plaster is made in the following way : into a large pail of perfectly clear soft water, enough fine plaster of

Paris is quickly sifted in, with constant stirring, until the mass becomes of the proper density.

(3) The liquid mass is now poured rapidly without the formation of any bubbles upon the surface of the glass on the table, filling all the space between the strips of wood. Then as quickly as possible, the other plate of glass is put over the liquid, great care being taken that no bubbles creep in, and then heavy weights are put on this glass, pressing out all excess of liquid plaster. In the course of fifteen or twenty minutes, depending on conditions not yet thoroughly understood, the upper glass can be separated from the plaque, by gradual lifting at one side.

In ten or fifteen minutes more, the plaque can be separated from the floor glass. At this time, a small hole is to be made in one corner, about an inch and a half from the edge; this serves for hanging the plaque on a nail in a dry room. The drying takes place slowly in winter, but in summer the whole sheet will be thoroughly dry in a few days.

The plate can now be cut into any desired shape and size by a simple device. First, make a deep scratch in the plaster where the break is desired, and then break exactly as a square of glass is cut. When the break has been made, the edge is finished by means of a plane, and it can be bevelled also, if necessary.

If the surface has too glossy a finish, reduce the luster by a common stiff brush carried evenly over the whole surface.

We have made many attempts to improve the color of the plaques by the addition of various fine pigments, but the effect has always been unsatisfactory. The color tints with a little Prussian-blue, and the warmer tints with a very little vermillion, were liked by many, but as a rule, the plain undazzling white has been found best.

We are now employing plaques of this sort also for our cases in which we are installing specimens of seeds, fruits, etc., which are better exhibited without any covering at all. In this way, for instance, specimens illustrating dissemination are placed before the public in a very attractive manner. The contrast between the specimen and the pure white plaster mount is in no instance unpleasing.

Cambridge, June, 1906.

2. *The American Association for the Advancement of Science.* —The special summer meeting of the American Association will be held in Ithaca, New York, from June 28th to July 3d. Several Societies, including the American Physical Society and the American Chemical Society, are to meet at the same time in affiliation with the Association. Professor William H. Welch, of Baltimore, is the President of the Association for the Ithaca meeting, and the Vice Presidents of the several sections are given in the following list: Section A, Mathematics and Astronomy : Edward Kasner, Columbia University ; B, Physics: W. C. Sabine, Harvard University ; C, Chemistry: Clifford Richardson, New York City ; D, Mechanical Science and Engineering : W. R. Warner, Cleveland ; E, Geology and Geography : A. C.

Lane, Lansing, Mich.; F, Zoology : E. G. Conklin, University of Pennsylvania; G, Botany: D. T. MacDougall, Carnegie Institution, Washington ; H, Anthropology : Hugo Münsterberg, Harvard University ; I, Social and Economic Science : Chas. A. Conant, New York, N. Y.; K, Physiology and Experimental Medicine : Simon Flexner, Rockefeller Institute, New York.

3. *Memoirs of the National Academy of Sciences.* — The fourth memoir of Volume X has recently been issued; the subject is : Phoronis Architecta, Its Life History, Anatomy, and Breeding Habits, by WILLIAM KEITH BROOKS and RHEINART PARKER COWLES. Pp. 75–148, with 17 plates.

4. *Zeitschrift für Gletscherkunde, für Eiszeitforschung und Geschichte des Klimas.* Organ der Internationalen Gletschercommission ; herausgegeben von EDUARD BRÜCKNER. Band I, Heft 1, pp. 80. Berlin, 1906 (Gebrüder Borntraeger).—A new journal devoted to Glaciology has recently been inaugurated as the organ of the International Glacial Commission, with Dr. Eduard Brückner as editor. He will be assisted by eleven associate editors ; the American representative is Dr. H. F. Reid, of Baltimore. The journal will contain discussions of subjects relating to glaciology and the investigation of the Ice Age in all its phases, with shorter communications on the same subjects, reviews of books and papers published elsewhere, and a general bibliography. It will be international in character; while the editorial matter will be in German, the papers and communications may be in any one of the four prominent languages. It will be issued at irregular intervals, not more than five parts annually, each part containing 80 pages octavo ; subscription price, sixteen marks. The first number has just been distributed and bears the date of May, 1906. This new journal fills an important gap in the series of special scientific organs, and will doubtless accomplish much in promoting interest in the subjects with which it deals ; it should receive liberal support.

5. *Publications of the Field Columbian Museum, No. 109, Geological Series, Vol. iii, No. 2.* The Shelburne and South Bend Meteorites; by OLIVER CUMMINGS FARRINGTON. Pp. 23, with 15 plates.—The account of the Shelburne meteorite as described by Borgström was given in the January number of this Journal (p. 86). Dr. Farrington now describes a second stone of the same fall weighing $12\frac{1}{4}$ pounds. Its fall was quite unusual, since it came down in a narrow space between a house and a shed, narrowly escaping both of them, and burying itself 18 inches in the ground. The South Bend meteorite, also described in this pamphlet, is a pallasite weighing $5\frac{1}{2}$ pounds, and was found in 1893 two miles from South Bend, in St. Joseph county, Indiana. This is the seventh pallasite which has been discovered in the United States ; it is referred to the Imilac group and the ratio of nickel-iron to chrysolite is 21·4 to 78·6.

No. 110, Geol. Series, Vol. ii, No. 7. The Carapace and Plastron of Basilemys sinuosus, a new Fossil Tortoise from the

Laramie Beds of Montana; by ELMER S. RIGGS. Pp. 249–256, with three plates.

6. *Carnegie Institution of Washington.*—The following are recent publications:

No. 49. Heredity of Hair-length in Guinea-pigs and its Bearing on the Theory of Pure Gametes; by W. E. CASTLE and ALEXANDER FORBES. Pp. 1–14. (No. 5 of Papers of the Station for Experimental Evolution at Cold Spring Harbor, N. Y.)

The Origin of a Polydactylous Race of Guinea-pigs; by W. E. CASTLE. Pp. 14–29 (No. 175 of Contributions from the Zoological Laboratory of the Museum of Comparative Zoology at Harvard College, E. L. Mark, Director).

No. 51. Studies on the Germ Cells of Aphids; by N. M. STEVENS. Pp. 28, with four plates.

7. *Personal Hygiene designed for undergraduates;* by ALFRED A. WOODHULL, A.M., M.D., LL.D. Pp. vii+221. New York (John Wiley & Sons), 1906.—This little book, the outcome of a course of lectures given to undergraduate students at Princeton, presents in simple language sound advice regarding the development and care of the body. A few introductory chapters briefly describing the general anatomy and physiology of the organ systems of the body are followed by chapters on physical culture, fatigue, elimination of waste, bathing, clothing, food, tobacco and alcohol. Careful reading of this book cannot fail to leave in the mind of the student a better appreciation of the common rules for hygienic living, and would in all probability increase his future health and happiness.

8. *The Bulletin of the Imperial Central Agricultural Experiment Station, Japan.* Vol. i, No. 1. Pp. 94. Nishigahara, Tokio, December, 1905.—Japan has already forty-seven independent agricultural experiment stations, and this new publication will serve to make public the results of the investigations carried on in them. The first number contains eleven articles, treating largely of the action of mineral substances on vegetable growth, or on bacterial action.

OBITUARY.

DR. ERNST SCHELLWIEN, Professor of Geology at Königsberg, died on May 14th in his fiftieth year.

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THE

AMERICAN

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FOURTH SERIES

VOL. XXII—[WHOLE NUMBER, CLXXII.]

No. 128—AUGUST, 1906.

AMERICAN JOURNAL OF SCIENCE

ART. XI.—*An Investigation into the Elastic Constants of Rocks, more especially with reference to Cubic Compressibility;* by FRANK D. ADAMS and ERNEST G. COKER.

Introduction.—In a paper published in 1901 an account was given of an investigation into the deformation of marble under varying conditions of heat and pressure.* Under a grant from the Carnegie Institution of Washington to F. D. Adams, the experimental investigation into the behavior of rocks under pressure has been continued in the laboratories of McGill University. As the investigation went forward, however, it was found necessary to follow out several separate lines of research, the results of which it is proposed to present in a series of separate papers.

In the present article a brief résumé is presented of the methods adopted and the results obtained in an investigation into the elastic constants of rocks, more especially with a view to ascertaining the amount of cubic compression which rocks will undergo when submitted to pressure from every side, all rocks of course being subjected to such compression to a greater or less extent, previous to the deformation which they suffer under conditions of differential pressure.

A full presentation of the results of the investigation will be found in a Publication of the Carnegie Institution of Washington, No. 46, having the same title as the present paper, and which is now in press, to which the reader is referred for full details of all the measurements carried out in the case of each of the specimens examined, as well as for detailed descriptions,

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* Adams, F. D., and Nicolson, J. T. An experimental investigation into the Flow of Marble. Phil. Trans. Royal Soc. London, Series A, vol. cxcv, pp. 363-401.

color process photographs and microphotographs of each of the rocks employed. Before the investigation was completed, Dr. Coker was called to the Professorship of Mechanical Engineering in the Finsbury Technical Institute of London, England, and was accordingly obliged to give up the work of the research. His place was taken by Mr. Charles McKergow, Lecturer in Mechanical Engineering in McGill University, but who, immediately on the completion of the work, was appointed to the Professorship of Mechanical Engineering in the University of Virginia. A large number of the very careful measurements of the elastic constants which are presented in the paper were made by Professor McKergow.

Methods which may be used in the determination of the Elastic Constants of Materials.

The determination of the cubic compressibility of solid substances is, as above mentioned, beset with serious difficulties. On one hand every direct method which has been suggested presents experimental difficulties which tend to impair its accuracy, while on the other hand the indirect methods are based on assumptions as to the isotropy of the materials, which are not warranted in the case of certain rocks. The indirect methods, however, depending on the theory of elasticity, are capable of considerable variation, and it is of interest to examine them in some detail in order to see whether certain of them at least may not be depended upon to give reliable and satisfactory results.

The determination of the elastic constants of metals has engaged the attention of many physicists and at the present time a large amount of information exists as to the values of these constants for various metals.

It is well known that in homogeneous elastic substances, a simple compression stress causes a lateral strain, which bears a fixed ratio to the compression strain for any particular substance within the limit of elasticity. If then[*] we call p_x the stress on a plane perpendicular to x in the direction x, and e_x the corresponding strain, then for a direct compression stress p_x there will be a strain in the direction of this stress of amount p_x/E, where E is Young's modulus, and lateral strain of magnitude p_x/mE, where m is the ratio of the longitudinal compression to the lateral extension per unit of length.

If we suppose further that a body is subjected to cubical stress of intensity p_x, we easily see that for small and therefore superposable strains, the cubical strain e_c is

$$e_c = 3p_x \frac{m-2}{mE}$$

[*] See Ewing's Strength of Materials, Chapters I and II.

and since the modulus of compressibility D is the ratio of the stress per unit of area to the cubical strain produced, we have

$$D = \frac{p_x}{e_c} = \frac{1}{3} \frac{m}{m-2} E$$

Hence if we know E and m we can calculate the value of D.

Further, it is shown in treatises on elasticity that if C is the modulus of shear, then

$$C = \frac{1}{2} \frac{m}{m+1} E$$

and since C and E are quantities which can be ascertained by experiment, we can from them calculate m and D.

In an important paper by Nagaoka[*] this latter method has been used to determine the elastic constants of a series of rocks. The value of E was determined by supporting a bar at the ends and measuring the angular change at the support due to a given load applied at the center; the value of E is then obtained by the formula $E = 3wl^3/4bd^3\theta$, where l is the length of the bar between the supports, b is the breadth of the bar, d the depth and θ the angular change at the ends for a load W. In order to determine the value of m, a specimen of rectangular section was twisted by a given torque, T, and the amount of the strain measured. It has been shown by St. Venant that for such a case the value of C is given by the formula

$$T = C\theta b^3 h \left[\frac{16}{3} - \frac{32^2 b^4}{\pi^5} \sum_0^\infty \frac{\tan h \,(2n+1)\, \dfrac{\pi h}{2b}}{(2n+1)^5} \right]$$

where θ is the angular change, and from this formula values of C were calculated from the observations.

This method appears to be open to some minor objections in that the formula for determining E is based upon a theory of flexure, which although sufficient for many purposes is nevertheless only approximate, and it is well known that values of E obtained by flexure experiments in this manner often differ from the values of E obtained by direct compression experiments by not inconsiderable amounts.

Further, in experiments upon the deflection of beams cut from rocks, it is difficult to obtain consistent readings because of the time effect of the loading, and this difficulty is noticed in the paper cited.

Experiments on the determination of the elastic constants of rocks when subjected to twist were also found to be fre-

[*] Elastic Constants of Rocks and the Velocity of Seismic Waves; H. Nagaoka.—Phil. Mag., vol. L, 1900, p. 53.

quently unsatisfactory owing to the low ultimate shearing value of many rocks.

While a glance at the list of rocks whose elastic constants have been measured by Nagaoka will at once show that most of them are rocks whose elasticity must be of a very imperfect kind, e. g., weathered clay slate, schalstein, tuff, etc.; the method which he has employed for the determination of Young's modulus gives very low results, even in the case of rocks such as marble and granite, where the elasticity might be supposed to be of a high order and comparable to that which these rocks are shown to possess in the case of the types selected for investigation in the present paper. This is seen in the following figures representing the values obtained by him for each of the marbles and granites contained in his list:

Paleozoic Marble:	E (Young's modulus).
No. 11A	10,120,000
11B	7,950,000
12A	5,440,000
12B	4,770,000
Granite	
No. 69 (Shodoshima)	6,140,000
68 (Hitachi)	2,853,000
71 (")	2,175,000
56 (")	1,588,000
52 (")	3,265,000

Of these, marble No. 11, if a mean of the two readings be taken, has about the same modulus as the average of those on our list, while No. 12 is very much lower. The highest value given for any granite in Nagaoka's list, viz: No. 69, is somewhat higher than that of the lowest of the granites in our series, that from Stanstead. The other granites examined by Nagaoka have values for E assigned to them which are so low that they are comparable only to that of the sandstone in our series. Of the three sandstones included in Nagaoka's list the Izumi sandstone of the Mesozoic has modulus of 1,322,000, while the other two, which belong to the Diluvium, have values for E of 587,500 and 583,000 respectively.

And so when an attempt is made to calculate the cubic compression (D) from the values given in Nagaoka's list and obtained by his method, it is found that a negative value is actually obtained in about one-third of the rocks which he has examined. His figures, however, were intended chiefly for the purpose of calculating the velocity of the propagation of earthquake shocks.

In consequence of a number of somewhat unsatisfactory results obtained by the writers in some preliminary experiments

with this method, as well as the facts with regard to Nagaoka's figures just mentioned, it was decided to adopt a somewhat different method and one which avoided both torsion and flexure and depended simply on strain produced by simple compressive stress.   This will be termed the "Method of Simple Compression."   Among the possible indirect methods, this seems to be the most satisfactory, since the assumptions necessary in the calculation of compressibility are reduced to a minimum, and the range of stress for which the ratio of stress to strain is practically constant is great.

It was found possible to measure the strain obtained very accurately by means of an apparatus forming part of the equipment of the testing laboratory of McGill University, for the
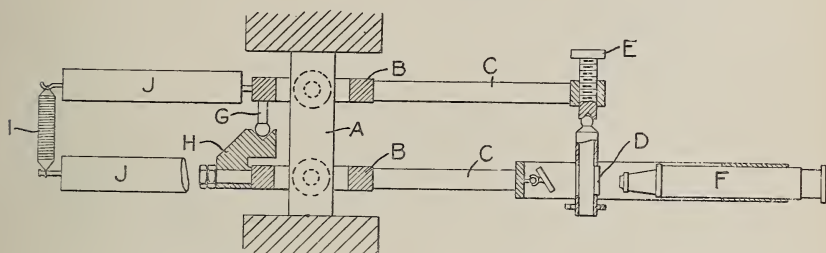
FIG. 1.   Instrument for determining the modulus of a simple strain.

use of which we are indebted to Professor H. T. Bovey.   This is an instrument designed by Professor Ewing, and of which a sketch is given in figure 1.   In this, A is a specimen of the rock gripped by screws passing through a pair of collars, B, which are 1·25 inch apart, to which latter metal rods, C, are attached.   The upper rod carries a glass plate, D, with a fine line scratched upon it, the position of which can be adjusted by a screw, E, while the lower rod carried a micrometer-microscope, F.   The upper and lower collars, B, are connected by a stud, G, the upper one engaging with the conical hole of the swivel piece, H, in the lower, and contact is maintained by a spring, I, while the weights of the microscope and projecting arms are balanced by lead cylinders, J.   A buzzer was attached to the upper lead cylinder which when operated caused a slight vibration in the instrument, producing a perfect adjustment as the pressure was applied.

The proportions of this instrument were so adjusted that one division on the micrometer scale corresponded to $\frac{1}{250000}$ of an inch, and before using it the instrument was calibrated by aid of a Whitworth measuring machine and was found to be in correct adjustment.

The linear strain perpendicular to the length of the specimen was measured by an instrument which had been designed by E. G. Coker some time previously for experiments on the lateral strains developed in metals.*   This is shown in figure 2, and consists of a pair of brass tubes, B, B', provided with set screws, A, A', for attachment to the specimen, and connected together by a flexible steel plate, F, forming the ful-
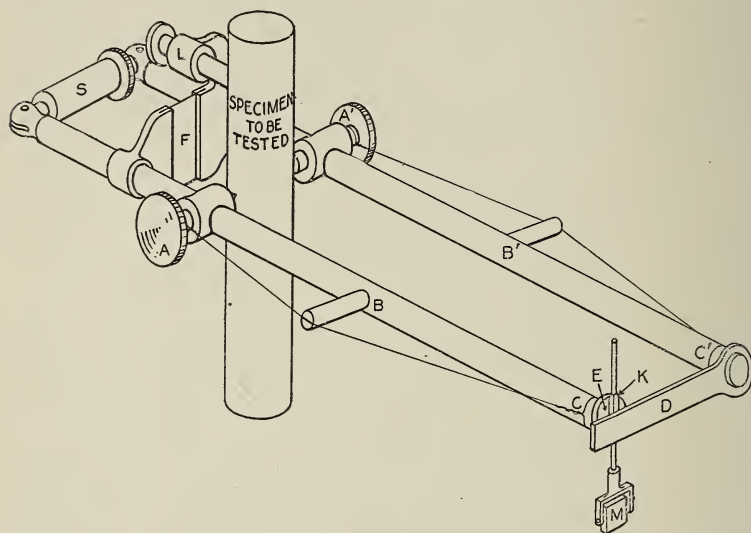
Fɪɢ. 2.   Perspective view of lateral extensometer.

crum.   The ends of the tubes near the fulcrum plate are pressed apart by an adjustable spring, S, to insure a uniform pressure on the screw points gripping the specimen.   On the opposite end of one of the tubes is a spring, D, of ebony pressing against a double knife-edge, K, seated in a shallow V-notch cut in the end of the other arm.   The knife-edge carries an adjustable mirror, M, so that if any change in the diameter of the specimen occurs the two tubes move relatively to one another in a horizontal plane, thereby causing the knife-edge mirror to rotate ; the rotation of this latter is observed and measured by a telescope and scale placed at a suitable distance.

For convenience in adjustment, there is a screw, L, for tilting the apparatus about the axis of the gripping screws, and the tubes, B, B', are trussed to prevent vibration.   This instrument was calibrated by aid of a Whitworth measuring

* See Proceedings Royal Soc. Edinburgh, Session 1904-5, vol. xxv, pt. vi.

machine and the scale adjusted so that one division corresponded to one millionth of an inch.

Application of the Method of Simple Compression to the Determination of the Cubic Compressibility of Metals.

The behavior of such metals as wrought iron and steel over a wide range of stress shows that these metals may be considered as almost perfectly elastic. The results of the theory of elastic bodies may therefore be applied in their cases with great confidence.

As a typical example of the behavior of such materials we may consider the deportment of a specimen of wrought iron when subjected to a cycle of compression stresses, commencing at 1,000 pounds and rising to 9,000 pounds, afterwards returning to the original load. The readings obtained for the longitudinal and lateral strains will show in such a case that equal increments or decrements of load produce strains which are very exactly proportional thereto. This is clearly shown in a plot of these readings, where the ordinates represent the total load and the abscissæ represent strains. In both cases the relation of stress to strain is represented by a straight line returning upon itself. Traces which vary but very little from the ideal straight line are given by black Belgian marble, as will be seen on page 114.

Such results afford an arbitrary standard by which can be judged the degree of approximation to perfect elasticity exhibited by other metals and by rocks under similar conditions.

If we now calculate the value of the modulus E for simple compression, since this is the relation of the compression stress p to the strain e, we have

$$p = Ee.$$

If we call A the cross-sectional area of the specimen when stressed by a load P, and x the decrease of length over a measured length L, gripped between the screw points of the measuring apparatus, we obtain

$$E = \frac{PL}{xA}$$

which in the case of a specimen of wrought iron examined for a range of 8,000 pounds, gave a value of 28,100,000, the units being pounds and inches.

The ratio m of the longitudinal strain to the lateral strain in the same case was 3·65, and using the formula

$$D = \frac{1}{3} \frac{m}{m-2} E$$

we obtain for the modulus of cubical compression (or bulk modulus) D, the value 21,300,000, a constant for the material, the reciprocal of which gives the decrease in volume of 1 cubic inch for 1 pound of pressure.

While certain rocks, such as many of the marbles, have a structure identical with that of wrought iron, most of the rocks constituting the earth's crust are composed of several minerals, and thus rather resemble cast iron in character, the gray variety of this substance being an aggregate of crystals or individuals of the metal iron (wrought iron), graphite, etc.

It will therefore be of interest to ascertain how a specimen of cast iron behaves under compression stress, and how far its elasticity falls short of that which would be exhibited by a perfectly elastic body.
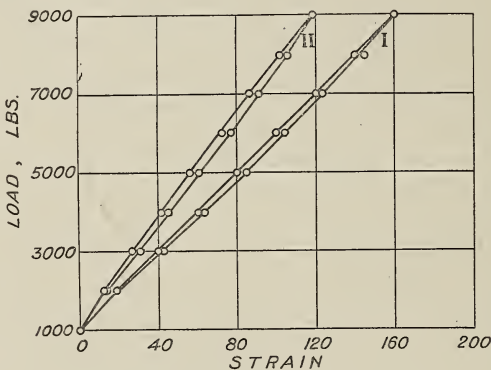
Fig. 3.   Cast iron stress strain curves.

For this purpose a fine-grained specimen of somewhat hard cast iron was faced and tested.   The stress strain curves are plotted in figure 3.   I represents longitudinal compression and II lateral extension.

The behavior of cast iron as exhibited by these experimental results shows a falling away from the theoretical standard of perfect elasticity, but even in the most perfectly elastic bodies there is probably a slight hysteresis effect, so that we are justified in using the results obtained to calculate the modulus of compressibility, if the error introduced thereby is negligible or very small.

It may be pointed out that this method and others of the indirect type have been freely used to obtain values of the bulk modulus for cast iron and metals of like character, and it will be shown that the composite crystalline rocks are very similar to cast iron in their behavior under stress, although generally more perfectly elastic.

Application of the Method of Simple Compression to the Determination of the Compressibility of Rocks.

As has been noted, it was found in the case of marble when subjected to bending stress, that the strain as exhibited by the deflection of a point of the bar increases with the time, and the strength under shear produced by a torque was also so small that a determination of the strain was very difficult to measure.

These difficulties have been noted by Nagaoka,[*] who states that "Preliminary experiments on granite showed that Hooke's law does not hold even for very small flexure and torsion, and that the after effect is very considerable when the prism is sufficiently loaded or twisted; the deviation from the direct proportionality between strain and stress was incomparably great as compared with that observed in common metals. This must be chiefly due to the low limit of elasticity, so that it is necessary to experiment only within narrow limits of loading and twisting. These limits are widely different for different specimens of rocks, and the modulus of elasticity as well as that of rigidity was always determined with such stresses as will approximately produce strains proportional to them. The deviation from Hooke's law was prominent in certain specimens of sandstone, and it was more marked in torsion than in flexure experiments; in certain rocks it is indeed doubtful if anything like a proportionality between stress and strain can be found, even for extremely small change of shape: on releasing these rocks from stress the return toward the former state is extremely small, showing that the elasticity of the rocks is of very inferior order."

If, however, the rock be subjected to direct compression, strains in which the time effect is small, and the lag of the strain is also small, are almost invariably obtained. This is especially the case if, before the actual experiment is carried out, the material be several times subjected to a range of stresses at least as great as those employed in the experiment itself. This preliminary stressing brings the material to a "state of ease," and is also commonly adopted when the elastic constants of metals are determined.

It is evident therefore that this Direct Compression Method may with confidence be applied to the measurement of the cubic compression of rocks, although as mentioned below the accuracy of the results obtained will differ with different classes of rocks. If the rocks be massive, compact and crystalline (or glassy), the method can be safely employed and good results will be obtained. If, on the other hand, the rock is

[*] Elastic Constants of Rocks and the Velocity of Seismic Waves; Nagaoka, H.—Phil. Mag., vol. L, 1900, p. 58.

schistose, porous or loosely coherent, the method will, from the nature of the case, be very much less satisfactory.

The plutonic igneous rocks as a class most nearly resemble the metals in structure, being holocrystalline and massive, and therefore present the nearest approach among rocks to perfectly elastic bodies : they are therefore a class of rocks to which this method is especially applicable.   It fortunately happens that they also form a class of rocks a knowledge of whose compressibility is of special importance for the elucidation of geological problems, constituting as they do the greater part of the earth's crust.

A second class of rocks which are comparable to them in their approach to perfect elasticity, comprises the marbles and certain limestones.

A series of sixteen typical rocks representative of these two classes were accordingly selected for measurement ; under the first class a number of granites were chosen as representing the acid plutonic rocks, and a number of types of the gabbro-essexite series were selected as representing the basic plutonic rocks.   In all cases great care was taken to choose the most homogeneous and massive rocks of each series, and to secure test pieces free from all flaws and cracks.   As representing the second class a number of typical marbles and limestones, also perfectly massive in character, were selected.   For purposes of comparison, or contrast, a sandstone was added to the list as being a rock which, on account of its more or less porous nature, could hardly be expected to yield satisfactory results by this method.

An examination of the stress strain curves of these 16 rocks, omitting the sandstone, shows that on the average they possess a rather more perfect elasticity and exhibit less hysteresis than cast iron.   Some of them, as for instance, the Baveno granite, the nepheline syenite, the diabase and the black Belgian marble, show much better curves, approximating in fact to the straight lines given by wrought iron, which may be considered for our present purpose as expressing perfect elasticity.

The close approximation to perfect elasticity is shown by the return of the curve to its initial or starting point, and the amount of the hysteresis is shown by the width of the loop.

The width of this hysteresis (or lag) curve or loop indicates the amount of the divergence from Hooke's law which the material exhibits—this law being that the stress and strain are *directly* proportional.   When the curve is narrow, as it is in all cases except the Stanstead granite and the sandstone, the divergence from Hooke's law is not great enough to seriously affect the result.

The rocks, therefore, with these exceptions, fulfil the conditions of elasticity necessary to the successful application of the

method. In these two cases the results are less certain owing to the greater hysteresis of the rock.

It might at first sight appear that while the method employed is theoretically perfect as applied to the measurement of the compressibility of vitreous rocks and of very fine-grained crystalline rocks, a considerable error might be introduced when the rocks are coarser in grain. In the case of all the common crystalline rocks, the individual grains of which the rock is composed are anisotropic, that is they have different moduli of elasticity in different directions. In massive rocks such as those investigated, however, these grains occur in the rock with an absolutely irregular orientation and would in the case of a fine-grained rock mutually compensate for one another in any transverse line along which the expansion of the rock under compression might be measured. If, however, the rock were coarser in grain, fewer individual crystals would be found in any transverse line of section, and there might possibly in this way be lack of compensation, as the rock in one section might be composed of grains whose axis of greater elasticity approximated on an average more nearly to the direction of measurement than in other sections. If such were really the case, there should be in these coarser-grained rocks an exceptionally great variation in the readings obtained from different specimens of the same rock, as well as from the different sections in the same specimen.

But such is not the case, as will be seen by an examination of the figures in the accompanying table. These represent the results obtained from ten measurements of the compressibility of Baveno granite, which is coarse in grain, and ten of Sudbury diabase, which is very fine in grain, together with eight measurements of Tennessee limestone, which is rather coarse grain, and seven of plate glass. They were made in each case on two or more specimens cut from the same mass, and the measurements of the expansion were made on several different planes through each, so that in every case the measurement was effected in a different line through the rock, all of these, however, of course being at right angles to the direction of the compressive stress and lying in the medial plane of the column.

	Maximum.	Minimum.	Difference.
Baveno granite (coarse), 10 trials	4,880,000	4,380,000	500,000
Sudbury diabase (very fine), 10 trials	11,170,000	9,655,000	1,515,000
Plate glass, 13 trials	6,930,000	6,020,000	910,000
Tennessee marble (rather coarse), 7 trials	6,130,000	5,770,000	360,000

It will thus be seen that there is no correspondence between the coarseness of grain and the magnitude of the variations in the readings obtained. The differences in glass, which is an

isotropic material in which the elasticity is equal in all directions, are greater than in the Tennessee marble, which is rather coarse in grain, and in Baveno granite, which is the coarsest rock of the set. The greatest differences obtained are those found in the finest-grained rock in the series, viz., the Sudbury diabase.

It is evident therefore that the different moduli of elasticity of the constituent grains of a rock do not introduce any perceptible error in measurements made by this method, when a column an inch in diameter is employed, and when the rocks are not coarser in grain than the Baveno granite. In fact, when surrounded on all sides by other grains, no individual grain can expand freely, as it would if subjected to compression unhampered by any surrounding medium, and thus the anisotropic character of the individual grains produces but little effect on the elasticity of the rock as a whole.

These experiments also show that in the case of rocks composed of several minerals, it makes no perceptible difference whether the points of attachment of the instrument are embedded in the grains of one mineral or of another. The chief source of error, and the one to which the variations observed are for the most part to be attributed, seems to be a mechanical one, viz., the difficulty of getting an ideal contact between these points of attachment and the specimen, especially in view of the extremely small dimensions of the movement to be measured.

The question of the influence of temperature on the elasticity and compressibility of rocks is of course one which has an important bearing on certain problems of geophysics. The only investigation of this subject, so far as can be ascertained, consists of a few preliminary experiments by Nagaoka and Kusakabe.* In these the torsion method was employed, and the experiments were carried out on a single rock, viz., sandstone. This rock, as has already been mentioned, being porous and stratified in character, is a material whose elastic properties are far from ideal. The results are summed up by the authors in the following words: "Preliminary experiments with sandstone show that the modulus of elasticity is much affected by the variation of temperature, i. e., about 0·5 per cent. per degree. It does not, however, necessarily diminish with the increase of temperature where the temperature is low, i. e., it is maximum about 9° C."

As has been shown, however, the values for the elastic constants obtained by this torsion and bending method have yielded results which cannot in all cases be correct, and which differ very considerably from those obtained by the much more

* Modulus of Elasticity of Rocks, and Velocities of Seismic Waves, Publications of the Earthquake Investigation Committee, No. 17, Tokyo, 1904, p. 43.

direct and simple method which has been employed in the present paper. These results bearing on the variation of elasticity induced by changes of temperature, especially in view of the fact that they are stated by the investigators to be " preliminary," can as yet hardly be taken as of general application to all rocks, even if correct for the specimen of sandstone examined.*

In our own investigations the laboratory was maintained at a temperature of from 63° to 68° F. (17·2° C. to 20° C.), and a thorough investigation into the effect of temperature was not undertaken, as this would be very difficult to carry out when employing the method of direct compression used, the difficulty consisting in heating the specimen itself without in any way affecting the measuring apparatus attached to it.

It seemed, however, possible to ascertain whether any serious change in the elastic constants of the massive crystalline rocks employed in the present investigation would result from a moderate change of temperature. For purposes of trial the rock selected was the Sudbury diabase, a typical fine-grained plutonic rock. A column of it was placed by Mr. McKergow in a small testing machine, having a capacity of 50 tons, and the temperature of the room in which the machine was set up having been lowered to +10° F. a cycle of compression readings was taken in the usual way adopted when Young's modulus is to be determined. The temperature of the room was then raised by about 10° and another cycle of readings was taken. It was then raised another 10° and a third series of readings was obtained, and so on through successive stages of 10° until the normal temperature of the room (about 65° F.) was reached. The initial reading of the instrument before the application of pressure was of course different in each case, owing to the expansion of the rock which followed from heating. These initial points were plotted on a line, and the results obtained when this specimen was subjected to a certain maximum load, together with the increase of temperature at each stage, were plotted on a second line. If the compression was greater at 65° than at 10° for the same load, these two lines should have diverged, but as a matter of fact they were

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* In two very interesting papers, received while the present paper was in press (Modulus of Elasticity of Rocks and some inferences relating to Seismology, Journal of College of Science, Imperial University of Japan, vol. xx, article 9, 1905 ; and Kinetic Measurements of the Modulus of Elasticity, etc., ditto, vol. xx, article 10, 1905), Kusakabe shows that the presence of moisture in a rock has a very marked influence in diminishing its modulus of elasticity. This influence, he has ascertained, is very much more pronounced in the case of porous rocks—such as sandstone—which absorb a large quantity of water, than in the case of the compact crystalline rocks. He suggests that the effect, which in the paper above mentioned was attributed to heat, may really be due to the presence of moisture. He is now engaged in investigating the influence of moisture combined with a high temperature upon the modulus of elasticity of various rocks.

practically parallel. The differences between the readings given by the same load at different temperatures were no greater than those obtained by different measurements under the same load at the same temperature. The conclusion therefore seems to be indicated that a change of temperature made no perceptible difference within the range of temperatures employed, although a difference of 0·5 per cent. for each degree centigrade would mean a difference of about 25 per cent in range of temperature employed by Mr. McKergow.

While therefore this experiment cannot be considered as supplying accurate information concerning the effect produced by a rise in temperature on the elastic constants of rocks, for the instruments themselves are in some measure affected by
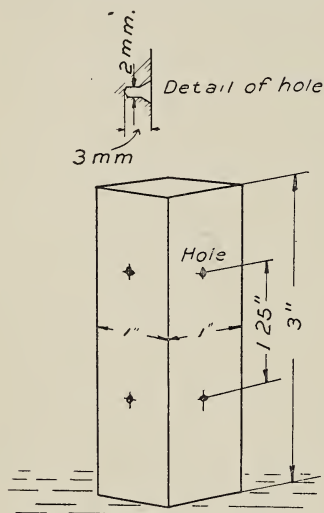
FIG. 4. Square test specimen of rock.   FIG. 5. Round test specimen.
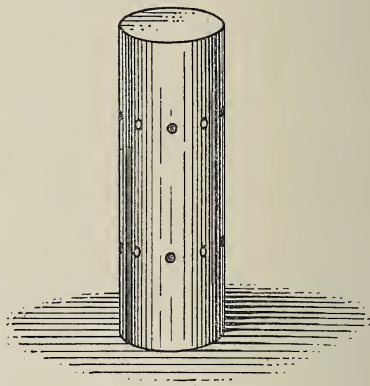
the same changes of temperature, yet they serve to show that in the case of the massive crystalline rocks, the influence of temperature is probably not very great.

The Method of Measurements.

In carrying out the measurements, prisms of the rock 1 inch square and 3 inches long were usually employed (see fig. 4). These were cut and ground with smooth faces but were not polished. In these two small round holes were drilled in the medial line of each vertical face for the purpose of attaching the instrument, when Young's modulus was to be measured. These holes were made by means of a small diamond drill and were perfectly round and smooth. They were each 0·05 to

0·08 inch in diameter and 0·125 inch deep and 1·25 inches apart, lying at equal distances above and below the center of the prisms. These holes were chamfered at the outer end as shown in figure 4, and were found to afford the most perfect attachment which could be secured for the points of the instrument.

By means of these prisms two sets of measurements of the vertical compression could be made with each prism, by attaching the instrument first to one pair of opposite faces and then to the other.

In some cases round columns were used (see fig. 5). These were approximately 1 inch in diameter and 3 inches in length. With these it was possible to make four sets of measurements in compression with each column, by drilling eight pairs of holes as above described, whose plains intersected at angles of 45° instead of 90° as in the square prisms.

It was of course necessary in every case, whether prisms or columns were employed, to exercise great care to have the end of the test pieces very carefully faced and absolutely parallel to one another. Before the actual measurements were made, the rock in every case was brought to a "state of ease" in the manner already described.

The pressure was applied in most cases by a 100-ton Wickstead testing machine, which was so carefully adjusted that it was sensitive to a load of 4 pounds.

The specimen having been placed in the testing machine and brought to a state of ease was then after careful adjustment submitted to loads increasing in successive stages of 1,000 pounds until the limit of safety had been reached, when the load was reduced successively by the same amounts, accurate readings being taken at each increment and decrement of load. The maximum load employed in the case of most rocks was 9,000 pounds, equivalent to from 9,000 pounds to about 11,500 pounds per square inch according to whether a square or round prism was employed. In the case, however, of some of the stronger rocks a load of as much as 15,000 pounds per square inch was employed.

In the determination of the lateral strain, which was made upon the same columns as those used for measuring the vertical compression, care was taken that the theoretical conditions were realized, and that the material was free to expand laterally, as otherwise the values obtained for the lateral extension would be inaccurate. In all cases, therefore, the measuring apparatus was set as nearly as possible upon the central section of the test piece, and the ends of the specimen, after being ground smooth, were coated with a thin film of oil, so that the polished pressure plates of the machine would have as little tendency as possible to prevent freedom of lateral expansion.

It was found that these precautions being observed, the expansion at the ends of the column was practically as great as at the center where the measurement was taken ; the difference being so small that no serious discrepancy was introduced.

In a number of cases accurate measurements were taken during the successive cycles of loading and unloading to which the specimen was subjected in order to bring it to a state of rest. These were recorded in the case of the Baveno granite and the Stanstead granite and serve to show how the hysteresis of the rock may be reduced to a minimum by subjecting the test-piece to this treatment. The measurements of each cycle usually occupied from ten to fifteen minutes.

In the case of a majority of the rocks investigated, a number of prisms or columns cut from the same block of rock were measured in order to ascertain whether different test pieces would give identical readings. It was found as a result of these investigations that the differences between the different specimens were no greater than those which were obtained by measuring the same specimens with the instrument attached to different sides.

In the case, however, of the Quincy granite, test pieces from two different blocks of the rock were prepared, and it was found that while the several measurements made on each test piece agreed among themselves, there was a distinct divergence in the elastic constants of the two specimens of the rock. This was probably due to a difference in composition, as the two rocks differed somewhat in appearance.

In the case of the green gabbro from New Glasgow, the results obtained by measurements made upon different parts of the same prism were discordant for reasons which will be pointed out and which were dependent upon the structure of the rock.

Fifty-five columns of rock, nineteen of glass, and two of iron were employed in this investigation and every precaution was taken to insure the attainment of accurate results. The rocks in all cases were air-dry, having been allowed to remain in the laboratory for several weeks after they had been cut, before the measurements were made.

In the accompanying tables the following elastic constants are given :

$E=$ Young's Modulus, i. e., the quotient of the longitudinal stress by the longitudinal compression.

$\sigma=$ Poisson's Ratio. This is the reciprocal of m.

$D=$ Modulus of Cubic Compression $= \dfrac{1}{3}\left(\dfrac{m}{m-2}\right)E$. The reciprocal of this gives the decrease in volume of a cubic inch of the material for a pressure of 1 pound per square inch applied on every side.

$C=$ Modulus of Shear $= \dfrac{1}{2}\left(\dfrac{m}{m+1}\right) E$, which is the quotient of torsional stress to torsional strain.

$m=$ The ratio of longitudinal compression to lateral extension per unit of length.

E and m are measured directly; the other values are calculated from them.

These values in the case of each rock are given in inch and pound units, and the results are summarized in a general table on page 121. The measurements were made in these units on account of the fact that the testing machine employed was graduated to read pounds.

For purposes of comparison, however, this latter table has been recalculated in C.G.S. units, and the results are set forth in the second table, to be found on page 121.

In the case of metal, Poisson's ratio is generally arrived at by stretching the bar and determining the value of the longitudinal extension divided by the lateral contraction. In case of rocks the tensile strength being low and the materials being brittle, it is more convenient and more accurate to make the determination by compressing a short bar or column, and determining the value of the longitudinal compression divided by the lateral expansion. This gives the value designated as m, of which Poisson's ratio is the reciprocal. Theoretically one method is as accurate as the other.

In each table the first transverse line designates the specimen employed as a, b, c, or d.

The second line gives the diameter of the specimen, which is often slightly different in the two directions. The length of the column in all cases was about three inches, but this is not stated in the table, as the compression is not measured on the total length of the column, but on the length of that portion of it which lies between the points of attachment of the instrument.

The third line gives the area, which is approximately one square inch in the case of a square prism and three-quarters of a square inch in the case of a round column.

The fourth transverse line contains the letters U or P, which designate the two diameters of the column when two measurements were made on the same square prism; these two directions being always at right angles to one another. In the case of round columns on which measurements were frequently made in several planes, these are designated as "first holes," "second holes," etc.

In the four succeeding lines the four elastic constants E, σ, D and C are given as determined by each measurement.

The sixteen rocks whose elastic constants were determined are enumerated in the following list:

Marbles and Limestones.

1. Black Belgian marble; an extremely fine-grained and massive black marble, largely used for ornamental purposes and known in trade as "Belgian Black".

2. White marble, Carrara, Italy; a typical fine-grained saccharoidal marble.

3. White marble, Vermont, U. S. A.; identical in appearance with the last.

4. Pink marble, Tennessee, U. S. A.; a highly metamorphosed coralline limestone which has been converted into a marble; largely used for purposes of construction and known as "Pink Tennessee."

5. Trenton limestone, Montreal, Canada; a highly fossiliferous variety, free from any signs of stratification, taken from a heavy bed in the Mile End quarries at this place; used extensively as a building stone.

Granites.

6. Granite, Baveno, Italy; a typical biotite granite of medium grain.

7. Granite, Peterhead, Scotland; a typical, rather coarse-grained, biotite granite.

8. Granite, Lily Lake, New Brunswick, Canada; closely resembles No. 7.

9. Granite, Westerly, Rhode Island, U. S. A.; a typical, very fine-grained reddish biotite granite.

10. Granite, Quincy, Massachusetts, U. S. A.; a rather coarse-grained hornblende pyroxene granite.

11. Granite, Stanstead, Quebec, Canada; a rather fine-grained muscovite biotite granite; the mica is relatively more abundant than in either the Peterhead or the Westerly granites.

Nepheline Syenite.

12. Nepheline syenite, Montreal, Canada; a typical fine-grained massive hornblende nepheline syenite.

Basic Plutonic Rocks.

13. Anorthosite, New Glasgow, Quebec, Canada; a rock composed of plagioclase with a subordinate amount of pale green augite and green hornblende; it is fine in grain and very tough, being used for paving sets in the city of Montreal.

14. Essexite, Mount Johnson, Quebec, Canada; a typical essexite, massive and uniform in character, composed of plagioclase, nepheline, augite, hornblende and biotite; used extensively as a building stone and for monuments.

15. Gabbro, New Glasgow, Quebec, Canada; this rock is deep green in color and occurs in the form of a large dike cutting the anorthosite (No. 13); composed of augite, hornblende and plagioclase, the two former minerals preponderating largely. It

shows a distinct parallelism in the arrangement of the constituents, to which may be attributed a considerable divergence in the results obtained in the different measurements of the elastic constants.

16. Olivine diabase, near Sudbury, Ontario, Canada ; a typical fine-grained, perfectly massive olivine diabase, occurring as a large dike cutting rocks of Huronian age.

Sandstones.

17. Sandstone, Cleveland, Ohio, U. S. A., a fine, even-grained yellowish sandstone, extensively used for building purposes. The bedding is marked by a slight variation in the color of the different beds. The prism used in the measurement of the elastic constants was cut from a single bed and was taken parallel to the plane of bedding.

A summary of the results obtained in the measurement of the elastic constants of these rocks is given on p. 121. The extended results are here presented in the case of three rocks only, which may serve as representatives of the others.

Carrara Marble :

Three specimens of the rock were used in measuring the elastic constants, two squares prisms (*a* and *b*) and a round column (*c*). Two sets of measurements were made on both *b* and *c*, the instrument as usual being affixed to the specimens in two positions at right angles to one another in each case. In this way five sets of measurements were made. The results are set forth in the following table :

Carrara Marble

No.	*a*	*b*	*b*	*c*	*c*
Size	1·032 × 1·035	1·017 × 1·016	. . . .	·985	·985
Area	1·07	1·033	1·033	·762	·762
E	8,120,000	7,800,000	8,055,000	8,210,000	8,045,000
σ	·281	·274	·273	·275	·269
D	6,170,000	5,750,000	5,920,000	6,100,000	5,790,000
C	3,170,000	3,060,000	3,160,000	3,210,000	3,170,000

The averages of the results obtained for the respective constants are as follows :—

E = 8,046,000; σ = 0·2744; D = 5,946,000; C = 3,154,000.

The difference between the highest and lowest determinations of D is 420,000 pounds.

Figure 6 shows the stress strain curves plotted from the results obtained from specimen *a*, the ordinates representing the load (stress) and the abscissae the amount of the strain. I

represents in all cases the longitudinal compression and II the lateral extension. The hysteresis is greater than in the case of the black Belgian marble (fig. 7), but about the same in amount as shown by the Vermont marble and the Trenton limestone from Montreal.
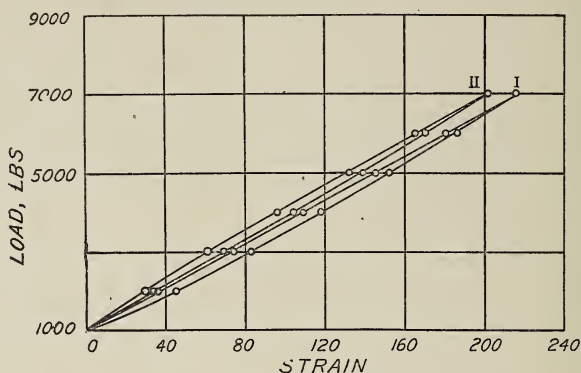
Fig. 6.   Carrara Marble, stress strain curves.
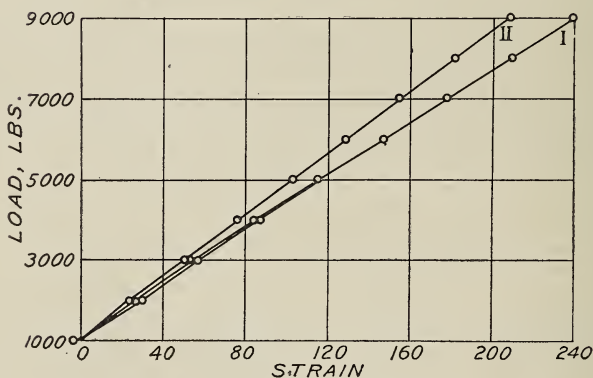
Fig. 7.   Black Belgian marble, stress strain curves.

Granite, Westerly, Rhode Island, U. S. A.

Four test pieces were used in measuring the elastic constants, viz : two square prisms, *a* and *b*, and two round columns, *c* and *d*. Two sets of determinations were made on each of the first three specimens, the instruments being attached to different pairs of sides in each case, and four sets of determinations were made on specimen *d* in planes making angles at 45° with one another. The results are given in the following table.

The averages of the values obtained are as follows:

$$E = 7,394,500 ; \qquad \sigma = ·2195 ;$$
$$D = 4,897,500 ; \qquad C = 3,019,700$$

The difference between the highest and lowest values in the four determinations of D on specimen d was only 280,000.

Of the other columns a gave on an average somewhat lower and b somewhat higher results.

The stress strain curves obtained from specimen a are shown in figure 8. The hysteresis is greater than that shown in the case of any of the other granites except that from Stanstead.

In figure 9 the stress strain curves for the Peterhead granite, and in figure 10 those for the nepheline syenite are shown for purposes of comparison.

Olivine Diabase, near Sudbury, Ontario, Canada.

Four test pieces were used in determining the elastic constants of the rock, viz: three round columns and one nearly square prism. They are designated as a, b, c and d. The three round columns were cut out of a block of the diabase by means of an annular diamond drill. Two measurements were made on each of these in planes at right angles to one another, in each case, while four measurements were made on the prism d using two pairs of faces. In this way ten complete sets of measurements were made for the elastic constants of this diabase.

The values obtained are given in the tables on p. 117.

As will be seen, the values obtained for D in this rock are considerably higher than those yielded by any other rock of the series examined. In the six independent measurements carried out on the first three specimens, the difference between the highest and lowest values for D amounted to 830,000 pounds, while on the four measurements made on specimen d there is a rather greater difference amounting to 845,000 pounds.

Granite, Westerly, Rhode Island, U. S. A.

No.	a	a	b	b	c	c	d	d	d	d
Size	1·008×1·002		·981×·929		·975		·975			
Area	1·01		·91		·75		·75			
Side	U.	P.	U.	P.	1st holes	2d holes	1st holes	2d holes	3d holes	4th holes
E	7,180,000	7,090,000	7,625,000	7,745,000	7,670,000	7,335,000	7,575,000	7,335,000	7,170,000	7,250,000
σ	·21	·1985	·241	·214	---	---	·225	·223	·2225	·222
D	4,110,000	3,950,000	4,925,000	4,515,000	---	---	4,600,000	4,420,000	4,320,000	4,340,000
C	2,970,000	2,960,000	3,070,000	3,185,000	---	---	3,090,000	2,980,000	2,940,000	2,961,000

Fig. 8.   Westerly granite, stress strain curves.

Fig. 9.   Peterhead granite, stress strain curves.

Fig. 10.   Montreal nepheline syenite, stress strain curves.

The averages of the determinations made on each of the columns are as follows:

	E	D	σ	C
a =	13,515,000	10,400,000	0·2838	5,270,000
b =	14,170,000	10,945,000	·2840	5,525,000
c =	14,170,000	11,085,000	·2870	5,505,000
d =	13,197,750	10,076,000	·2812	5,155,000
Av.	13,763,187	10,626,500	·2840	5,363,750

The stress strain curves given by this rock are shown in figure 11. As will be seen from these curves, in its approach to perfect elasticity the rock is comparable to plate glass.

The Elastic Constants of Glass.

As in geophysical speculations, the earth in respect to its rigidity and compressibility is often compared to a globe of glass, it seemed advisable to determine as accurately as possible the elastic constants of glass, for the purpose of comparing them with the results obtained in the case of the various rocks considered in this paper, employing the same methods and carrying out the work under exactly the same conditions. This material lends itself excellently to this method of measuring these constants, provided the glass is free from all irregularities in its substance and is isotropic in character. The first difficulty experienced was that of obtaining such a glass. At the outset it was thought that thick glass rods such as are used for various purposes in the chemical and physical laboratory might be employed, but although several lots of the purest variety of this material were procured, the glass constituting it was found in all cases to contain minute air bubbles, and when examined between crossed nicols in polarized light, showed brilliant colors—red, yellow and blue. This indicated a state of marked tension in the glass, evidently due to the rod having been drawn when the glass was in a viscous state, which was also shown by the circular arrangement of the little bubbles in the rod, following the direction of its surface. Short lengths of this rod moreover when tested in compression, so soon as the maximum load had

Olivine Diabase, Sudbury, Province of Ontario, Canada.

No.	Size	Area	E	σ	D	C
a	·981	·756	13,250,000	·2865	10,340,000	5,160,000
a	·981	·756	13,780,000	·281	10,460,000	5,380,000
b	·983	·758	14,020,000	·291	11,170,000	5,430,000
b	·983	·758	14,320,000	·277	10,720,000	5,620,000
c	·983	·758	14,020,000	·291	11,170,000	5,430,000
c	·983	·758	14,320,000	·283	11,000,000	5,580,000
d	1·000 × ·864	·864	13,150,000	·276	9,810,000	5,170,000
d	- - -	·864	13,330,000	·285	10,340,000	5,200,000
d	- - -	·864	13,450,000	·287	10,500,000	5,230,000
d	- - -	·864	12,860,000	·279	9,655,000	5,020,000

Plate Glass.

	a	*b*	*c*	*d*	*e*	*f*	*g*
No							
Size	0·9855 × 1·0205	0·9865 × 1·0055	0·981 × 1·0135	1·016 × 1·008	1·0215 × 0·9955	1·022 × 1·0025	1·025 × 0·994
Area	1·0057	0·992	·994	1·024	1·017	1·024	1·016
E	10,350,000 10,590,000	10,950,000 10,500,000	10,480,000 10,350,000	10,380,000 10,380,000	10,450,000 10,930,000	10,380,000 10,600,000	10,450,000 10,230,000
σ	0·2281 0·228	0·236 0·2341	0·226 0·235	0·233 0·227	0·221 0·23	0·229 0·225	0·216 0·215
D	6,370,000 6,480,000	6,930,000 6,580,000	6,460,000 6,520,000	6,480,000 6,350,000	6,380,000 6,760,000	6,370,000 6,430,000	6,140,000 6,020,000
C	4,220,000 4,310,000	4,440,000 4,250,000	4,280,000 4,190,000	4,210,000 4,230,000	4,280,000 4,440,000	4,220,000 4,330,000	4,300,000 4,360,000

been exceeded, instead of splitting from top to bottom, broke as if composed of a series of rudely concentric shells.

After a prolonged search for isotropic glass in masses of sufficient size to measure the elastic constants, it was found that plate glass answered the requirements. A piece of one inch plate glass, m a d e in Great Britain, was accordingly secured and was cut into strips an inch wide, and these again into three inch lengths. The square prisms thus produced w e r e then properly faced and polished. The glass was found to be absolutely free from all flaws and impurities, and when examined between crossed nicols, the prisms although an inch thick, showed in one direction at right angles to vertical axis absolute blackness throughout a complete revolution, while in the other direction at right angles to this there was during a revolution an alternation of blackness with a pale grayish illumination. This change was so slight that considering the thickness of the glass and the sensitiveness of the test, the material may be considered to be practically f r e e from internal tension. and to be isotropic in character.

In order to get a good average and to eliminate chance errors so far as possible, seven of these prisms were taken, and two complete sets of determinations were made on each of them, using in every case different pairs of faces. Fourteen determinations w e r e thus made of each of the elastic

constants. The figures obtained are set forth in the table on p. 118.

In this table a complete series of values obtained from each specimen are given in double rows. When the average of all these results is taken, the values obtained for the several constants of plate glass are as follows:

$$E = 10,500,000 ; \quad \sigma = 0.2273; \quad D = 6,448,000 ; \quad C = 4,290,000$$

The stress-strain curves given by one of the prisms is shown in figure 12. In this figure I represents longitudinal compression and II lateral extension.

Determinations of the cubic compressibility of glass, D, have been made by other observers using various methods.
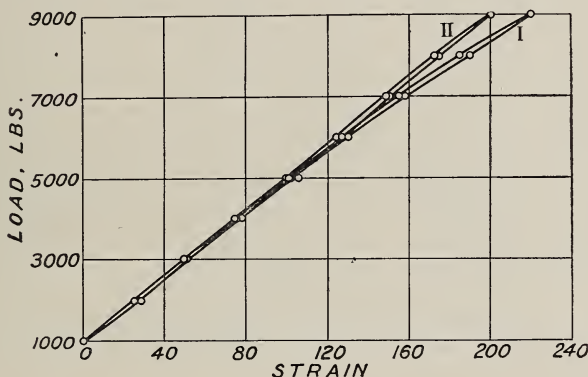
Fig. 11. Sudbury Diabase, stress strain curves.

The results go to show that different varieties of glass vary considerably in their compressibility. These determinations may be tabulated as follows:*

Everett _____ 5,074,600 to 6,379,400 (C.G.S.=3.5 to 4.4×10¹¹)
Amagat-common
    glass _____ 6,745,000 (.000002181 per atmosphere)
Amagat-crystal
    glass _____ 6,112,300 (.000002405 "   "   )
Tait _____ 5,657,700 (.0000026   "   "   )

As will be seen, the figures obtained for plate glass in the present investigation lie a little above the average of the various values here given, and are nearly those of the highest value obtained by Everett.

* See Everett, Illustrations of the C.G.S. System of Units with tables of Physical Constants. Macmillan & Co., 1902, pp. 60 to 64. The figures there expressed in various units have been here recalculated into inch-pound values.

Summary of Results.

In the table on the following page a summary is shown of the average values obtained for E, σ, C and D in the case of all the rocks examined in this investigation. Together with these are placed for purposes of comparison the results obtained for these constants in the case of wrought iron, cast iron and glass. In the second table these values are again presented, recalculated into C.G.S. units.

The rocks fall naturally into three groups differing from one another in compressibility, but the several members of each group agreeing fairly closely among themselves.
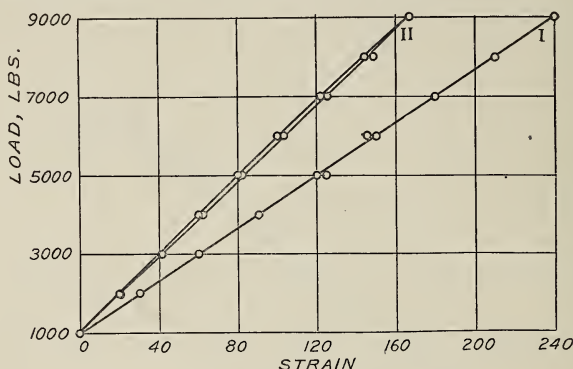
Fig. 12.   Plate glass, stress-strain curves.

These three groups show a corresponding difference in composition.

The first group consists of the marbles and limestones. These have an average value for D of 6,345,000. One of these, however, the Black Belgian marble, which is very much finer in grain than the others, and breaks almost like a piece of glass, has a very much higher value for D than that possessed by the other rocks, which among themselves are nearly identical. If we omit this Belgian marble, the average of D for the other limestones and marbles is 5,855,000.

The second group comprises the granites. These again show a close agreement of values among themselves, except in the case of the Stanstead granite, which rock as already mentioned shows a defective elasticity. The average value of D for the granites is 4,399,000.

The third group embraces the basic intrusives (gabbro, anorthosite, essexite and diabase). These show greater differences, but have an average value for D of 8,825,000. The nepheline syenite, although higher in silica and therefore properly speaking an acid rock, in its freedom from quartz and its richness in feldspar (although the feldspar is largely orthoclase instead of plagioclase), in mineralogical composition

belongs with these basic rocks rather than with the granites. It also approaches the essexite most nearly in its compressibility.

ELASTIC CONSTANTS OF ROCKS.
Summary of Results (average) expressed in Inch-Pound Units.

	E	σ	C	$D=\frac{1}{3}\left(\frac{m}{m-2}\right)E$
Wrought iron	28,100,000	0·2800	11,000,000	21,300,000
Cast iron	15,000,000	0·2500	6,000,000	10,000,000
Black Belgian marble	11,070,000	0·2780	4,330,000	8,303,000
Carrara marble	8,046,000	0·2744	3,154,000	5,946,000
Vermont marble	7,592,000	0·2630	3,000,000	5,341,000
Tennessee marble	9,006,000	0·2513	3,607,000	5.967,000
Montreal limestone	9,205,000	0·2522	3,636,000	6,167,500
Baveno granite	6,833,000	0·2528	2,724,800	4,604,000
Peterhead granite	8,295,000	0·2112	3,399,000	4,792,000
Lily Lake granite	8,165,000	0·1982	3,380,000	4,517,500
Westerly granite	7,394,500	0·2195	3,019,700	4,397,500
Quincy granite (1)	6,747,000	0·2152	2,781,600	3,984,000
Quincy granite (2)	8,247,500	0·1977	3,445,000	4,555,000
Stanstead granite	5,685,000	0·2585	2,258,700	3,940,000
Nepheline syenite	9,137,500	0·2560	3,635,000	6,237,500
New Glasgow anorthosite	11,960,000	0·2620	4,750,000	8,368,000
Mount Johnson essexite	9,746,000	0·2583	3,872,600	6,750,000
New Glasgow gabbro *	15,650,000	0·2192	6,365,000	9,555,000
Sudbury diabase	13,763,000	0·2840	5,364,000	10,626,500
Ohio sandstone	2,290,000	0·2900	888,000	1,816,000
Plate glass	10,500,000	0·2273	4,290,000	6,448,000

Summary of Results (average) expressed in C.G.S. Units.

	E	σ	C	$D=\frac{1}{3}\left(\frac{m}{m-2}\right)E$
Wrought iron	$19\cdot37 \times 10^{11}$	0·2800	$7\cdot590 \times 10^{11}$	$14\cdot680 \times 10^{11}$
Cast iron	$10\cdot34 \times 10^{11}$	0·2500	$4\cdot132 \times 10^{11}$	$6\cdot897 \times 10^{11}$
Black Belgian marble	$7\cdot24 \times 10^{11}$	0·2780	$2\cdot982 \times 10^{11}$	$5\cdot736 \times 10^{11}$
Carrara marble	$5\cdot54 \times 10^{11}$	0·2744	$2\cdot171 \times 10^{11}$	$4\cdot090 \times 10^{11}$
Vermont marble	$5\cdot24 \times 10^{11}$	0·2630	$2\cdot069 \times 10^{11}$	$3\cdot680 \times 10^{11}$
Tennessee marble	$6\cdot21 \times 10^{11}$	0·2513	$2\cdot482 \times 10^{11}$	$4\cdot115 \times 10^{11}$
Montreal limestone	$6\cdot35 \times 10^{11}$	0·2522	$2\cdot504 \times 10^{11}$	$4\cdot250 \times 10^{11}$
Baveno granite	$4\cdot71 \times 10^{11}$	0·2528	$1\cdot875 \times 10^{11}$	$3\cdot178 \times 10^{11}$
Peterhead granite	$5\cdot71 \times 10^{11}$	0·2112	$2\cdot340 \times 10^{11}$	$3\cdot300 \times 10^{11}$
Lily Lake granite	$5\cdot63 \times 10^{11}$	0·1982	$2\cdot330 \times 10^{11}$	$3\cdot103 \times 10^{11}$
Westerly granite	$5\cdot09 \times 10^{11}$	0·2195	$2\cdot080 \times 10^{11}$	$3\cdot029 \times 10^{11}$
Quincy granite (1)	$4\cdot64 \times 10^{11}$	0·2152	$1\cdot916 \times 10^{11}$	$2\cdot750 \times 10^{11}$
Quincy granite (2)	$5\cdot68 \times 10^{11}$	0·1977	$2\cdot373 \times 10^{11}$	$3\cdot140 \times 10^{11}$
Stanstead granite	$3\cdot92 \times 10^{11}$	0·2585	$1\cdot556 \times 10^{11}$	$2\cdot718 \times 10^{11}$
Nepheline syenite	$6\cdot29 \times 10^{11}$	0·2560	$2\cdot505 \times 10^{11}$	$4\cdot290 \times 10^{11}$
New Glasgow anorthosite	$8\cdot25 \times 10^{11}$	0·2620	$3\cdot275 \times 10^{11}$	$5\cdot760 \times 10^{11}$
Mount Johnson essexite	$6\cdot71 \times 10^{11}$	0·2583	$2\cdot670 \times 10^{11}$	$4\cdot650 \times 10^{11}$
New Glasgow gabbro *	$10\cdot80 \times 10^{11}$	0·2192	$4\cdot380 \times 10^{11}$	$6\cdot589 \times 10^{11}$
Sudbury diabase	$9\cdot49 \times 10^{11}$	0·2840	$3\cdot700 \times 10^{11}$	$7\cdot329 \times 10^{11}$
Ohio sandstone	$1\cdot58 \times 10^{11}$	0·2900	$\cdot612 \times 10^{11}$	$1\cdot250 \times 10^{11}$
Plate glass	$7\cdot24 \times 10^{11}$	0·2273	$2\cdot960 \times 10^{11}$	$4\cdot439 \times 10^{11}$

If the nepheline syenite be included with the basic rocks, an average value of D is obtained of 8,308,000.

This omits from consideration the sandstone, it being a rock

* See page 112.

of an entirely different class from the others, and furthermore one which shows so much hysteresis that the application of this method to it is less satisfactory than in the case of the other rocks of the series.

These results may be presented as follows:

	Average of D
Marbles and limestones	6,345,000
Granites	4,399,000
Basic intrusives	8,308,000

The cause of the much greater compressibility of granite as compared with the marbles and basic intrusives is not clear, but would seem to be connected with the presence of quartz. The only determination of the cubic compressibility of quartz, so far as can be ascertained, is one by Voigt,[*] the value obtained being 5,504,190 pounds (387×10^6 grams per. sq. cent.). This compressibility, as will be seen, is much greater than that found in the case of either the limestones or the basic intrusives, and while not in itself sufficiently great to account for the high compressibility of the granites, goes to show that in the quartz we have a mineral which is more compressible than the ordinary rock-making minerals which form the chief constituent in the rocks of the series examined.

The marbles and the limestones of the earth's crust are confined to its most superficial portion, resulting as they do from the process of sedimentation. There is every reason to believe, however, that what we may term the sub-structure of the earth's crust is composed of acid and basic plutonic igneous rocks. These make up the lowest part of the crust to which we have access, and are found coming up from the still greater depths.

The cubic compressibility, D, of the earth's crust must lie between the values given above for the granites and the basic intrusives, approaching one or other of these values according to the relative proportion in it of one or other of these classes of rocks.

If we take the average of the values obtained from these two classes of rocks as represented by the seven granites and the five basic intrusives (including the nepheline syenite), the value obtained for D is 6,353,500.

This, as will be seen, differs but little from the value of D obtained for plate glass, which is 6,448,000.

If, therefore, the earth's crust be composed of granite and basic igneous rocks in approximately equal proportions, its compressibility will be that of glass. If it be composed almost exclusively of granite, the earth's crust will be more compressible than glass; and if the basic rocks preponderate very largely, it will be less compressible than this substance.

[*] Quoted in Becker, Experiments on Schistosity and Slaty Cleavage, Bulletin 241, U. S. Geol. Survey, p. 32.

It is, however, in any case much more compressible than steel, which has a value for D of from 26,098,000 to 27,547,000 (18 to 19×10^{11}, C.G.S.)*.

The compression to which the rocks were subjected in this investigation ranged from 6,000 to 17,340 pounds to the square inch. Most of the rocks, however, were subjected to a load of from 9,000 to 15,000 pounds per square inch, and their bulk compression was determined for these loads as maxima. Higher pressures could not be employed without incurring the risk of breaking the specimen, and at the same time of destroying the measuring apparatus. One apparatus was in fact so destroyed.

The question arises as to whether under still higher pressures, if rupture could be avoided, the ratio of load to compression would be maintained. Judging from the deportment of much stronger substances, such as steel, when similarly tested, it is inferred that this ratio of bulk compression will remain constant for very much higher pressures, or until deformation sets in and the rock begins to flow.

With regard to the accuracy of the results obtained by this method as compared with those obtainable by any method in which cubic compression is actually produced and measured, it may be observed that by far the best method of this kind hitherto suggested seems to be that proposed by Richards and Stull.† We have endeavored to make use of this method in order to obtain results for purposes of comparison with those given in the present paper, but have not hitherto succeeded in overcoming certain experimental difficulties. The experimental errors in this method, though apparently small, still exist, and in applying it to rocks, which are much less compressible than the substances examined by Richards and Stull, these errors become proportionately more serious. Moreover, higher pressures than those used in the method employed in the present paper could scarcely be employed in this direct method, while difficulties dependent on the possible lack of absolute continuity in the substance of the rock and the danger of minute air-filled spaces, would probably present themselves in the case of most rocks. It seems that all things being considered, the indirect method here employed is probably as accurate as any direct method which can be used. The attempt to apply Richards and Stull's method to the same rocks is still being continued, however, and it is hoped that satisfactory results may be eventually obtained by its use.

McGill University, Montreal.

* Illustrations of the C.G.S. System of Units with tables of Physical Constants. Macmillan & Co., 1902, p. 60.

† New method of Determining Compressibility. Published by the Carnegie Institution, Washington, D. C., Dec., 1903 (No. 7).

ART. XII.—*The Dakotan Series of Northern New Mexico;* by CHARLES R. KEYES.

STRATA that have been referred to the Dakota division of the Cretaceous age have been long known in the Southwest, around the southern end of the Rocky Mountains in northern New Mexico. The section there exposed has been generally regarded as exactly representing the "Dakota Group" as first defined by Meek and Hayden[*] for the upper Missouri region. Late observations in the New Mexican region indicate clearly that the formation called the Dakota sandstone has never been carefully delimited, that it has been given quite different limits by different authors, and that the section usually so called actually belongs to several geological ages.

As recently made out, the general Mesozoic section of northeastern New Mexico presents the following elements:

General Mesozoic Section of Northeastern New Mexico.

Age.		Series.	Thickness.
Cretacic	Late	7. Laramian sandstones	2500
		6. Montanan shales	1600
	Mid	5. Coloradan shales	1000
		4. Dakotan sandstones	500
	Early	3. Comanchan shales	100
Jurassic		2. Morrisonian sandstones	250
Triassic		1. Red Beds (upper part)	1000

As usually considered in the literature of the subject, the Dakota sandstone has been made to cover of the above section not only No. 4, but No. 2 and No. 3, and not infrequently part of No. 1. The reasons for these long standing errors of interpretation recalls one of the unpleasant chapters in the history of American geology. It goes back to the very beginning, to the early sixties, when there was a concerted attempt to thoroughly discredit the work of Jules Marcou in this country. The proofs of the conclusions which the Swiss geologist submitted may have been insufficient at the time, or they may have been happy guesses, but the fact yet remains that the latest work in the region has, in the main, substantiated his observations and there are too many of his statements that are correct to assert at this day that they were anything less than a display of geological acumen such as none of his critics possessed. Newberry, Hayden, Meek and others appear to have become so absorbed in their side of the controversy that they all but lost sight of the facts, and they not infrequently went

[*] Proc. Acad. Nat. Sci., Phila., vol. xiii, pp. 410–420, 1862.

so far as to discuss in the most positive manner sections which they had never been near. Instead of clearing up the points under discussion, this long drawn out controversy only served to make the entire question more obscure.

When I was first suddenly made acquainted with the Cretaceous formations of the region, it was in the field, before it was possible to consult carefully very much of the literature on the subject. In mapping and in local descriptions in the northern New Mexican province I assumed the Dakota sandstone to be the great massive plate of yellow sandstone about 500 feet in maximum thickness. Above it were the Colorado shales and beneath in many places a peculiar succession of sandy shales, shaly sandstones and clay shales. Several papers were even published on New Mexican geology in which this idea of the Dakota formation of the region was expressed. The chief reasons for considering this great plate as a formation by itself and as representing the Dakota sandstone were (1) that it immediately underlay the Colorado shales, which were well identified by numerous fossils, and (2) that the sandstone rested in marked unconformity upon the formations beneath. When, later, the literature was gone over carefully in order to compare the published observations of others with my own, it was with much surprise that I found that prevailing opinions included in the Dakota section a much greater sequence than I had done. This led immediately to a detailed examination of many of the more critical of the described sections ; and the location of the real difficulties of former interpretations.

The use of the term Dakotan series for the sequence of massive yellow sandstones which form the bottom of the Cretaceous section over the greater part of New Mexico is based upon the accepted terminology of the general Mesozoic section of the Rocky Mountain region. As a definite geologic title the name Dakota was first applied by Meek and Hayden,[*] in 1862, to the basal member of the Cretaceous of the Upper Missouri River district. Although included in their "Earlier Cretaceous" division, this is not the Early Cretaceous division as at present understood, but is the base of what has long been known as the "Upper Cretaceous." In the general geological section the formation belongs properly to the Mid Cretaceous period.

As the entire succession of the Mid Cretaceous and Late Cretaceous formations is upturned along the eastern flank of the Rocky Mountains, the Dakotan division is readily traced from the original locality southward into central New Mexico, and the title given to the series in the north appears to be

[*] Proc. Acad. Nat. Sci., Phila., vol. xiii, pp. 510–520, 1862.

fully applicable to certain sandstones widely distributed in the south.

Many different titles have been given to the sandstones belonging to the Dakotan series; and the term itself has been used in many different senses by the various writers who have passed through the New Mexican field. Among the first to call attention to the formation in question was Jules Marcou,* who, as early as the year 1853, traversed this region in connection with an expedition sent out by the Federal government to survey a railroad route to the Pacific coast along the thirty-fifth parallel of latitude.

Capping Pyramid Mountain, Cerro Tucumcari and the cliffs of the Canadian river near the eastern border of New Mexico, Marcou noted about 50 feet of massive yellow sandstones which, with other underlying beds, he regarded as Jurassic in age. The massive yellow sandstone of these sections subsequently proved to be the attenuated eastern edge of what is now denominated the Dakotan series; while lately the age of the beds beneath was finally adjudged in accordance with Marcou's original designation.

During the year 1858 Newberry† crossed northern New Mexico and recognized an extensive development of rocks which he regarded as of Cretaceous age and which he divided into a lower group and an upper group. These divisions are not regarded as representing the similarly named subdivisions of the general Cretaceous section. In the "Lower" division, as thus understood, the Dakotan sandstones were included; and the terms so far as they apply to northeastern New Mexico may be considered as practically co-extensive. In northwestern New Mexico he embraced in this Lower division also the Jurassic Zunian beds. His "Lower Cretaceous" does not, as has been widely believed, correspond to Meek and Hayden's subdivision of the "Early Cretaceous." This is very clearly shown in his descriptions of the region around Las Vegas.‡ In the year following Newberry's return from the Colorado River of the West, and two years before the publication of his official report just referred to, this author published a criticism§ on Marcou's Jurassic system of New Mexico, in which he attempted to show that all of the so-called Jurassic rocks are really Cretaceous in age, and correspond to Meek and Hayden's Fort Benton and Niobrara groups, or the Coloradan series of present nomenclature. This, however, is not strictly correct. The larger part of Marcou's Jurassic system of rocks

* Exp. and Sur. Pacific R. R. Route, vol. iii, p. 137, 1856.
† Ives Rept. Colorado River of West, pt. iii, p. 107, 1861.
‡ Loc. cit., p. 106.
§ This Journal (2), vol. xxviii, pp. 298–299, 1859.

of the New Mexican region belongs to the Dakotan series, or below. The discussion is quite remarkable and, in the light of recent investigations, is strangely incongruent. Marcou and Newberry traversed very different routes; that of the first named explorer being up the Canadian river valley a hundred miles south of the old Santa Fe trail which the last mentioned observer followed. While Newberry was discrediting Marcou's recognition of Jurassic rocks, he himself passed over country where they were not present except at one point—at the Cimarron crossing; and years afterward,[*] with no reference whatever to his former contention, he assigned certain beds in this vicinity to a Jurassic age. Recently Stanton[†] finds that these and the Tucumcari beds of Marcou are continuous and form part of the Morrisonian series.

Newberry[‡] in his later report subdivided the Cretaceous into three sections, the "Lower" division embracing only the Dakota sandstone.

Although Hayden,[§] who with Meek originally defined the Dakota division of the Cretaceous, recognized his formation within the limits of New Mexico in traveling from Raton to Santa Fe, it is not possible to determine from his meager descriptions just how much of the general section of the region he intended to include under the title. However, it is known from the route which he followed that he had at no time any other than the main massive sandstone in view. At no point which he visited are any of the lower, or Morrisonian, beds exposed.

As originally described, the "Lower Cretaceous" of Stevenson,[‖] of northeastern New Mexico, appears to embrace only what is now called the Dakotan series. In a later publication[¶] this writer uses the terms "Dakota Group" to cover not only the Dakotan series, as at present understood, but also the Jurassic section, and a part of the underlying Triassic beds of previous writers. This group was subdivided by him into three sections called the Lower Dakota, the Middle Dakota and the Upper Dakota. The last mentioned alone can now be considered as the equivalent of Meek and Hayden's original Dakotan series. This author[**] says: "The grouping to be proposed is merely provisional; dependence has been placed

[*] Macomb's Expl. Exp. Junc. Grand and Green Rivers, p. 28, 1876.
[†] Journal of Geology, vol. xiii, pp. 657–669, 1905.
[‡] Macomb's Expl. Exp. Geol. Rept., 121, 1877.
[§] U. S. Geol. Surv. Terr., Third Ann. Rept., 2d ed., p. 162, 1873.
[¶] Ibid., Supp., p. 90, 1881.
[‖] U. S. Geol. Surv. W. 100 Merid., vol. iii, p. 400, 1975.
[**] Loc. cit., p. 88.

solely upon lithological characters and stratigraphy, since testimony of fossils is either unattainable or indecisive. When the work shall have been prosecuted in detail and carried systematically toward the south and west to localities already well determined by evidence of fossils, this classification may prove to be somewhat arbitrary. For the present, however, it seems desirable to include under one group the Dakota of Meek and Hayden and the greater part of the Triassic of authors found in New Mexico. The whole series may be Triassic or it may be wholly Cretaceous. It is included under the Dakota here merely for convenience of description."

It is quite clear from a consideration of the various localities mentioned that the author had somewhat mixed his stratigraphy, a fact not to be wondered at when the limited time he had for examination is taken into account. His "Upper Dakota" of one locality is the "Lower Dakota" of another. Elsewhere the latter is of undoubted Early Cretaceous age, and not Mid Cretaceous (Upper Cretaceous) at all.

So far as is known, it is largely due to this report that the confusion regarding the delimitation of the Dakotan series arose in this region. Although the Hayden reports make scant reference to the New Mexican region, the various allusions are of similar tone. And the way was paved by Newberry's denunciations of Marcou based upon very incomplete observations.

In northwestern New Mexico, Holmes[*] ascribes about 1,200 feet of strata to the Dakota group, which he divides into "Lower" and "Upper" portions. Only the massive Upper division is now regarded as properly representing the Dakotan series. The so-called "Lower Dakota" formation is quite different lithologically from the "Upper" portion, and Dutton[†] more recently gave it the name of Zuñi sandstones. It is now regarded as Jurassic in age, as already noted.

In later years Cummins[‡] has proposed to put the attenuated Dakota sandstone, as exposed in the Cerro Tucumcari in eastern New Mexico, with the Early Cretaceous and Jurassic formations of that section, and to call the whole the Tucumcari beds, or formation.

The unity of the great sandstone plate as a distinct and easily recognizable stratigraphic formation seems to be now fully demonstrated, and also finds corroboration in the recent observations of Stanton in southeastern Colorado. The name Dakotan series is properly restricted to it.

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[*] U. S. Geol. and Geog. Sur. Terr., 9th Ann. Rept., p. 224, 1877.
[†] U. S. Geol. Sur., 6th Ann Rept., p. 140, 1886.
[‡] Texas Geol. Sur., Third Ann. Rept., p. 201, 1892.

Art. XIII.—*The Plauenal Monzonose (Syenite) of the Plauenscher Grund ;* by Henry S. Washington.[*]

Of the group of syenites, composed essentially of orthoclase and hornblende, biotite or augite, that of the Plauenscher Grund near Dresden has been the longest known and is regarded as one of the most typical,[†] especially of the hornblende-syenites or syenites proper. It has also been regarded as one of the few known highly potassic representatives of these rocks, or those in which the amount of potash far surpasses that of soda.[‡]

In the course of a study of the highly potassic volcanic rocks of Italy the close similarity of the well-known analysis by Zirkel of the Plauen syenite to those of some of the Italian lavas was noted, a similarity so great that the former might be considered as a plutonic representative of the same magma as that which furnished the lavas farther south.

As the older analysis was not altogether satisfactory because of the high summation, and its incompleteness, the oxides of iron not having been separated nor TiO_2 and P_2O_5 determined, as well as on account of its early date, a new analysis of the rock was undertaken. The material used for this was a specimen collected by myself in 1897 at one of the large quarries on the left bank of the Weisseritz south of the Gasanstalt. The results of this were quite unexpected, diverging very much from the older one in some particulars, most especially in the relations of the alkalies, as will be seen later. Some hesitation was felt about publishing the new analysis, the more so because I was informed by Professor Zirkel, to whom the analysis was shown in 1904, that the mass of syenite varied considerably from place to place, a fact which might explain the discrepancies.

It was finally decided to test this last point, and to determine the true composition of the rock, by examining specimens from different parts of the mass. As a second visit was impracticable, the object was accomplished by obtaining specimens from different sources and collected at different times. These would presumably be derived from different parts of the mass and should reveal any differences in composition should such exist, or, on the other hand, by their uniformity show that the variations were not as great as had been supposed.

[*] The results in this paper form part of an investigation conducted for the Carnegie Institution of Washington, the Trustees of whom I must thank for permission to publish it here.

[†] Cf. Zirkel, Lehrbuch, II, 1894, p. 300 ; Rosenbusch, Mikr. Phys., II, 1896, p. 120.

[‡] Brögger, Eruptivgest. Krist. Geb., II, 1895, p. 30.

For this purpose Dr. Whitman Cross furnished me with material from a specimen (No. 234) in the Petrographic Reference Collection of the United States Geological Survey, Prof. J. F. Kemp with part of a specimen collected by himself in 1886 and now in the collection of Columbia University, and Prof. L. V. Pirsson with a piece of a specimen which had been bought by him in 1891 of Blatz in Heidelberg, and now in the collection of the Sheffield Scientific School. Each of these specimens was practically identical with mine in all respects, and the pieces, though not large, were amply sufficient to furnish representative material for analysis. It is a great pleasure to express my thanks to these friends, who have so kindly and generously aided the present investigation.

As three complete analyses would have involved the expenditure of much valuable time, it was decided instead to determine the alkalies alone in each of these specimens, since the divergencies between Zirkel's analysis and mine were most serious as regards these constituents, and it was considered that any marked variation in the igneous mass would be surely manifest in the figures for these. The results of the determinations were fully confirmatory of my first complete analysis, and indicate a remarkably uniform composition throughout the mass, at least as far as the specimens extend. Not only is this uniformity of interest as showing the true chemical composition of this well-known rock-type, but it is of some importance in a more general way by indicating the uniformity which may obtain through large igneous masses. It may be added that the alkali determinations were made in every case by the Lawrence Smith method, which experience has shown to be the most expeditious and fully as accurate as, if not more so than, the Bunsen method usually employed abroad. Since this paper has been set up the chief constituents in Cross's specimen have been determined, the results being embodied in the table of analyses.

Although the rock is well-known to all petrographers, it will be briefly described in terms of the quantitative system of classification, as an illustration of the methods of this and of the form in which the descriptions of rock-types according to this system may be stated.

I may add that it is with reluctance that I am thus compelled to point out and to correct an error of my teacher and friend, Professor Zirkel, and can but mention the fact that the analytical methods and standards of forty years ago had not attained the degree of accuracy which they have at present.

Plauenal Monzonose.

Megascopic characters.—General color, light pinkish-brown; phanerocrystalline and apparently holocrystalline, medium grain, 1 to 5^{mm}, granular equant fabric, inclining to trachytic; composed of dominant feldspar, of a brownish-pink color, mostly in tables about 5^{mm} wide and 1^{mm} thick, without twinning lamellae, which show a subparallel arrangement; subordinate hornblende in greenish black, equant anhedra, 1 to 3^{mm} in diameter; a few grains of colorless quartz and rare, small, brownish titanites.

Microscopic characters.—Holocrystalline, automorphic granular. Minerals present: alkali-feldspar, hornblende, quartz, plagioclase, magnetite, titanite, apatite.

Soda-orthoclase.—About 65 per cent; in stout subhedral plates, tabular parallel to b (010), Carlsbad twinning common; evidently a soda-orthoclase, with moirè appearance and microperthitic structure very common, but no microcline.

Hornblende.—About 17 per cent; in stout, subhedral prismoids or irregular anhedra, often twinned on a (100); color olive-green, pleochroic, c and b olive-green, a greenish yellow, $c = b > a$; some individuals have a narrow, irregular border of bluish green hornblende; magnetite a common inclusion, titanite and apatite less so, and orthoclase rare.

Quartz.—About 10 per cent; xenomorphic, in irregular anhedra, interstitial between the other constituents, especially the feldspar and hornblendes; occasional undulatory extinction.

Oligoclase.—(Ab$_4$An$_1$). About 3 per cent; stout subhedral tables, twinning lamellae according to the albite law very narrow and numerous.

Magnetite.—About 2 per cent; small, subhedral to anhedral grains.

Titanite.—About 2 per cent; automorphic, giving the usual lozenge sections; pale brown, slightly pleochroic.

Apatite.—About 1 per cent; automorphic, stout prisms; clear.

Chemical composition.—The chemical composition is shown in the table, the earlier analyses by Zirkel and Griffith (quoted from Brögger) being given in columns I and II, the complete analysis of my specimen in III, that of Cross's specimen in IV, followed by the alkali determinations of the other specimens, and the final average with the molecular ratios in VII and VIII.

The two older analyses are very closely alike, a fact to which Brögger has called attention. They are, however, both unsatisfactory according to modern standards, the summation of I being unwarrantedly high,[*] and both being incom-

[*] The sum would be still higher were the ferric oxide reckoned.

Analyses of syenite from the Plauenscher Grund.

	I	II	III	IV	V	VI	VII	VIII
SiO_2	59·83	60·02	62·49	58·70			60·60	1·010
Al_2O_3	16·85	16·66	16·49	17·09			16·79	·165
Fe_2O_3	- - -	7·21	2·36	3·17			2·77	·017
FeO	7·01	- - - -	2·04	2·29			2·17	·031
MgO	2·61	2·51	1·87	2·41			2·14	·054
CaO	4·43	3·59	4·23	4·71			4·47	·080
Na_2O	2·44	2·41	4·38	4·38	4·34	4·49	4·40	·071
K_2O	6·57	6·50	4·65	4·35	4·33	4·93	4·57	·049
H_2O+	1·29	1·10	0·32	0·89			0·61	
H_2O-			0·28	0·23			0·25	
CO_2	- - - -	· - - -	none	none			none	
TiO_2	- - - -	- - - -	0·85	0·95			0·90	·011
ZrO_2	- - - -	- - - -	none	- - - -			none	
P_2O_5	- - - -	- - - -	0·32	0·23			0·28	·002
SO_3	- - - -	- - - -	none	- - - -			none	
S	- - - -	- - - -	none	- - - -			none	
MnO	n.d.	n.d.	n.d.	n.d.			n.d.	
BaO	- - - -	- - - -	0·15	- - - -			0·15	
SrO	- · - ·	- - - -	trace	- - - -			trace	
	101·03	100·00	100·43	99·40			100·10	

Sp. Gr.   2·730

I.   F. Zirkel, Pogg. Ann. cxxii, 1864, p. 622.
II.   Griffith, Chem. News, xlvii, 1882, p. 170 (cf. Brögger, op. cit., p. 30).
III.   Specimen of H. S. Washington.
IV.   Specimen from W. Cross.
V.   Specimen from L. V. Pirsson.
VI.   Specimen from J. F. Kemp.
VII.   Average of III, IV, V and VI.
VIII.   Molecular ratios of VII.

plete, especially as regards the iron oxides, while the total of II (exactly 100·00) gives rise to some uneasiness.

They both resemble III and IV in the figures for silica, alumina, magnesia and lime, but differ much in those for the oxides of iron and the alkalies, though the total amount of these last is about the same in all. It may be noted, however, that the specimens analyzed by Zirkel and Griffith and that of Cross are evidently slightly more femic than mine. This is shown by the lower silica and higher iron oxides, magnesia and lime, as well as by the alumina when it is remembered that the Al_2O_3 of I and II include the TiO_2 and P_2O_5 of the rock.*

* The SiO_2 will also include some of the TiO_2 and possibly a little Fe_2O_3, etc., if it was not checked as to purity by evaporation with hydrofluoric and sulphuric acids. It may be noted that the unchecked silica in IV amounted to 59·45 per cent.

If the ferrous oxide of I is divided up in about the ratio shown by III, that is 3·89 Fe_2O_3 and 3·50 FeO, the norm calculated on this basis is as follows:

Quartz	7·08
Orthoclase	38·92
Albite	20·44
Anorthite	15·57
Diopside	5·19
Hypersthene	7·31
Magnetite	5·57
	100·08
Water	1·29
	101·37
Extra oxygen	0·38
	100·99

This gives as the systematic position ciminose (II.5.2.2), a rare subrang which is abundantly represented at the Italian volcanoes, but which is unknown outside of these except as the durbachite of the Schwarzwald, a rock with very abundant biotite, which is quite absent from the Plauen syenite.

The figures for the alkalies in the new analyses are remarkably constant, Na_2O varying only from 4·34 to 4·49, while the range of K_2O is slightly greater, from 4·33 to 4·93: the former being within the acceptable limits of analytical error and the latter scarcely more than this.[*] Silica varies within a range of 3·19 per cent, and the other constituents are somewhat higher in IV than in III, though not very much so. Taken as a whole, when we remember that silica is the most abundant constituent and the one in which a greater range of variation is to be expected, and when the different times when, and the different parts of the mass where, the specimens were collected are considered, the results of my analyses imply a remarkable uniformity in the mass of syenite. It is true that highly feldspathic, as well as highly hornblendic, schlieren occur here and there, but these are of very minor importance, besides being complementary to each other. While the close correspondence between I and II might argue a composition similar to these, their earlier date and unsatisfactory character, as well as the improbability of the systematic position to which they lead, make one feel confident that the true composition of the mass is shown by the new rather than by the older analyses, and that it is best represented by the average of these, as given in VII.

[*] Dittrich, Neues Jahrb., 1903, ii, p. 81 ; Washington, Manual Chem. Anal. Rocks, 1904, p. 24.

The norm of VII calculates out as follows:

	Norm.				Ratios.

Q   6·90   6·90

Or   27·24

Ab   37·20   76·95   83·85

An   12·51

Di   6·11

Hy   2·93   9·04

Mt   3·94   13·85

Il   1·67   5·61

Ap   0 72   0 72

      99·22

Rest   1·01

    100·23

Ratios:

$\dfrac{\text{Sal}}{\text{Fem}} = 5\cdot53$, Class II, dosalane.

$\dfrac{F}{Q} = 11\cdot15$, Order 5, germanare.

$\dfrac{K_2O' + Na_2O'}{CaO'} = 2\cdot67$, Rang 2, monzonose.

$\dfrac{K_2O'}{Na_2O'} = 0\cdot69$, Subrang 3, monzonose.

The average rock therefore falls in monzonose (II.5.2.3), as do both Cross's specimen and mine, and presumably the others also. It will have been seen that Zirkel's analysis places the rock in the same class, order and rang, but in the dopotassic instead of the sodipotassic subrang. As the somewhat more femic character of his specimen cannot be considered to be connected with, or to bring about, such a radical difference in the proportions of the alkalies, their total amount in I and VII being about the same, we are forced to suppose that the discrepancy is due to some analytical error, such as, possibly, a dehydration of the sodium platinichloride.

Mode.—The mode of the plauenal monzonose was determined by numerous measurements in different directions across a typical section of my specimen. The results were:

	Vol. per cent.	Wt. per cent.
Quartz	11·50	11·09
Soda-orthoclase	67·58	63·96
Oligoclase	2·90	2·79
Hornblende	14·26	16·61
Magnetite	1·38	2·61
Titanite	1·55	1·97
Apatite	0·83	0·97
	100·00	100·00

As the chemical compositions of the hornblende and of the soda-orthoclase, which may contain some lime, are unknown, it is impossible to check the measured mode satisfactorily by calculation of the mode from the chemical composition, nor conversely to calculate the chemical composition from the

measured mode as given above. It is clear, however, that the mode is decidedly abnormative, the hornblende taking up nearly all of the normative diopside and hypersthene, with a very considerable amount of the anorthite, and a little of the albite, magnetite and ilmenite. The greater part of the ilmenite is used up in forming titanite, the silica and lime needed coming from diopside and the ferrous oxide of the ilmenite taking its equivalent of silica from the normative quartz to enter the hornblende. On the other hand the estimated amounts of quartz, orthoclase and albite as given above correspond well with the figures for these in the norm calculated from III. That the mode here given is close to the truth is indicated by the specific gravity. That of my specimen was found to be 2·73 at 23°, identical with Zirkel's, while that calculated from the amounts of the several minerals shown by Rosiwal's method was 2·697, a very satisfactorily close agreement.

Name.—In a general way therefore this rock may be spoken of as hornblende grano-monzonose, but on account of its importance we may regard it as a type, to which the name of *plauenal monzonose* may be appropriately given. This name, it will be seen, implies the modal and textural characters involved in Rosenbusch's Plauen Typus of the hornblende-syenites, but more strictly defined and with a very definite indication of the chemical composition as well.

Locust, N. J., June.

Art. XIV.—*Colloidal Nuclei and Ions in Dust-free Air saturated with Alcohol Vapor ;* by C. Barus.

1. *Introductory.*—In my report* on the solutional nucleus and elsewhere† I came to the conclusion that the differences in promoting condensation exhibited by positive and negative ions were more probably to be ascribed to the difference in chemical structure or composition involving a difference of size, than to the electrical differences as such. Experiments made in Wilson's apparatus by Dr. Donnan‡ with vapors of methyl and ethyl alcohol, carbon tetra-chloride, carbon-disulphide, benzol, chloro-benzol, show that the supersaturation needed to produce condensation was not necessarily greater in ionizing than in non-ionizing solvents. With similar apparatus Dr. K. Przibram§ recently examined a series of alcohols and other bodies ionized by the X-rays, obtaining among a variety of data a noteworthy result with a direct bearing on the question here at issue. It appears that whereas in the case of water-vapor the negative ions are more efficient condensation nuclei than the positive ions, the reverse holds for the alcoholic vapors. In cases of methyl, ethyl, amyl and heptyl alcohols (including some other bodies like chloroform) the positive ions invariably require less supersaturation to precipitate condensation than the negative ions of the same body.

Interesting differences are therefore manifest in the behavior of vapors, and it seemed desirable to test the nucleation of a dust-free medium of ethyl alcohol and air in comparison with the media of water-air and water-carbon-dioxide hitherto examined. The former behaves in fact as if the nuclei were throughout larger than in the latter cases. Hence the colloidal nuclei of dust-free wet air should be associated rather with the saturated vapor than with the gas.

2. *Apparatus. Method.*—The experiments were conducted with an apparatus in which the connecting pipes between the fog chamber (18 inches long, 5 in. in diameter) and the vacuum chamber (5 feet long, 1 foot in diameter) were 4 inches in diameter containing a 4-inch counterpoised, plug stop-cock. The whole connecting system was about 22 in. long, one-half of it belonging to the fog chamber. Experiments made with water-vapor, however, did not show any further marked advantage arising from the use of the large passage way specified, over the former apparatus, in which the corre-

* "Structure of the Nucleus": Smiths. Contrib., No. 1373, 1903, p. 161.
† "Ions and Nuclei": Nature, lxix, 1903, p. 103.
‡ F. G. Donnan : Phil. Mag. (6), iii, p. 305 to 310, 1902.
§ K. Przibram : Wien. Sitzungsber., cxv, pt. IIa, p. 1 to 6, 1906.

sponding tube was 2 inches in diameter. It is therefore super-
fluous to adduce for comparison the new data for water-vapor.
The general method of work was that frequently described in
connection with these investigations. With the exceptions
stated all data, to be at once comparable, must be obtained
with a given pair of fog and vacuum chambers.

3. *Properties of alcohol fog.*—While the experiments of my
last paper with the medium of water-vapor and carbon-dioxide
gas showed unusually high values of the exhaustions needed to
produce coronal condensation, the case of alcohol air shows
correspondingly low values of exhaustion, as compared with
those for water-air. The number of colloidal nuclei entrapped
by alcohol vapor are about 3·5 times larger than is the case for
water-vapor under like conditions. Hence the coronas for
alcohol are exceedingly dense by contrast. They are also
much less regular in color and, particularly at high exhaustions,
become fog-like. The phenomenon is coarsened and measure-
ment less satisfactory.

As the alcohol fog particles are larger in size, they subside
more rapidly at the same exhaustion than water particles : but
the occurrences are in the former case far from simple. While
in the earlier experiments the corona (if not too large) remained
nearly the same throughout the slow subsidence of water parti-
cles, the coronas for water and for alcohol particles in the
present work decreased one-half or more in size during this
period. In other words, the fog particles now experience very
rapid growth* during subsidence, from which it follows many
of them must evaporate to compensate in part for the eight-
fold or more enlargement in bulk of the survivers, or further
vapor may condense. The same fact may account in alcohol,
where the phenomenon is more rapid, for the blurred coronas ;
for the true initial corona, being very evanescent, is probably
not seen. Conformably with this view, it is impossible to
exceed large white reddish forms in the present apparatus and
to reach the high greens observed with water-vapor.

4. *Number of particles.*—In order to determine the num-
ber† of particles corresponding to a given corona, it is first
necessary to compute the amount of alcohol precipitated per
cubic centimeter of the exhausted vessel, by the sudden cool-
ing incident upon exhaustion. This may be done by a straight-
forward approximation‡ with results shown in the following
table, where t_1 is the initial temperature of the saturated air
within the fog chamber, t_2 the temperature after sudden
exhaustion and before condensation, and t the temperature

* The precise reasons for this growth may be of some importance in rela-
tion to rain.

† C. T. R. Wilson : Phil. Trans., London, vol. clxxxix, 1897, p. 300.

‡ The size of fog particles in terms of the apertures of the coronas is found
as shown in my earlier papers (Smithson. Contrib., No. 1373, Chap. viii).

after the precipitation of the m grams of alcoholic fog per cubic centimeter. The drop in pressure* is δp from $p = 76^{cm}$ at 20° C. The data of the last columns will be presently explained.

δp cm	t_1 °C	t_2 °C	t °C	$m \times 10^{-6}$ grams	p_r/p_∞	$r \times 10^7$ cm
10	20°	+ 3·2°	+14·8	10·0^g	2·42	1·44
20	20	−15·3	+10·2	18·3	6·21	·75
30	20	−36·1	+ 3·2	22·8	21·4	·48

These may be compared with the case of water vapor.

85	20°	+ 5·8°	+14·7°	2·6^g	2·17	1·65
17	20	− 9·6	+ 8·8	4·6	5·68	·77
22	20	−18·9	+ 4·6	5·5	11·1	·58
30	20	−36·1	− 3·5	6·4	69·7	·35

We may infer from the table that in a perfect apparatus, water fog particles would reach freezing (0° C.) at $\delta p = 24^{cm}$ and alcohol fog particles at $\delta p = 34\cdot5^{cm}$. Moreover for the same corona there must be on the average about 3·5 times more particles in the alcoholic fog than in the water-fog, which accounts for the opaqueness of the former.

For the reasons adduced it is not worth while to express the results otherwise than in round numbers, for the data involved are inevitably crude. The assumption of the law of adiabatic cooling as far as −36° C. is questionable in view of the admixture saturated vapor: but as the densities of vapor are for alcohol about 8 per cent that of air and for water vapor about 7 per cent, this approximation in a rarified atmosphere, as well as the use of Boyle's law for a wet gas, is probably admissible. It is different, however, with the latent heat of the vapor, which is required at the low temperatures, but is known (as a rule) only at temperatures near the boiling point. From this and similar points of view, measurements of latent heat for the more common vapors at very low temperatures would be desirable.

Finally the point at which the drop in pressure ceases to be efficient, because of the increasingly rapid inward radiation of heat from the vessel, is the most serious of the outstanding errors. I have endeavored to diminish it compatibly with the desideratum of a large and easily adjusted fog chamber, by successively increasing the bore of the exhaust pipes and stopcocks; and this plan has been in a large measure successful. The extent to which the error is present, as the drop in pressure increases more and more, is nevertheless left unanswered.

* The value of δp here referred to is the experimental value observed under isothermal conditions at the fog chamber. The value computed from the dimensions of fog and vacuum chambers is $\delta p \times \cdot775$, as will be shown elsewhere.

If the upper inflection of the distribution curve (fig. 2) is a criterion, i. e., if adiabatic cooling ceases with the occurrence of identical terminal coronas for successively increasing exhaustions, the fog chamber with water-air is efficient to about $\delta p = 31$ or 32^{cm}, with water and carbon-dioxide to about $\delta p = 37^{cm}$, with alcohol and air to about $\delta p = 20^{cm}$. In the former case the vapor would be cooled from 20° to about $-10°$ C. even after condensation : in the latter case to about $+10°$. On general principles and in view of the low temperatures of the water particles, it would seem probable that the efficiency of the fog chamber must vanish gradually. But the appearance of the curves is such, as if the action were unimpaired up to a given terminal drop in pressure.

In every case the fog particles with the surrounding medium of vapor soon reach the temperature of the air again, so that additional moisture must arrive from somewhere. It has been instanced above that the marked constancy of the water-coronas during this period in the work done heretofore gave no evidence of the evaporation ; while the present water and alcohol coronas decrease one-half in aperture, i. e., the preponderating fog particles actually grow, because the exhaustion is slowly but steadily incremented when the stop-cock is not quite tight, the fog particles acting like very large nuclei. Even if this is compatible with the evaporation of the smaller particles, there is again no evidence for it. Much of the moisture must therefore come from the wet cloth and the water within the vessel, which are not cooled by the expansion.

5. *Size of the nuclei.*—Here it may be worth while to inquire into the reason why the precipitation in alcohol is apparently so much easier ; or what is the same thing, into the estimated size of the nucleus on which precipitation takes place in these several cases. The Kelvin equation as modified by Helmholtz[*] may be used[†] for this purpose (as was done by the latter and by Wilson[‡] in the form $p_r/p_\infty = \epsilon^{2T/Rs\theta r}$ where p_r and p_∞ are the vapor pressures at the convex areas of radius r and radius infinity respectively, T the surface tension of the liquid of density s, R the gas constant of its vapor at the absolute temperature θ. Since p_r is the adiabatically reduced vapor pressure (without condensation) in the volume expansion due to the drop of pressure δp, and p_∞, the normal vapor pressure at the same temperature $\theta = 273° + t_2$ in Table I, r follows from the equation. The values of $S = p_r/p_\infty$ and r so found are both given in Table I, and have been constructed in

[*] Helmholtz : Wied. Ann., xxvii, p. 524, 1886.

[†] Similar estimates of my own are given in Bull. U. S. Weather Bureau, No. 12, 1895, p. 48.

[‡] C. T. R. Wilson : Phil. Trans., vol. clxxxix, 1897, p. 305.

the chart, figure 1, where their relation to the usual order of molecular size (m in the figure) is also indicated. Clearly these values of r, the radius of the nuclei differing so little from molecular radii (say 10^{-8} cm), can only indicate an order of values; for apart from the difficulties above enumerated in computing θ, r depends on surface tension T, which has no meaning for molecular dimensions. Granting this, it is none

1
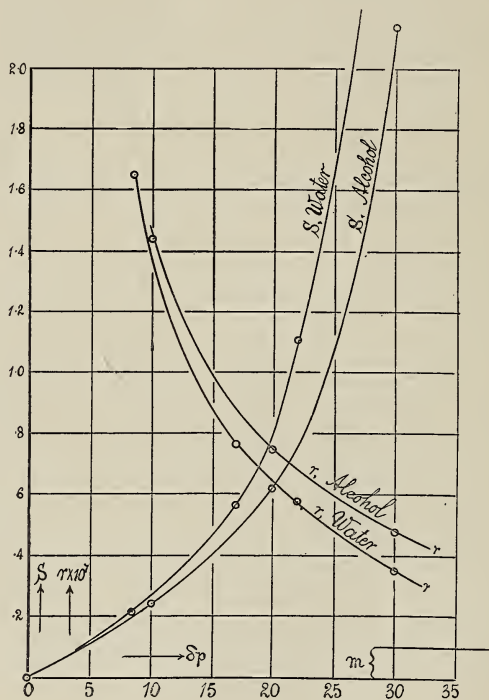
the less remarkable that the values of r obtained should be so nearly alike for water and alcohol, where different constants (T, R, s, etc.) occur throughout; in other words, that at a given temperature a given drop of pressure will condense both vapors on nuclei of about the same size.

In so far as these estimates are admissible, it follows that the alcohol air nucleus is larger than the water air nucleus; in the former case coronal condensation begins at about $\delta p = 15^{cm}$, where $r = 10^{-7}$, while in water vapor it begins at $\delta p = 26^{cm}$, where $r = 4 \times 10^{-8}$ about, less than half as large. These relations once established are retained through all successions of nuclei, as the following data for alcohol vapor in compari-

son with water vapor show. It is a little difficult to understand why the ionized nuclei in alcohol vapor should, like the colloidal nuclei, be larger than the corresponding cases for water vapor, unless the ions are aggregated colloidal nuclei, a point of view tentatively advanced elsewhere.[*]

6. *Data for alcohol vapor.*—The behavior of alcohol vapor is shown in the usual way in the following chart, fig. 2, where δp is the sudden fall in pressure from normal atmospheric pressure, producing the corona of the angular diameter

2
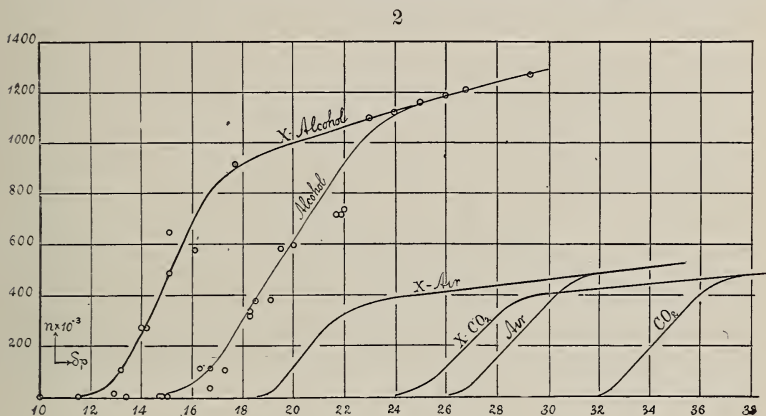
s / 30, when the eye and the source of light are at distances 40 and 250^{cm} on the opposed sides of the fog chamber. The nucleation n deduced from s is computed in the way given above, §4, and indicates the number of nuclei in the *exhausted* fog chamber. It is assumed therefore that the nuclei are reproduced more quickly than they can be withdrawn by the exhaustion. Measurement of s is not very satisfactory, as the coronas are blurred and accompanied by dense fogs and change rapidly on subsidence. The effect of X-radiation leads to the same terminal corona which appears for the non-energized vapor.

The results as exhibited in fig. 2 are seen in connection with earlier results for media of water-air and water-carbon-dioxide, the same condensation apparatus and method underlying all experiments. One may notice at once that in the cases CO_2-water and air-water, both for the non-energized and for the energized state, the observed data would be obtained by shifting the air-water diagram as a whole to the right, as if the cooling in case of CO_2-water vapor were less efficient.[†] The

[*] This Journal, xx, 1905, p. 453 ; Phys. Review, xxii, 1906, p. 109.
[†] Phys. Review, April, p. 252, August, 1906.

graphs are of the same kind, nearly parallel, and all of them (energized or not) again terminate in the same asymptote or large green-blue-purple corona.

The alcohol curves differ from the water curves chiefly in three respects: (1) though the graphs both for the non-energized and energized states terminate in a common asymptote, this is not the green-blue-purple corona, but the white-yellow corona lying slightly below it; (2) the curves as a whole lie with a somewhat larger slope in a region of much lower exhaustions (δp); (3) the number of nuclei caught in alcohol vapor is relatively very large. The second and third observations have already been discussed. The first deserves especial consideration. The question occurs at once why both the energized and the non-energized curves should be limited by the same final corona, irrespective of the size of the nuclei, and why this should be lower for alcohol than for water. For the ionized state one might infer that the total number of ions has been precipitated, as is actually the case at low ionization; but if under strong ionization this were true for alcohol vapor, it could not be true for water vapor, where the number of ions caught is less than one-half the number in alcohol. In general it is improbable that the terminal corona for ions should in such a case be the same as the terminal corona for colloidal nuclei.

The explanation which seems plausible to me is this; each nucleus must drain the air of its supersaturated moisture within a certain radius large as compared with the size of the nucleus and increasing in the lapse of time.

A limit of the phenomenon will be reached when for an indefinite number of graded nuclei the enveloping spheres free from supersaturation form a system in contact. In case of water vapor the distance between centers would be $\cdot014^{cm}$; in case of alcohol $\cdot010^{cm}$, distances which are both enormous as compared with the estimated size of nuclei (r), Table I. At all events, when the limiting *number* of nuclei has been captured, the apparatus is powerless to produce condensation on a greater number of nuclei, be they relatively large as the ions or small as the colloidal nuclei, however many other (inefficient) nuclei may be present.

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Art. XV.—*The Russian Carboniferous and Permian compared with those of India and America. A Review and Discussion;* by Charles Schuchert.

Part III. The Work of Diener.

1. *The Permocarboniferous Fauna of Chitichun No. I.* Mem. Geol. Surv. India, ser. xv, Himálayan Fossils, vol. i, pt. 3, 1897, pp. 1–105, pls. i–xiii.
2. *The Permian Fossils of the Productus Shales of Kumaon and Gurhwal.* Ibid., pt. 4, 1897, pp. 1–54, pls. i–v.
3. *Permian Fossils of the Central Himálayas.* Ibid., pt. 5, 1903, pp. 1–204, pls. i–x.

In the central Himalayas at the limestone crag of Chitichun No. 1, at an elevation of 17,700 feet, Griesbach, Middlemiss, and Diener, in the year 1892, discovered a lot of fossils described in the work cited above (1). The stratigraphical results of this collection are described by Diener on pp. 85–105, from which are taken the following extracts :—

" Karpinsky and Tschernyschew, two authors to whom the most detailed studies of the Artinskian fauna are due, strongly advocate the distinction of the permocarboniferous from carboniferous and permian systems, and are decidedly averse to uniting it with either the one or the other. Tschernyschew especially strongly combats the view of the majority of geologists who proposed to unite the permocarboniferous with the permian, as a lower division of the system. According to him a separation of the permocarboniferous from the permian system is demanded by the general aspect of the fauna, in which the carboniferous types greatly predominate, chiefly among the brachiopods. If it ought to be united either with the carboniferous or permian system, in spite of its distinctly intermediate position, it must necessarily be placed in the former, on the strength both of the carboniferous character of its fauna and of historical priority, since the Artinskian sandstone had been correlated with the carboniferous millstone-grit of Western Europe by Sir Roderick Murchison, who first introduced the name permian.

" Against the first argument the objection may be raised that notwithstanding the prevalence of carboniferous types in the Artinskian fauna, the latter 'marks a very important moment in the history of development of organic remains, namely, the first appearance of true ammonites with complicated sutures.' Nor is the large percentage of carboniferous types in the Artinskian fauna an astonishing fact, in view of the absence of any break in the sequence of marine beds from the upper carboniferous to the true permian strata. Even in beds, which must be placed very high in the permian system, in the upper Productus limestones of the Salt Range and in the Oto-

ceras beds of Julfa, the fauna contains a proportionately large number of carboniferous forms. It is to the faunas of these deposits, the normal representatives of the pelagic permian [by this the author means a *normal* marine fauna], not to the local fauna of the Zechstein, that the permocarboniferous fauna must be compared, if we want to get a clear idea of its relationship to those of the upper carboniferous and permian. Bearing in mind the gradual passage from an upper carboniferous to a permian fauna through the intermediate group of rocks, the question to be answered is, which consideration is of the greater importance in defining the boundary between the two systems, the appearance of a new group of cephalopods, which become of an unparalleled stratigraphical value in mesozoic times, or the presence of a belated fauna, composed of forms which are generally not well adapted for the characterization of narrowly limited horizons.

"The majority of geologists have decided in favour of the first alternative. Gümbel, Krassnopolssky, Kayser, Waagen, Credner, Munier-Chalmas and A. de Lapparent, Frech—to enumerate only a small number among them,—are unanimous in regarding the permocarboniferous as the lowest division of the permian system" (pp. 87–88).

"In the Mediterranean region three different rock groups have yielded fossil remains of this pelagic development of the permian epoch. These rock groups are the Fusulina limestones of the valley of Sosio in Sicily, the Bellerophon limestone of South-eastern Tyrol and Friaul, and the Otoceras beds of Julfa in Armenia. All of them are of a rather isolated occurrence and, as far as one may judge from their faunas, of different age.

"The lowest position is apparently held by the Fusulina limestone of Sicily. Its cephalopod fauna seems to be more nearly related to the Artinskian one than to those of the Jabi beds of the Salt Range or of the Otoceras beds of Julfa. Ammonites with ceratitic sutures are yet absent. According to Karpinsky's statement, one species of *Medlicottia* is identical with an Artinskian form; ten more species are very nearly allied. On the other hand, Karpinsky and Waagen noticed the first appearance of *Waagenoceras* and *Hyattoceras* in Sicily, two genera which show a much more complicated sutural line than any of the Artinskian *Ammonea*. Waagen consequently places the Fusulina limestone of Sicily on a higher level than the permo-carboniferous stage, but on slightly lower level than the Jabi beds of the upper Productus limestone. . . .

"The Otoceras beds of Julfa with their strongly marked triassic affinities must certainly be higher in the upper palæozoic series than the Fusulina limestone at Sosio. They cannot be much different in age from the Otoceras beds of the Him-

alayas, although the latter certainly hold a somewhat higher stratigraphical position, and they may consequently be placed on a level with the upper Productus limestone or with the Chidru group of the Salt Range.

" The youngest of the three rock groups is probably the Bellerophon limestone of South-eastern Tyrol. Its fauna is a very peculiar one, species identical with those known outside this rock group being almost completely absent. The predominance of palæozoic types induced Stache to fix the homotaxis of these beds as upper permian, whereas Gümbel supposed them to be of lowest triassic age. . . .

" In none of these three permian rock groups of the Mediterranean region is a normal sequence of marine beds exposed, with the possible exception of the Bellerophon limestone of the Carnian Alps, which, however, is underlaid by an enormous mass of unfossiliferous limestones and dolomites. Their correlation must consequently be based on palæontological evidence alone " (pp. 90–91).

Recently, Schellwien and Kossmat (Monatsber. No. 9, Deutsch. Geol. Gesellsch., 1905, pp. 357–9) found in the Bellerophon limestone (usually regarded as the topmost Permian of the Alps) of Krain, west of the Laibach plain, a fauna consisting in the main of brachiopods, corals, and Foraminifera. As yet the fossils are not worked out of the matrix, but the following species are determined: *Richtofenia* aff. *lawrenciana, Productus indicus, P. abichi, Marginifera ovalis*, and *Lonsdaleia indica*. In regard to these fossils Schellwien concludes as follows :—

" The finding of this fauna dispels all doubt as to the Permian age of the Bellerophon limestone. The value of this discovery in fixing the time position of this limestone, however, is overshadowed by the greater one,—that of fixing the chronologic position of the Productus limestone [of India], the correlations of which, as is known, are still at variance. The fossil-bearing beds of the Bellerophon limestone are everywhere in close association with the lower Werfen beds [Triassic]: in southern Tyrol the boundary between the Werfen deposits and the Bellerophon limestone is difficult to establish. At Krain the fossiliferous zones of the Bellerophon limestone are also separated, but by a thin dolomite series from the Trias. These upper dolomites introduce micaceous layers and gradually pass into the Werfen slates, with their well-known bivalve fauna. The Bellerophon limestone, therefore, can represent only the highest zone of the Permian, and for the Productus limestone the same view may also be affirmed. Worthy of note is the fact that of this fauna of the Bellerophon limestone, it is also not only those of the higher zones of the Indian Productus limestone but likewise forms of the

lower horizons.   Should the detailed examination show that the fossils of the various horizons of the Productus limestone are also found associated in the thin fossiliferous zone of the Bellerophon limestone of Krain, the conclusion will be una· voidable that the various zones of the Productus limestone are of Upper Permian age."

In the second paper cited above, treating of the fauna of the Productus shales, Diener states the following :—

"The only decisive evidence for a permian age of the Productus shales is however based on their stratigraphical relations to the triassic beds of the mesozoic belt of the Central Himalayas, not on their fossil remains.   One of the chief results of Griesbach's geological survey of the Bhot Mahals of Kumaon and Gurhwal is the proof of an unconformity, existing at the base of the Productus shales, which locally overlap successive strata of carboniferous age.   With this unconformity another uninterrupted sequence begins, with conformable bedding throughout, which ranges from the Productus shales to the topmost beds of the triassic system.   So intimate is the stratigraphical connection between the Productus shales and the following Otoceras beds of lowest triassic age, that a sharp boundary cannot be drawn between them " (pp. 53–54).

In the third publication above cited, Diener reviews his former work on the fossils of Chitichun No. 1, owing to larger and more significant collections subsequently made by Walker. These collections have not altered Diener's correlations with the Salt Range, but they have, when interpreted in the light of Noetling's publications, caused him to depart strongly from the nearly unanimous views of European stratigraphers and to agree in the main with the intercontinental correlation of Noetling.   Great weight should be attached to the correlation of these two paleontologists, for they have collected the fossils of the Permian in India and studied them in the laboratory. Diener's conclusions are as follows :—

"So far there is no reason for any change in my correlation of the Chitichun fauna with Indian faunæ of permian age, as proposed by myself in 1897.   I am, however, bound to confess that the affinities of the Chitichun fauna to those of Europe have not been correctly interpreted, and that my examination of Walker's materials is apt to lead in this respect to results remarkably different to those deduced in my first memoir.

"In that memoir [here numbered 1] the conclusions at which I arrived with regard to the stratigraphical position of the Chitichun fauna were summed up as follows :—

" 'The Chitichun limestone is approximately homotaxial with the upper division of the middle · Productus limestone (Virgal and Kalabagh beds) in the Salt Range.   It probably corresponds in age to the permo-carboniferous horizon (Artin-

skian stage) in Russia, but the description of the Brachiopoda
from the Fusulina limestone of Sicily must be awaited before
it is possible to decide whether it does not hold a slightly
higher position in the stratigraphical sequence than the Artin-
skian deposits.'"

" This mistake of correlation is the legitimate outcome of an
erroneous interpretation of the stratigraphical position of the
Salt Range Productus limestone. The supposition ' that the
entire Productus limestone forms a series, which cannot be
separated from the carboniferous system and that the Fusulina-
bearing Amb beds certainly belong to the latter,' was not my
fault. I followed the majority of European palæontologists
in this, and my error was due to the ignorance of the leading
palæontologists as to the right means of correlating rock-equi-
valents of anthracolithic age in Europe and in India.

" Waagen believed the Productus limestone to be permian,
but to represent the entire permian system. He consequently
correlated the lower Productus limestone and the Katta beds
of the middle Productus limestone with the Artinskian stage
of Russia, considering them as permo-carboniferous. The
palæontological investigations of Nikitin, Frech and Tscherny-
schew raised doubt as to the validity of this correlation. The
affinity of the fauna of the lower Productus limestone to those
of the upper carboniferous rocks of Russia and the Ural Moun-
tains and of the Carnian Fusulina limestone of the Eastern Alps
induced Rothpletz (Palæontographica, vol. xxxix, p. 63),
Frech (Die Karnischen Alpen, p. 372), Oldham (Manual of
the Geology of India, 2nd edn., p. 125), and Suess (Denkschr.
kais. Akad. d. Wissensch. Wien, math. nat. Cl., vol. lxi, p. 439)
to correlate the lower Productus limestone with the upper car-
boniferous rather than with permo-carboniferous beds. In
the meantime Tschernyschew called attention to the strongly
marked affinities of the faunæ of the middle Productus lime-
stone and the Artinskian stage. On palæontological grounds
he tried to prove that the entire middle Productus limestone
ought to be synchronised with the Artinskian strata of Russia.

" In admitting this homotaxis I merely followed the almost
unanimous judgment of European geologists. The equiva-
lence of the Chitichun limestone to the Virgal and Kalabagh
beds in the Salt Range having been clearly demonstrated, the
necessity of correlating it with the Artinskian stage of Russia
was obvious.

" I have been convinced of the incorrectness of this correla-
tion both by the recent reports of Dr. Noetling on the classi-
fication of the Productus limestone and of the Ceratite forma-
tion in the Salt Range, and by my own examination of the
fossil materials collected by Walker" (pp. 53–54).

" I do not, however, believe that the Chitichun limestone

should be placed on a level with the Fusulina limestone of Sicily. So far as it is possible to judge from its Cephalopoda, the Chitichun fauna appears to be geologically younger. Ammonites with ceratitic sutures such as *Xenaspis carbonaria*, or with complicated sutures, such as *Cyclolobus Walkeri*, speak clearly in favour of a homotaxis of the Chitichun limestone with true upper permian strata of Europe" (p. 57).

" The evidence afforded by the two species of ammonites which were collected by Walker, together with Noetling's discovery of the true horizon of *Xenaspis carbonaria* in the Productus limestone of the Salt Range, is sufficiently strong to affect my view as to the correlation of the Chitichun limestone with permian beds of other countries, and obliges me to consider the latter as about homotaxial with the permian rocks of Timor and as slightly younger than the Sosio limestone of Sicily. I am therefore compelled to admit the correctness of Noetling's statement that there is at present no proof of the existence of a fauna of Artinskian age in the Himalayas" (p. 58).

Diener then takes up the " Correlation of the Anthracolithic System in Spiti with the Carboniferous and Permian Systems in Europe and India."

" Wherever in Spiti a complete series of the anthracolithic system is developed and well exposed, *two groups* can be recognised and distinguished, as has been stated by Hayden. Both groups are separated by a great *unconformity*, and differ remarkably in their faunistic character and in their lithological features.

" The group above the great unconformity, which corresponds to the Productus shales of the Niti area, is much better known than the lower division, because richer collections of fossils have been examined " (p. 193).

" The fossils to which the greatest stratigraphical importance must be attributed are the ammonites of the two genera *Cyclolobus* and *Xenaspis*. The presence of a species which is most nearly allied if not actually identical with *Cyclolobus Oldhami*, Waag., and the frequent occurrence of representatives of the genus *Cyclolobus*, speak very strongly in favour of a correlation with the upper Productus limestone of the Salt Range. In the Salt Range *Xenaspis carbonaria* is, according to Noetling, restricted to one single horizon only, namely, to the top beds of the middle Productus limestone " (p. 195).

" As faunistic elements of special interest in the Kuling shales of Spiti, *Grypoceras* sp. ind., *Myophoriopis Krafti* and *Spirigera* cf. *protea* var. *alata* may be quoted. The first and second are remarkable for their decidedly triassic affinities, the third belongs to a group of forms which has hitherto been recorded only from the permian rocks of Djulfa " (p. 196).

" Our knowledge is much more scanty with regard to the lower series of the anthracolithic system in Spiti, which is situated below the great unconformity.

" According to Hayden, the total thickness of this series is not less than 5,000 feet in the section above Lio on the Lipak river, where the sequence of the beds is most complete. Two fossiliferous horizons only have been discovered in this mighty sequence " (p. 198).

The fossils of the " upper horizon," or the Fenestella beds, are not stratigraphically significant, and the little there, considered in connection with the fauna of the lower beds, is rather in favor of regarding it as of Lower Carboniferous age.

In the lower flaggy limestone horizon (8a of Griesbach) the fossils are " unfortunately, scarce, generally ill preserved, and of a rather indifferent character." Diener thinks the age of the fossils is " more in favor of an upper carboniferous age," but his evidence is completely shattered in the appendix to his work, in a " Note on *Spirifer Curzoni*, Diener. By H. H. Hayden, Geological Survey of India." This author shows in the most convincing manner that the original generic identification of Diener was correct and that the species is to be called *Syringothyris curzoni*. A careful examination of Mr. Hayden's note, his illustrations, and those of Diener, will convince any American student of the Brachiopoda that the form in its general expression and size is to be compared with American forms low down in the Lower Carboniferous series. In further support of this lower Lower Carboniferous suggestion may be cited *Spirifer* cf. *strangwaysi* comparable to American *S. forbesi*.

Therefore it would seem that the entire 5,000 feet of material beneath the great unconformity may be Lower Carboniferous. The lower portion is certainly so and apparently nearly basal Lower Carboniferous.

Part IV. The Work of Girty in the Trans-Pecos Region of Texas.

1. *The Upper Permian in Western Texas.* By George H. Girty. This Journal, Nov., 1902, pp. 363–368.

2. *Report of a Reconnaissance in Trans-Pecos Texas.* By G. B Richardson. Univ. Texas Mineral Surv., Bull. 9, 1904, pp. 32–45. Fossils determined by G. H. Girty.

3. *The Relations of some Carboniferous Faunas.* By George H. Girty. Proc. Washington Acad. Sci., vii, 1905, pp. 1–25.

The work of this paleontologist on the Carboniferous and Permian of southwestern Texas is best summarized in tabular form, the data being taken from his three papers on the subject.

Beginning with the highest beds, the facts are as follows :—

Guadalupian.

Capitan Limestone.

Above the Guadalupian or Capitan limestone there seemingly follows an unconformity of considerable extent. Then follow beds of gypsum, a white magnesian limestone, and a sandstone the age of which is unknown but apparently is best referred to the Triassic.

A massive white limestone. At least 1800 feet thick. Top not seen.

From the middle of this limestone comes a fauna, nearly all of which is new.

> *Fusulina elongata, Acanthocladia, Goniocladia, Geyerella, Orthothetina, Productus popei, P. mexicanus, Spirifer mexicanus, Squamularia* (?) *guadalupensis, Spiriferina billingsi, Hustedia meekana, Pugnax swallowiana, Rhynchonella (?) indentata, Leptodus (= Lyttonia), Richthofenia permiana, Myoconcha,* etc.

Delaware Mountain Formation.

Essentially sandstone and limestone. Maximum thickness about 2300 feet.

At the base, in black limestone, occur: *Enteletes, Meekella, Hustedia meekana, Pugnax, Richthofenia permiana, Foordiceras,* and other ammonoids.

Higher up in the sandstone occur: *Fusulina elongata, Productus* cf. *subhorridus, Leptodus (= Lyttonia), Richthofenia permiana, Laevidentalium canna,* etc.

In the limestone occur: *Fusulina elongata,* Bryozoa of Mesozoic type, *Chonetes permianus, Hustedia meekana, Rhynchonella bisulcata, Leptodus (= Lyttonia), Richthofenia permiana,* and ammonites.

Hueconian or Pennsylvanian.

Mainly massive limestone with local shales and sandstones. Maximum thickness at least 5000 feet, more. than 2000 feet of which are limestone.

Near the base occur: *Triticites, Productus cora, Marginifera* cf. *wabashensis, Reticularia perplexa, Spirifer rockymontanus,* etc.

Near the top occur (those marked "1" are Ural and "2" Indian types): *Fusulina, Enteletes* cf. *hemiplicatus,* 1 *Productus* cf. *inflatus,* 1 *P.* cf. *pustulatus,* 1 *P.* cf. *longus,* 1 *P.* cf. *irginœ, Marginifera* cf. *wabashensis,* 1, 2 *Spirifer* cf. *marcoui, Seminula mexicana,* 1 *Camarophoria* cf. *mutabilis,* 1, 2 *C.* cf. *crumena,* 2 *Dielasma* cf. *truncatum,* 1 *Omphalotrochus obtusispira.*

Regarding these formations and their correlation, Girty writes :—

"The Carboniferous faunas of the Trans-Pecos region, especially the upper ones, differ widely from those of the Central and Eastern States. The fauna of the Hueco formation, however, is found with some modifications over most of the area west of the Rocky Mountains; but the remarkable group of fossils occurring in the Capitan limestone is only known in the Guadalupe Mountains. The fauna of the Capitan limestone differs to a marked degree from that of the Hueco formation, and was assigned to the Permian epoch both by Shumard, its original discoverer, and by Girty. The fact that the faunas of the Hueco formation in some respects strikingly resemble those of the *Spirifer marcoui* zone, the *Omphalotrochus whitneyi* zone, the *Productus cora* zone and the *Schwagerina* zone of the Carboniferous section of eastern Russia, which immediately underlie the typical Permian, seems to support the views of these authors. On the other hand, there are some matters of difference between the Russian faunas and those of the Hueco formation, part of which are points of agreement with the Capitan fauna. Thus, the Russian faunas, even the highest (that of the Schwagerina zone), seem, aside from containing aspects not found in either, to combine features of both the Hueconian and the Capitan faunas, features, moreover, which these formations do not possess in common.

"The American beds can hardly be looked on as being a mere expansion of the Russian series, since the Hueco, Delaware Mountain and Capitan formations combined have a thickness much exceeding 5000 feet, while the four zones recognized by Tschernyschew are considerably less than 1000 feet thick. In view, therefore, of the preponderating resemblance shown in the Hueco faunas and the differences in that of the Capitan limestone, the latter is retained under the title of Permian, and with it, provisionally, the Delaware Mountain formation" (2, pp. 42–43).

The latest paper by this same author makes the following important statement regarding the Permian question, and gives his views concerning the equivalence of the formations in the various American regions :—

"The opinion has been expressed that the Pennsylvanian faunas of eastern and western United States may belong in different provinces, and that they are probably to some extent equivalent. The belief is tentatively held that the highest of our Western horizons are considerably younger than the highest known invertebrate horizons of the East, those of the Kansas section, for instance, which are characteristic of the so-called Permian of the Mississippi Valley. In spite of the able pen

which have traversed this subject, the correlation of these beds is still one of the unsettled problems of the American Carboniferous. If the Capitan fauna is Permian, then certainly that of Kansas is not, for 2 Carboniferous faunas could scarcely have less in common. While it is possible that the so-called Kansas Permian is a provincial phase of the Guadalupian, this is yet to be demonstrated, and it is questionable whether for 2 faunas so essentially unlike, even if proved to have been contemporaneous, the same name could with propriety be used. On the assumption that the Kansas beds are Permian, so closely are they connected, faunally and stratigraphically, with those below, the term Permian must be reduced to denominate a difference not much greater than that between the Burlington and Keokuk, or else most of the Kansas section must be placed in the Permian, a disposition against which there is much evidence. It seems probable that the Kansas Permian represents a faunal development in a distinct province from that of the West, the Western faunas being co-provincial with the typical Permian sea. The equivalence of the Kansas Permian is not to be determined upon the basis of a community of a few slightly differentiated long-lived types, but must be worked out by a consideration of the fauna as a whole and the facies which it receives from the presence of equivalent but probably not equal species.

" The Guadalupian faunas are not only widely different from those of Pennsylvanian age in the Mississippi Valley, but they appear to have a distinctly younger facies, biologically considered. So far as the significance of the somewhat hastily reviewed evidence has been grasped, it seems to assign the Kansas faunas to about the horizon of the Hueco formation, placing the entire Guadalupian series, or at all events the Capitan, as a younger evolution, whether the 2 faunas were developed in distinct provinces or in the same " (3, pp. 25–26).

The late Paleozoic formations have great development in Alaska, but as yet the faunas have only been partially studied. Schuchert's (Prof. Paper 41, U. S. Geol. Survey, 1905, pp. 42–45) conclusions regarding these fossils are as follows :—

" In looking over the collection listed in the large table not submitted in this report, the first impression made is its strangeness when compared with other American late Paleozoic faunas, excepting that of northern California as yet unpublished. Nearly every species is new, certainly new for North America so far as the published record goes. The developmental aspect is clearly late Paleozoic, and yet there is not present a single diagnostic upper Carboniferous or Permian species of the Mississippi Valley. Further, we miss of the brachiopods of the last-named basin the ever-present

Rhipidomella, Enteletes, Derbya, Meekella, Seminula, and *Hustedia.* On the other hand, this arctic fauna predominates in *Productus* and *Spirifer.* Of the former genus the species are nearly all strangers to American paleontologists, since the bilobed or deeply sinused and the abundantly spinose forms are the common ones. The *Spirifers* also are strange in that hardly any have the plications strongly bundled as in *S. cameratus,* while such little known groups as that represented by *S. arcticus* and *S. supramosquensis* (also recalling *S. neglectus* of the Lower Carboniferous) predominate.

" Ten or more species of Bryozoa are present, of *Fenestella, Pinnatopora, Goniocladia,* and *Rhombopora.* None, however, can be specifically identified and those of the genus *Rhombopora* are of a type—stout branches from $\frac{1}{4}$ to $\frac{3}{8}$ inch in diameter—unknown in the Mississippi basin. This is also true of *Goniocladia.* Pelecypoda are all small and rare (5 species), and the Gasteropoda (3 species, 4 specimens) almost absent. Not a trace of a cephalopod is present, and this is all the more strange since the Indian Permian has 14 forms of nautiloids and 7 of ammonoids. Nor is there a trace of a trilobite, while the corals are represented by one or two species of cyathophylloids.

" The work of the United States Geological Survey in California and Alaska is establishing two facts of great value in general geology, namely, that on the west coast of North America there is (1) a great thickness and grand sequence of Carboniferous and Permian strata [between 6000–7000 feet of Permian in Copper River region of Alaska] ; (2) that these have faunæ of the Pacific type and not of that of the Mississippi basin " (p. 44).

Conclusions.

As the great Russian geologist has stated in his introduction that he will be the first to greet friendly criticism " with pleasure," the present reviewer takes the opportunity of concluding this long review with the following friendly remarks :—

1. The foregoing review of the recent work of four excellent investigators in the correlation of Carboniferous and Permian strata and faunas shows clearly that a final interpretation of the sequence of events closing the Paleozoic is still far from attainment. Further, that while harmony exists regarding the basal zone of the Carboniferous (Upper Carboniferous of most writers), there is as yet no agreement as to the upper limits of this system of rocks and hardly any concerning the delimitation and sequence of the Permian. As has been seen, there is little or no difference of opinion in regard to the sequence of

events in a given area ; but when it comes to correlating these local sections with those of other continents, there is great diversity of interpretation relative to the values to be placed on the varying faunas. This lack of harmony is primarily due to the absence of a continuous faunal sequence in any one region. Further, some paleontologists draw their species finely, others broadly ; and as all the Carboniferous faunas have a general facies in common, far more decided than that of any other Paleozoic system, and finally, as many of the groups of brachiopods, the prevailing fossils of the Carboniferous and Permian, have lost their power for rapid or marked progressive evolution, with a decided tendency toward degeneracy, the possibility for wide differences of opinion regarding sequential change in faunas is apparent. Then, too, the centers of radial dispersion of the faunas have not yet been determined, so that no reliable means exists for ascertaining the differences in age of the same or closely related faunas between widely separated areas. However, as the Carboniferous is nearly everywhere characterized by an abundance of fossils, and as there is already an extensive literature on the subject, a final interpretation of the sequence of events, that will carry conviction to all workers, may very soon be looked for.

2. To the present writer, it is clear that the Permian fauna of the Urals and Timan is not the normal marine one perpetuating the Paleozoic sequence in the Mesozoic. (The same is true for Germany and England.) Of brachiopods are missing here the plicate and other types of terebratuloids other than *Dielasma* and everything from which the rhynchonelloids can be developed, spire-bearing forms and the strophomenoids of the type of the Lyttoniidæ. The same is largely true for the other classes of organisms ; in fact, one can better trace the Triassic faunas of the Alps through the Ural and Timan faunas of a lower horizon, *i. e.*, those of the Schwagerina zone. These facts are admitted by Tschernyschew, but it seems to the reviewer that he fails to give proper weight to the probability which one almost wishes to state with certainty, that somewhere the Schwagerina fauna or one closely related to it continued to maintain itself, and, further, that in some region far away from the Urals and Timan it will necessarily hold a higher tratigraphic position, although somewhat changed in faunal facies. This center of dispersion was seemingly the Mediterranean region ; in fact, it is the belief of the reviewer, derived from a knowledge of the Permian of Sicily and Austria, that this great body of water, Thetys, was the home of the normal marine Carboniferous and Permian faunas of Europe and Asia. From Thetys, the faunas spread to the north into the epicontinental seas of Germany and European Russia, but in

these waters, during Permian time, conditions were not favorable for the continuance of a normal marine life, and finally these faunas die out here in the gypsum and copper-depositing seas. To the south in a mediterranean, the faunas maintain themselves in a healthy and prolific condition, spread eastward across Asia and probably westward as far as El Paso, Texas; while other migrations seemingly of a somewhat different facies, but having more of the Himalayan-Arctic impress, are met with along the Pacific coasts from California far north into Arctic western America. Under these circumstances, it should not be expected that the Schwagerina zone of the Urals will hold a horizon in India or America similar to that in the Urals and Timan.

3. The question—Is there a Permian system or only a Permian formation?—is far from answered. In the area typical for the rocks under consideration, the Perm Province in the Urals of Russia, the normal marine Carboniferous fauna passes into Permian deposits of an abnormal marine character and finally into red gypsiferous shales devoid of life. Under such an enviroment, an abundance of life, with progressive or normal evolution, is excluded and, as a rule, there remains only the widely distributed species, and too often merely characterless forms are present, which do not permit safe deductions to be made in determining the chronology of a Permian system. At present, there is no acceptable sequence of faunal events for intercontinental correlation in the typical area and as far as can now be seen there will certainly be none for the closing events. The German Permian faunas are better known, but as they are clearly only a part of a great sequence and as the lower and upper stratigraphic members of this region are either devoid of fossils or have no normal marine succession, positive proof as to the entire sequence of events in a Permian system can not be looked for in this country. In England, the conditions seem to be those of Germany. In the Salt Range of India, either toward the close of the Carboniferous or early in the Permian, a great glacial period was in progress, so that in this region there are no normal marine beds in the lower part of the section; hence, no possible biological base for the system is yet apparent. On the other hand, in the central Himalayas above a vast series of Lower Carboniferous strata (5,000 feet thick), there is a marked unconformity above which occurs Permian sediments, parts of which are positively correlated with the uppermost group—the Chideru—of the Salt Range. These strata then continue without apparent break in sedimentation into the Ceratites beds of the Triassic. This time hiatus—a land interval with erosion—is probably equivalent not only to all the Upper Carboniferous but possibly also to

a part of the Productus-limestone of India.   This great unconformity will be of much value in the final interpretation as to the proper position in the time scale of the entire Productus-limestone and as well the date for the period of glaciation in the late Paleozoic of India.

In America, however, in southwestern Texas, there is an unbroken section of more than 9000 feet in thickness, having more than 4000 feet of limestone, with normal marine faunas at various levels.   As has been evident from the statements of Girty, this section has Carboniferous faunas of the Euro-Asiatic type, which are directly comparable with the *Spirifer marcoui, Omphalotrochus whitneyi, Productus cora,* and the *Schwagerina* zones of Tschernyschew.   These Carboniferous faunas are in the lower portion of the section, above which, in the Capitan limestone, are faunas comparable with those of the Productus-limestone of India (*i.e.* faunas having *Goniocladia, Richthofenia, Lyttonia (= Leptodus)* etc.),—faunas that for some years have been regarded by several of the leading stratigraphers as the normal marine record toward the close of the Paleozoic.   It is to be hoped that the U. S. Geological Survey will soon enable Dr. Girty to complete his studies, both stratigraphic and faunal, regarding this, the most complete Carboniferous and Permian section known to stratigraphers.

4. The question as to what name the closing Paleozoic system shall bear can not as yet be answered.   If the rocks of the Permian area of Russia should fall into the Carboniferous, the way will open for another term for the closing system.   From the accumulated evidence, there appears to be need of such a system in the classification.   However, should the Permian rocks of Russia form but a member of a " Permian system " (the trend of evidence is in this direction), there would then be a choice between the Permian of Russia, the Dyas of Geinitz, the Guadalupian of Girty (Oklahomian of Keyes is rather a formation than a time term), and possibly other terms.

As workers in many countries are coming more and more to adopt a classification expressing the local physical and faunal events, the time does not seem far away when the matter of an all-embracing or world chronogenesis will have to be taken up by the International Geological Congress.   Whatever the criterion for such a terminology, indicating the grander events in the world's chronogenesis, may be, it certainly can not be the one now in use, *i.e.,* the local events of a given area, the first to propose a term or terms however badly understood. A new set of system terms for general application suggested by an organization like the International Geological Congress would at once bring into use, for local areas, such despised terms as Taconic and Cambrian, and thus furnish relief from

the ever-recurring disputes concerning Lower Silurian, Cambrian, Cambro-Silurian, Ordovician, or Champlain.

5. Tschernyschew lays great stress upon the occurrence of a form of the brachiopod family Lyttoniidæ in the Schwagerina horizon of the Urals. Certainly it has great faunal value, but the acumen of Tschernyschew also led him to note the fact that it is not of the Indian genus *Lyttonia* (=*Leptodus*). To it he gave the generic name *Keyserlingina*, and the few involutions of the brachia indicate that it has not yet progressed to that degree of specialization shown in the brachia of the Indian genus *Lyttonia*. In other words, *Keyserlingina* holds a lower stratigraphic horizon than *Lyttonia*. In the Austrian Alps, another primitive form of the Lyttoniidæ is found, but here the brachial folds are not laterally directed as in the other forms, but anteriorly. Hence, it is not in the direct line of evolution with the Indian genus, which has also been discovered in Nevada and at El Paso, Texas (Dr. Girty states that he also has it from the Robinson beds of California). The reviewer therefore believes that while *Keyserlingina* unmistakably indicates that the Schwagerina fauna is of the Asiatic type, it is less highly specialized than *Lyttonia*, and consequently holds a lower geological horizon.

6. In regard to Tschernyschew's conclusion that the Russian Permian brachiopods show "atavistic trends," the writer does not think it is borne out by the facts. A list of the species is given on page 31. All of the forms occur below either in the Artinsk or the Upper Carboniferous. In fact all are persisting or long-lived species and are therefore not atavistic in any phylogenetic sense. The brachiopod fauna of the typical Permian, however, may be said to be atavistic in aspect because all of the progressive forms of the Artinsk have failed to continue into this formation.

7. The reviewer, from his knowledge of the late Paleozoic brachiopods, is confident that this class of fossils can be relied on for detailed correlation of stratigraphic horizons over widely separated regions, and further on account of their persistence and wide distribution they are among the best evidence for facial affinity. The Carboniferous and Permian brachiopods are given too great specific latitude by many paleontologists, so that it is common in the literature of the subject to note that many species are found on more than one continent. *Productus semireticulatus* is believed to occur throughout all Carboniferous time and is common to the world. Such a condition permits of no exact correlation.

8. The writer can not see that the evidence as presented by Tschernyschew breaks down the laboriously attained conclusions of Waagen, Noetling, and Diener, that the Productus-

limestone (certainly the upper member or Chideru formation) is not younger than any part of the Permian of the Urals or Timan. The Schwagerina brachiopod fauna of the Urals seemingly arrives later in India, and during this interval has greatly changed. It is this altered character that dominates the faunas of the Middle and Upper Productus-limestone. This alteration is seen in the progressive development and specialization, not only of the Lyttoniidæ, but as well of the Richthofenidæ and the terebratuloids.

9. In regard to the contention of the Indian geologists and Noetling that the Indian Productus-limestone passes without stratigraphic break into the Triassic, some weight should be given to Tschernyschew's faunal argument. In Kentucky, the Devonian overlaps the Ordovician, and in Alabama, the Carboniferous the Ordovician, without visible stratigraphic break; if it were not for the fossils entombed, the maps of these regions would have shown but one formation. From the fact that not a single species is known to pass from the Productus-limestone into the higher Ceratites-bearing beds of India, one would naturally look here for a late Permian or early Triassic land interval, followed by an overlap of Triassic age. However, the fact that no unconformity nor break in sedimentation has been discovered either in the Salt Range or in the central Himalayas, and further that in the latter area there is a great unconformity between the Permian and the Lower Carboniferous (which has a thickness of 5,000 feet), are evidence rather against the supposition that the Triassic overlaps the Permian. The absence of any Permian species in these lower Ceratites beds and the rapid lithologic change between the Permian and Triassic may here be necessary conditions resulting from the great " revolution " taking place in both hemispheres between the Paleozoic and Mesozoic. It is not only the colder glacial land waters poured into the oceans of Permian time at many widely separated areas that have changed the long previous equable habitat of marine faunas, but extermination came as well through the greatly reduced continental shelves, due to the higher altitudes of the continents in the Northern Hemisphere during late Permian time. (This is especially true for North America.) In other words, the stable conditions of the Productus-limestone were interrupted by the Permian revolution going on elsewhere, killing the entire fauna of this immediate region. That this revolution did affect the Salt Range seas is seen by the change in sedimentation, and with it came extermination of its life followed very shortly by an immigration of a new but not greatly changed ammonite fauna.

Art. XVI.—*Notes on Some Eruptive Rocks in Mexico ;* by
F. N. Guild, University of Arizona.

Introduction.—The central portion of Mexico is an elevated
mesa or plateau extending from the United States border to
the southern limits of the Republic. Its elevation varies from
about 3,000 feet on the United States line to nearly 8,000 feet
in the valley of Mexico. Its regularity is broken by numer-
ous mountain ranges, some of whose peaks reach above the
line of perpetual snow. The origin of this great central mesa
is one of the important geological questions in Mexico to-day.
Some authors* consider it to be due to great lateral fractures
and uplifts, while others, though admitting that no definite
explanation can be given until the region has been more thor-
oughly studied, are inclined towards different views.†

The eruptive rocks on this plateau are represented by enor-
mous masses of rhyolite and andesite presenting great varia-
tions in texture, color, etc. Basalt is also abundantly devel-
oped but is of much less importance. The rhyolites and light-
colored porphyritic andesites are found quite uniformly
representing geologically older outflows, while the recent and
modern products of volcanic activity are practically all ande-
sites of poorly developed crystalline texture and of basaltic
aspect. Excellent descriptions of many of these rocks may be
found in the publications of the Geological Institute of
Mexico.‡

One of the most interesting places in the whole Republic is
the valley of Mexico whose interior consists of fertile sedi-
ments of great thickness derived from the disintegration of
the rocks along its border and from accumulations of volcanic
sand from many craters. It was formerly largely occupied by
extensive lakes; Chalco, Xochimilco and Texcoco in the
south, San Cristobal, Xaltocan and Zumpango in the north.
Some of them have overflowed at times and inundated the city
of Mexico, causing great loss of life and property. Extensive
projects for draining them, begun by the Aztecs and carried
out by the Spaniards and Mexicans, have finally removed all
danger from this source. The valley is enclosed on all sides
by eruptive masses, some of which reach an altitude of nearly

* Felix and Lenk, Beiträge zur Geol. und Paleont. der Rep. Mex., Leipzig.
 † La Mesa Central de México es un fenómeno totalmente secundario y no
debe referido á grandes fracturas laterales, sino que se formaba por el rel-
lenamiento de los valles masaltos de la montaña antigua, por masas de rocas
eruptivas, arenas volcánicas y aluviones modernos. "Böse, Sobre el origen
de la Mesa Central Mexicana." Bul. Num. 13, El Instituto Geol. de Mex.,
1899, pp. 35–49.
 ‡ E. Ordóñez, Las Rhyolitas de Mexico, Bul. del Ins. Geol. de Mex. Num.
14 y 15, 1900. Las Rocas Eruptivas del S. O. de la Cuenca de Mex. Bul.
Num. 2, 1895.

18,000 feet above sea level, and contain numerous craters in various stages of decay. The rocks composing them are andesites and basalts with the same characteristics and variations as elsewhere in Mexico, the older outflows being of lighter color and more crystalline texture, the newer showing vitreous and darker colored types. These lavas are associated with large quantities of other products of volcanic activity such as ashes, pumiceous material, etc.

The object of this paper is to describe the mode of occurrence of some of these rocks, especially those found in and near the valley of Mexico, and to describe their mineralogical and chemical composition.

Popocatepetl.

One of the most beautiful views which greets the visitor entering the valley of Mexico, is that of two lofty peaks situated on its extreme southeastern border and reaching above the line of perpetual snow. They are called in the Aztec tongue Popocatepetl, the Smoking Mountain, and Ixtaccihuatl, the White Woman. The former is a symmetrical cone-shaped peak whose cap of dazzling white presents a strong contrast to the dark pine forests of the lower slopes. Ixtaccihuatl is less symmetrical and has an irregular elongated summit.

It is said that the first ascent of Popocatepetl was made by one of the captains of Cortes in 1521; one of the men is reported to have been let down into the crater by a rope for the purpose of collecting sulphur to make gunpowder for carrying on the conquest.* At the present time frequent ascents are made and a well-equipped party experiences no serious discomforts.

The height of the peak above sea level is 17,876 feet, and it has the form of a symmetrical cone obliquely truncated. Its slopes may be divided into three parts, a lower area of vegetation reaching to about 12,000 feet, then steep slopes of soft volcanic sand with occasional ridges of dark andesite up to about 14,000 feet, and finally the snow cap reaching to the crater. The latter is probably not very thick, since there are no crevasses or other evidences of glacial movements.

The crater is elliptical in shape with a maximum diameter of 612 meters and a minimum diameter of 400 meters.† The inner rim is made up of irregular ledges or blocks of black andesite, with a slope towards the crater of about 20 meters, and then there is a perpendicular cliff varying from 80 to 75 meters in height. At its base is a talus slope extending towards the center of the crater, which contains a small pond formed by the

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* Prescott, Conquest of Mexico, p. 44, vol. ii.
†Aguilera y Ordóñez, Expedicion Cientifica al Popocatepetl, Mexico, 1895.

melting of the snow. The maximum depth of the crater from the surface of the lake to the highest point of the rim is said to be 505 meters. At the malecate, or hoist, formerly used in extracting sulphur from the crater, the depth is considerably less, being but 205 meters.* The bottom of the crater contains several small solfataras, from which steam and sulphur vapor escape. It is impossible to enter the crater except by means of a rope down a perpendicular cliff 250 feet high. The descent, how-

Fig 1. Popocatepetl, a bank of volcanic ash projecting through the snow. About 1000 ft. below the crater.

ever, has been made by members of the Geological Institute of Mexico, who spent forty-eight hours in the crater investigating it.* The interior heat of the volcano is still sufficient to prevent the crater becoming filled up with snow.

The rocks of Popocatepetl † consist of andesites and basalts with the usual accompanying pumiceous and scoriaceous forms, which are especially well developed immediately below the snow line, where many barrancas, or deep cuts, commence and radiate outward, giving an excellent opportunity for studying it. One of the deepest of them, the Barranca de Tlamacas, cuts through this material to the depth of 200 feet or more and exposes beds made up alternately of fine volcanic ash and coarse pumiceous

* Aguilera y Ordóñez, Expedicion Cien. al Popocatepetl.
† An excellent account of an ascent of Popocatepetl, with observations upon its geography and geology with a brief description of its lavas, has been given by Farrington—Geological Series of the Field Columbian Press, vol. i, No. 2, 1897.

matter. In the lapilli there are frequently embedded blocks of black compact lava which have evidently rolled down from above. Narrow ledges of lava are occasionally found projecting above the sand and mark the position of some outflow from the crater which has solidified before reaching the base of the volcano. (Fig. 2.)

Petrography of the andesites of Popocatepetl.—The results of the petrographic study of four specimens collected from various places will be given as illustrative of the variations in these andesites.

No. 1 was from one of the large blocks at the rim of the crater near the Malacate. Hand specimens appear as black

FIG. 2. Popocatepetl, showing a ridge of black andesite projecting through the volcanic sand.   Near the snow line.

basaltic rocks containing numerous phenocrysts of feldspar averaging about two millimeters in diameter, rather rounded in outline and evenly distributed.   One square centimeter of surface usually contains about fifteen phenocrysts.   Under the microscope the feldspar appears as broken fragments and idiomorphic crystals presenting the ordinary characteristics of rocks of this type; zonal structure, abundant inclusions of the dark groundmass, and twinning according to the albite and pericline laws. Optical determinations place some of the crystals in the andesine-oligoclase, others in the andesine-labradorite series.   The chemical analysis given below shows that the feldspars, taken as a whole, are of rather more acid type than the phenocrysts,

which is doubtless due to more acid plagioclases in the ground-mass. Pyroxene is present in both orthorhombic and monoclinic varieties. Some are slightly pleochroic. The groundmass is a dark, nearly opaque glass.

No. 2 was also taken from the rim of the crater. It is more compact and contains much less conspicuous phenocrysts. The microscope shows the same mineralogical composition as in No. 1. The feldspar is developed in much smaller crystals and twinning and zonal structure is not marked. Nearly all of the crystals are filled with inclusions of the groundmass.

No. 3 was taken some distance below the snow line from a large ledge near Tlamacas and extending towards the north. Hand specimens appear as medium dark gray rocks of non-porphyritic structure. The material is very uniform in different portions of the same mass and probably represents an outflow of considerable extent. Green crystals of pyroxene and occasionally a small fragment of feldspar can be seen without the microscope. An optical study shows that the crystals are well formed and possess sharp angular outlines. Zonal structure and twinning are both developed as in No. 1, but the pyroxenes are much more abundant and hypersthene greatly predominates over augite. The groundmass is a felt of magnetite, pyroxene microlites and obscure feldspar rods. An optical determination of the feldspar crystals makes them mostly labradorite of medium acidity, though a few belong to less basic types.

No. 4 was taken from the Barranca de Tlamacas. It may be classified as a dark yellowish gray to brown andesitic pumice. It is filled with large cavities one or two centimeters in diameter, at or near the center of which is frequently to be found a small rounded mass of dark glassy material sometimes containing a few phenocrysts and supported by radiating threads of delicate glass which appear not unlike spiders' webs. The microscope shows this rock to be made up mostly of threads and fragments of light yellow glass with only an occasional crystal of feldspar or pyroxene.

Many other specimens, collected from various points about the volcano, show practically the same mineralogical composition as those described but with variations in structure and texture due doubtless to more or less rapid cooling rather than to difference in chemical composition. Basalts and trachites have been described from Popocatepetl by Aguilera and Ordoñez. The basalts occur as representatives of older out-flows and are not at all abundantly represented. The writer did not observe any occurrences of this type of rock during his recent expedition to the volcano. Specimens, however, studied at the Instituto Geologico de Mexico, through the kindness of the Director, appear as typical fine-grained basalt with abundant olivine. The latter mineral is sometimes devel-

oped in unusually large phenocrysts. The trachites of Popocatepetl might better be described as andesites with trachitic texture since plagioclase seems to predominate.

The chemical composition of the hypersthene-andesites from Popocatepetl is shown by two analyses made by the writer. The first (No. 1, described above) represents a recent outflow, the other (No. 3, from near Tlamacas) is representative of an earlier period of activity.

	No. 1.	No. 3.
SiO_2	62·51	58·07
Al_2O_3	16·62	15·83
Fe_2O_3	1·12	2·97
FeO	3·75	3·89
MgO	3·30	5·56
CaO	5·10	6·70
Na_2O	4·28	3·89
K_2O	1·86	1·73
H_2O. Above 110	·53	·23
H_2O. Below 110	·15	·18
TiO_2	1·02	1·27
P_2O_5	·23	·29
Cr_2O_3	·015	·01
MnO	·10	·06
SrO	·03	·04
BaO	·14	·07
Li_2O	trace	trace
	100·755	100·79

The normative mineralogical composition and position of the rock according to the quantitative classification is given in the table below.

No. 1.

Quartz, SiO_2			13·98%
Orthoclase, $K_2O.Al_2O_3.6SiO_2$			11·12
Albite, $Na_2O.Al_2O_3.6SiO_2$			36·16
Anorthite, $CaO.Al_2O_3.2SiO_2$			20·57
Diopside	$FeO.SiO_2$	·52	
	$CaO.SiO_2$	1·62	3·27
	$MgO.SiO_2$	1·00	
	$MnO.SiO_2$	·13	
Hypersthene	$MgO.SiO_2$	7·20	10·90
	$FeO.SiO_2$	3·70	
Magnetite, $FeO.Fe_2O_3$			1·86
Ilmenite, $FeO.TiO_2$			1·82
Apatite			·31
Rest			·86
			100·85

$$\frac{\text{Sal}}{\text{Fem}} = \frac{81\cdot83}{18\cdot16}\ ,\quad <\frac{7}{1}>\frac{5}{3}\ ,\ \text{Class II, Dosalane}$$

$$\frac{\text{Q}}{\text{F}} = \frac{13\cdot98}{67\cdot85}\ ,\quad <\frac{3}{5}>\frac{1}{7}\ ,\ \text{Order 4, Austrare}$$

$$\frac{\text{K}_2\text{O} + \text{Na}_2\text{O}}{\text{CaO}} = \frac{89}{74},\quad <\frac{5}{3}>\frac{3}{5}\ ,\ \text{Rang 3, Tonalase}$$

$$\frac{\text{K}_2\text{O}}{\text{Na}_2\text{O}} = \frac{20}{69},\quad <\frac{3}{5}>\frac{1}{7}\ ,\ \text{Subrang 4, Tonalose}$$

No. 3.

Quartz, SiO_2		8·88%
Orthoclase, $K_2O.Al_2O_3.6SiO_2$		10·01
Albite, $Na_2O.Al_2O_3.6SiO_2$		32·49
Anorthite, $CaO.Al_2O_3.2SiO_2$		20·85
Diopside	$CaO.SiO_2$ 4·52 $FeO.SiO_2$ ·66 $MgO.SiO_2$ 3·40	8·58
Hypersthene	$MgO.SiO_2$ 10·40 $FeO.SiO_2$ 2·11	12 51
Magnetite, $FeO.Fe_2O_3$		4·18
Ilmenite, $FeO.TiO_2$		2·28
Apatite		·62
Rest		·59
		100·99

$$\frac{\text{Sal}}{\text{Fem}} = \frac{72\cdot23}{28\ 17}\ ,\quad <\frac{7}{1}>\frac{5}{3}\ ,\ \text{Class II, \quad Dosalane}$$

$$\frac{\text{Q}}{\text{F}} = \frac{8\cdot88}{63\cdot35}\ ,\quad <\frac{3}{5}\qquad ,\ \text{Order 4-5}\ \begin{cases} \text{Austrare} \\ \text{Germauare} \end{cases}$$

$$\frac{\text{K}_2\text{O} + \text{Na}_2\text{O}}{\text{CaO}} = \frac{80}{75},\quad <\frac{5}{3}>\frac{3}{5}\ ,\ \text{Rang 3}\ \begin{cases} \text{Tonalase} \\ \text{Andase} \end{cases}$$

$$\frac{\text{K}_2\text{O}}{\text{Na}_2\text{O}} = \frac{18}{62}\ ,\quad <\frac{3}{5}>\frac{1}{7}\ ,\ \text{Subrang 4}\ \begin{cases} \text{Tonalose} \\ \text{Andose} \end{cases}$$

Sierra de Guadalupe.

The regularity of the valley of Mexico is broken in many places by branches extending from the high mountain ranges and reaching in some cases almost to the city of Mexico. One of the most conspicuous of these is the Sierra de Guadalupe located directly north of the city, and consisting of a series of rounded hills of low altitude (fig. 3). The three elevations nearest the city of Guadalupe are known as Cerro de Guerrero, Cerro de San Isabel and Cerro de Chiquihuite. At the base,

especially in the vicinity of the city, they are composed of rocks presenting the appearance of volcanic breccia with cementing material of a dark vitreous andesite, with sometimes small phenocrysts of feldspar; the fragments are of very much the same material with occasionally lighter colored and more porphyritic varieties. The most common type is that of a dark brown to black compact rock, with a few visible phenocrysts of green pyroxene. These rocks are nearly all opal-bearing, the

Fig. 3. A view of the Sierra de Guadalupe. Aqueduct of Guadalupe in the foreground.

mineral occurring in cracks and occasionally in amygdaloidal cavities.* It is usually colorless (hyalite), but sometimes presents various shades of yellow, red and blue. More porphyritic types of these andesites occur in other portions of the series.

Microscopically these rocks are similar to those from Popocatepetl and are hypersthene andesites. While there is great mineralogical similarity in the specimens from different places, there is also great diversity in the arrangement of the constituents, variations in texture due to more or less rapid cooling. The feldspar appears as rods, broken fragments, and larger crystals with zonal structure frequently possessing a clear border, but containing dark inclusions in the interior. The

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* For an excellent description of the occurrence of opal in the eruptive rocks of Mexico, and how they are frequently found filling decayed spherulitic growths, see, Las Rhyolitas de Mexico, Bul. Num. 14 y 15, Inst. Geol. de Mex.

groundmass varies from a pure glass swarming with crystallites to a semi-crystalline condition, frequently containing obscure globulitic and microlitic growths. Hypersthene andesites of this type have been described from Crater Lake, Oregon,* and other portions of the United States.

Colima de Chapultepec.

This is a small rocky eminence rising abruptly from the plains, about three miles southwest of the city of Mexico. On the summit is the beautiful castle of Chapultepec, and around its base are artificial lakes and roadways which make it one of the most beautiful parks in the world. Although isolated, it is considered to belong topographically to the Sierra de las Cruces, a range bounding the valley on the southwest.† Specimens collected from it appear as dark gray mottled rocks with porphyritic hornblendes and feldspars, the latter being most conspicuous. Under the microscope both feldspar and hornblende are found to occur in two generations, the feldspar in large idiomorphic crystals with zonal structure, and symmetrically arranged inclusions and smaller rod-shaped growths; the hornblende is in elongated crystals and is of a basic variety possessing strong pleochroism and dark to opaque borders. The groundmass is partly crystallized, containing needles of both hornblende and feldspar with patches of transparent glass. (A, fig. 5, p. 172.)

An analysis of this rock was made by the writer with the following results :

Analysis of Hornblende Andesite from Chapultepec.

SiO_2	62·89%
Al_2O_3	16·42
Fe_2O_3	2·64
FeO	2·24
MgO	2·50
CaO	4·77
Na_2O	4·07
K_2O	2·15
H_2O. Above 110	1·00
H_2O. Below 110	·55
TiO_2	·83
P_2O_5	·20
Cr_2O_3	·01
MnO	·08
SrO	·03
BaO	·07
Li_2O	Trace

100·45

* Diller & Patton, The Geology and Petrography of Crater Lake National Park, U. S. Geol. Sur. PP No. 3, plate xv.
† Ordóñez, Bul. Num. 2, Ins. Geol. de Mex.

Normative Mineralogical Composition and Classification.

Quartz, SiO_2 .... 17·52%
Orthoclase, $K_2O.Al_2O_3.6SiO_2$ .... 12·79
Albite, $Na_2O.Al_2O_3.6SiO_2$ .... 34·58
Anorthite, $CaO.Al_2O_3.2SiO_2$ .... 20·02

Diopside $\begin{cases} MgO.SiO_2 & ·90 \\ FeO.SiO_2 & ·13 \\ CaO.SiO_2 & 1·15 \end{cases}$ 2·18

Hypersthene $\begin{cases} MgO.SiO_2 & 5·40 \\ FeO.SiO_2 & ·53 \end{cases}$ 5·93

Magnetite, $FeO.Fe_2O_3$ .... 3·71
Ilmenite, $FeO.TiO_2$ .... 1·50
Apatite .... ·30
Rest .... 1·74
                                                    ─────
                                                    100·27

$$\frac{Sal}{Fem} = \frac{84·91}{13·62}, \ <\frac{7}{1} > \frac{5}{3}, \ \text{Class II, Dosalane}$$

$$\frac{Q}{F} = \frac{17·52}{67·39}, \ <\frac{3}{5} > \frac{1}{7}, \ \text{Order 4, Austrare}$$

$$\frac{K_2O + Na_2O}{CaO} = \frac{89}{72}, \ <\frac{5}{3} > \frac{3}{5}, \ \text{Rang 3, Tonalase}$$

$$\frac{K_2O}{Na_2O} = \frac{23}{66}, \ <\frac{3}{5} > \frac{1}{7}, \ \text{Subrang 4, Tonalose}$$

Basaltic lava sheets.

The extreme southern portion of the valley of Mexico in the vicinity of Tlalpam is flooded with an enormous outflow from the craters of Zeutli, Xicalco and Xitli. Although no records are preserved in the ancient Aztec's writings regarding eruptions from these volcanoes, there are abundant evidences showing their recent origin. The lavas are in a very fresh condition and human bones and implements are found beneath them. Their surfaces are very rough, consisting of bowlders and loose fragments of all sizes. Compact and scoriaceous modifications are both represented. The most common type is an exceedingly fine-grained black rock lacking phenocrysts, but filled with numerous small cavities, and containing frequent inclusions of other rocks, usually andesitic in character, especially where the lava stream has encroached upon elevations representing older outflows, as in the vicinity of Cerro de Xochitepetl.

Microscopically the rock is a typical fine-grained basalt with about equal quantities of olivine and pyroxene, both of which are clear and undecomposed, and rather difficult to distinguish from one another, since the pyroxene is orthorhombic. The remainder of the rock is made up of fine rods of feldspar crowded together and pressed against the larger crystals of olivine and hypersthene, together with magnetite, and considerable dark isotropic matter. The writer has described basalts of this texture from Arizona,[*] and they are common in other parts of the United States.

Fig. 4.   Columns in Basalt, Salto de San Anton, Cuernavaca.

A section was prepared from one of the large inclusions of andesite in the basalt near Xochitepetl (B, fig. 5, p. 172). In general the structure and composition is similar to that of the andesite of Chapultepec. Hornblende and plagioclase are developed in well formed crystals. The hornblende has been the first to decompose, and some crystals are nearly opaque from the separation of magnetite.

Basaltic outflows similar to the ones described above are found in the vicinity of Cuernavaca, and in places, as at the Salto de San Anton, have a beautiful columnar structure (fig. 4). An analysis of the basalt from this locality shows it to have the composition given below.

[*] Petrography of the Tucson Mountains, this Journal, xx, p. 313, pl. ix.

Analysis of Basalt from El Salto de San Anton.

SiO_2	51·56%
Al_2O_3	15·24
Fe_2O_3	2·73
FeO	5·99
MgO	8·30
CaO	7·67
Na_2O	3·74
K_2O	1·25
$H_2O.$ Above 110	·16
$H_2O.$ Below 110	·15
TiO_2	1·81
P_2O_5	·47
Cr_2O_3	·005
MnO	·15
SrO	·05
BaO	·07
Li_2O	Trace

99·945

Normative Mineralogical Composition and Classification.

Orthoclase, $K_2O.Al_2O_3.6SiO_2$			11·12%
Albite, $Na_2O.Al_2O_3.6SiO_2$			31·44
Anorthite, $CaO.Al_2O_3.2SiO_2$			19·18
Diopside	$CaO.SiO_2$	6·38	
	$MgO.SiO_2$	4·60	12·17
	$FeO.SiO_2$	1·19	
Hypersthene	$MgO.SiO_2$	5·10	
	$FeO.SiO_2$	1·45	6·81
	$MnO.SiO_2$	·26	
Olivine	$2MgO.SiO_2$	7·70	
	$2FeO.SiO_2$	2·45	10·15
Magnetite, $FeO.Fe_2O_3$			3·94
Ilmenite, $FeO.TiO_2$			3·34
Apatite			1·24
Rest			·43

99·82

$$\frac{\text{Sal}}{\text{Fem}} = \frac{61{\cdot}74}{37{\cdot}65}, \quad < \frac{5}{3} > \frac{3}{5}, \quad \text{Class III}, \quad \text{Salfemane}$$

$$\frac{\text{F}}{\text{Q}} = 61{\cdot}74, \qquad > \frac{7}{1}, \quad \text{Order 5}, \quad \text{Gallare}$$

$$\frac{\text{K}_2\text{O} + \text{Na}_2\text{O}}{\text{CaO}} = \frac{80}{69}, \quad < \frac{5}{3} > \frac{3}{5}, \quad \text{Rang 3}, \quad \text{Comptonase}$$

$$\frac{\text{K}_2\text{O}}{\text{Na}_2\text{O}} = \frac{20}{60}, \quad < \frac{3}{5} > \frac{1}{7}, \quad \text{Subrang 4}, \text{Comptonose}$$

Sierra Catarina, one of the most interesting features in the valley of Mexico, consists of a series of crater cones rising abruptly from the level plains in the southeastern part of the valley. Some are in groups of four or five, while others are isolated truncated cones with an average height of 400 feet. Five of them were visited by the writer during the summer of 1905, and all but one were found to have a well defined crater on the summit. Their component material varies from pure volcanic sand to compact lava, while scoriaceous forms, lapilli and volcanic blocks of all sizes are abundant. A compact lava is found near the base of several of them but has never flowed to great distances. The predominating color is black for the compact varieties of lava and black or red for the more scoriaceous modifications—porphyritic types are entirely lacking.

Las Calderas, perhaps the best known of these crater cones, is about one mile south of the railroad station of Los Reyes. It is an elongated truncated cone with a sloping summit due to the erosion of the rim on the southern extremity. The cone contains two craters with a narrow rim between them. Barometric observations gave the following elevations:

Highest point on the rim, 650 feet above the plain.
Lowest point on the rim, 275 feet above the plain.

The bottom of the crater was found to be at practically the same level as the surrounding plain, its diameter is about 1,500 feet and its interior walls are quite precipitous.

This cone consists almost entirely of a yellowish gray stratified tuff of about the hardness of adobe brick and with an occasional volcanic block embedded in it. Microscopically the ash is made up mostly of transparent glass with some microlites of feldspar and decomposed particles of ferromagnesian minerals. The volcanic block mentioned above contains small and rather scattered rods of feldspar in an exceedingly dark, glassy, structureless groundmass. Ferromagnesian minerals are present only in isolated grains. The rock is of too vitreous a nature to admit of accurate classification from its mineral constituents.

Directly southwest of Las Calderas is a series of crater cones the best formed of which is called Cerro de Catarina. The
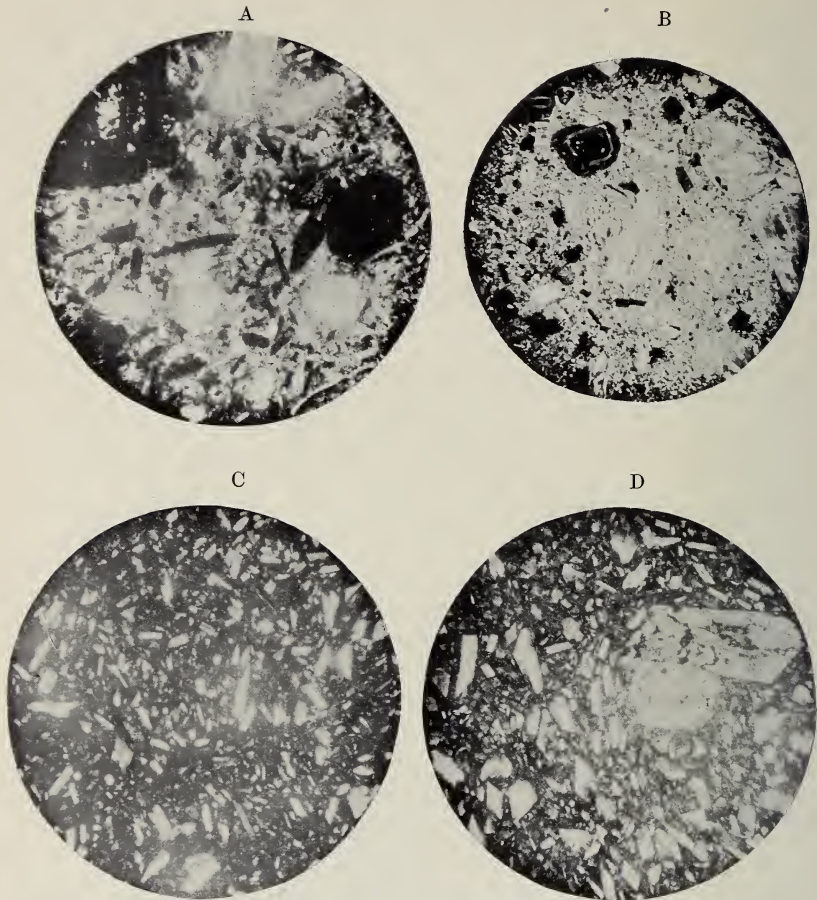
Fig. 5.   Description of Photomicrographs illustrating the types of andesites in the valley of Mexico.

A. Porphyritic hornblende andesite from Chapultepec, showing both feldspar and hornblende in two generations.   The groundmass is nearly all crystallized material.   14 diameters.

B. Hornblende andesite from Xochitepetl.   Zonal structure in feldspar. Crystalline groundmass.   Crossed nicols.   14 diameters.

C. Andesite of basaltic aspect from Popocatepetl.   Abundant feldspar and less pyroxene in a vitreous groundmass.   Pyroxene cannot be distinguished from feldspar in the cut.   14 diameters.

D. Andesite of basaltic aspect from Sierra de Guadalupe showing a large hypersthene with smaller feldspar crystals in a semi-vitreous groundmass. 14 diameters.

A and B are light-colored porphyritic andesites representing an old outflow of great extent.   C and D are megascopically non-porphyritic and belong to an outflow of recent date.

approach to them from Los Reyes is over an exceedingly rough bow of compact lava.

Several specimens were collected from this elevation, one of a lustrous black rock with conchoidal fracture and free from cavities or inclusions. Others collected from the loose material around the crater were more scoriaceous and contained many cavities. Under the microscope they all show about the same characteristics, the chief variation being in the relative amount

Fig. 6. View taken from the interior of the crater of Las Calderas, showing the walls and stratified condition of the volcanic ash.

of glass present. The description of the block found on Las Calderas applies to most of the fragments found near the summit of Catarina. The rock of the rough lava flow mentioned above, while probably of the same mineralogical composition, has quite a different texture. It is basaltic, consisting of dark glass swarming with minute rods of feldspar. The rods are not pressed together as is usual in these types of rock but each individual appears quite distinct from its neighbor.

Cerro Xaltepetl, located still further south, is similar to the last described cone except that it is of less altitude, contains a greater quantity of the finer products of volcanic activity and the outflow of lava at the base is lacking, and there are stratified beds of ash in its place. Sections prepared from volcanic blocks, lapilli and scoriaceous material reveal nothing new as compared with that from the other cones of the same group. The crater is very shallow and probably not more than 500

feet across; the soil formed at its bottom is very fertile and these craters seem to be favorite places for cultivating corn.

Next in line in this interesting group of volcanoes is Cerro de San Nicolas, one of the smallest but most symmetrical of the cones. It is about 350 ft. high, as found by barometric measurements, and contains a small crater possibly 50 feet deep. The material ejected from this crater both from a megascopic and microscopic standpoint presents about the same characteristics as in the last two cones.

About three miles from San Nicolas is another low elevation called Cerro de Ixtapalapa whose crater has been completely removed by erosion. Near the summit the component material is the same as that of the other craters of the group, but its base is of compact lava which has spread out for some distance forming gentle slopes. In this respect Cerro de Ixtapalapa resembles Cerro de Catarina more than the other cones. Under the microscopes this compact lava is more crystallized than any of the others examined. Feldspar occurs in two distinct generations although no phenocrysts can be detected by the naked eye. Orthorhombic pyroxene is abundantly developed in the form of isolated crystals and clusters. This rock resembles quite closely those already described from the Sierra de Guadalupe. It may be called a hypersthene andesite.

Summary.

It will be seen from the foregoing descriptions that the valley of Mexico and vicinity represent a petrographic province in which the intermediate and basic types of rocks are abundantly developed. In this respect it resembles regions of recent volcanic activity in the western portion of the United States and other parts of the world. The hypersthene andesite from Popocatepetl and the Sierra de Guadalupe are very similar to those described from Crater Lake, Ore.,[*] Mt. Shaster, Cal.,[†] Buffalo Peak, Col.,[‡] and other well known localities. Further the material ejected from Colima[§] and other active volcanoes in Mexico during their recent periods of eruption seems to be of the same general mineralogical composition. The chemical composition is also similar, as may be observed by comparing the analyses accompanying this paper with those from the localities mentioned above. It is interesting to observe the relation between the chemical composition of the older crystalline andesites as illustrated by the rock from Chapultepec, and the newer, non-porphyritic, more vitre-

[*] Diller and Patton, The Geology and Petrography of Crater Lake National Park. PP No. 3, U. S. Geol. Sur.
[†] Diller, U. S. Geol. Sur. Bul. No. 150, p. 227.
[‡] Cross, U. S. Geol. Sur. Bul. No. 150, p. 224.
[§] Ordóñez, Les Dernières Eruptions du Volcan de Colima, Mexico, 1903. Also a review by the writer in Geologisches Centralblatt, Bd. VII, No. 8.

ous and basaltic-like lava from Popocatepetl. These are almost identical in chemical composition yet have given rise to dissimilar mineralogical developments. The one has developed abundant hornblende, the other pyroxene. This of course is easily explained on the ground that the consolidation has taken place under diverse conditions, the one being erupted in large masses which formed mountain ranges and so cooling very slowly and under great pressure, the other in small out-flows which in some cases barely spilled over the rim of the crater. Farrington* in comparing the rocks of Popocatepetl and Ixtaccihuatl speaks of the remarkable fact that they differ completely in character, the one being hypersthene andesite and the other a quite dissimilar appearing hornblende ande-site. It is quite possible that in this case as in the one men-tioned above a similar chemical composition is masked by a dissimilar mineralogical structure. This view is further sub-stantiated by comparing the analysis given above (No. 1) with an incomplete analysis of hornblende andesite from Ixtaccih-uatl made by Felix and Lenk.† As is well understood, horn-blende requires for its formation unusual conditions of pressure, etc., while the pyroxenes do not. The recent lavas of Popo-catepetl are more acid in composition than the old. The few basalts are mostly covered up by andesitic outflows. The older andesite of Tlamacas is of a more basic type than those collected about the rim of the crater.

Volcanic sand and ashes are developed in enormous quanti-ties around the base of the older mountains in many places in Mexico, and constitute one of the chief sources of the great fertility of the soil. The writer has been told that after the coffee plantations in that country have become covered for many square miles with a thin mantle of gray ash from the volcanoes, contrary to the expectations of the haciendadoes the soil has been improved and better yields experienced. The older volcanic sands frequently become cemented and consti-tute a material of sufficient strength to be used as a building stone. It is often so soft that it can be worked into various shaped bricks by means of a hatchet, and not infrequently becomes harder on exposure to the air. The texture varies from a fine-grained stratified deposit like that described from Las Calderas, to rounded semi-pumiceous grains somewhat larger than peas cemented by finer material. Many of the varieties frequently have a peculiar, not unpleasing and rusty appearance. Intermediate varieties sometimes show oolitic structures.

* Op. cit., p. 109.
† SiO_2 61·24, Al_2O_3 18·32, Fe_2O_3 and FeO 6·17, MgO 3·76, CaO 5·06, Na_2O 3·15, K_2O 2·37, H_2O 0·67, Felix und Lenk, Btr. Geol. Mex., II, p. 229, 1899.

Art. XVII.— *The Hydrolysis of Salts of Iron, Chromium, Tin, Cobalt, Nickel, and Zinc in the Presence of Iodides and Iodates;* by SETH E. MOODY.

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

Iron.

It has been shown in a former paper* that the action of a mixture of potassium iodide and potassium iodate upon aluminium chloride and aluminium sulphate may serve as the basis for the iodometric determination of aluminium.

Just as salts of aluminium are hydrolyzed in the presence of the iodide-iodate mixture with the liberation of iodine, so are salts of iron. The reaction by which ferric sulphate is hydrolyzed is similar to that for the hydrolysis of aluminium chloride and aluminium sulphate, as already given.

$$Fe_2(SO_4)_3 + 5KI + KIO_3 + 3H_2O = 2Fe(OH)_3 + 3K_2SO_4 + 6I.$$
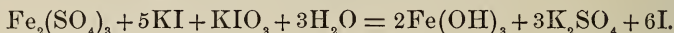
The hydrolysis of ferrous sulphate is accompanied by oxidation of the ferrous hydroxide at the expense of the iodate, as follows :

$$3FeSO_4 + 5KI + KIO_3 + 3H_2O = 3Fe(OH)_2 + 3K_2SO_4 + 6I$$
$$6Fe(OH)_2 + KIO_3 + 3H_2O = 6Fe(OH)_3 + KI.$$
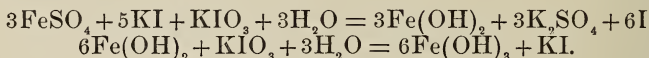
The iodine eliminated is an exact measure of such hydrolysis as in the case of aluminium and becomes known by the use of a standard solution of sodium thiosulphate for its titration.

A solution of ferrous sulphate was used in the experiments performed, made up to about $N/10$ strength. Its v a l u e was obtained with potassium permanganate as s h o w n in Table I. Of this solution portions of 25^{cm^3} were drawn from a burette into a Voit flask, the iodide-iodate mixture added and the whole boiled for 30 minutes in the presence of a current of hydrogen to transfer the iodine to the receiver, a Drexel flask charged with potassium iodide, when it was estimated with a standard solution of sodium thiosulphate.

Table II shows results of these experiments.

* This Journal, xx, 1905, p. 181.

TABLE I.

FeSO$_4$. cm^3.	K$_2$Mn$_2$O$_8$. cm^3	Fe. grm.	Iodine equivalent. grm.	grm. (Mean.)
25	10·60	0·0734	0·3326	
25	10·60	0·0734	0·3326	
25	10·57	0·0732	0·3317	0·3322
25	10·58	0·0733	0·3320	
25	10·59	0·0734	0·3323	

TABLE II.

FeSO$_4$. cm^3.	KI. grm.	KIO$_3$. cm^3.	Time in minutes.	Na$_2$S$_2$O$_3$. cm^3.	Iodine calculated. grm.	Diff. grm.
25	1·0	15	30	26·67	0·3324	+0·0002
25	1·0	15	30	26·68	0·3325	+0·0003
25	1·0	15	30	26·65	0·3321	−0·0001
25	1·0	15	30	26·67	0·3324	+0·0002
25	1·0	15	30	26·66	0·3323	+0·0001

So it appears that the hydrolysis of ferrous sulphate is complete in the presence of the iodide-iodate mixture and that the iodine set free is an exact measure of the SO$_4$-ion present and of the iron in the ferrous sulphate of ideal composition.

Chromium.

Chromium sulphate, in the form of the alum, was next examined. The standard of the solution was found by precipitating with ammonia and igniting the chromic hydroxide to constant weight. For the purpose of comparison other portions of the solution were treated with the iodide-iodate mixture and boiled for half an hour in a trapped Erlenmeyer beaker to expel the iodine. A few drops of sodium thiosulphate were added to take up the last trace of iodine and thus insure complete hydrolysis. The precipitate was filtered off on asbestos, washed with boiling water and ignited to constant weight. Results of these experiments are given in the following table:

TABLE III.

Approx. N/10 chrome alum. cm^3	Precipitant. Ammonia. Cr$_2$O$_3$ found. grm.	Iodide-iodate mixture. Cr$_2$O$_3$ found. grm.	Mean of entire series. grm.
25	0·0643	0·0638	
25	0·0638	0·0645	
25	0·0646	0·0641	0·0642
25	0·0641	0·0640	
25	0·0644	0·0643	

The sulphuric acid set free by hydrolysis upon boiling with the iodide mixture was then found by the iodide-iodate reaction, one gram of potassium iodide being in each case dissolved in 10^{cm^3} of a solution of potassium iodate (30 grms. to a liter) and added to the measure of chrome alum in the Voit flask. The mixture was boiled thirty minutes with a current of hydrogen to aid in removing the iodine liberated to the Drexel flask containing about 3 grams of potassium iodide dissolved in water. The iodine collected in the receiver was estimated with sodium thiosulphate as in previous experiments. That the hydrolysis of the sulphate had been complete was shown by dissolving the washed precipitate in nitric acid and testing the solution with barium chloride, no barium sulphate being found.

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

Approx. N/10 chrome alum. cm³.	Time in minutes.	$Na_2S_2O_3$. cm³.	I. grm.	Cr_2O_3 corresponding to SO_3, equivalent of iodine set free. grm.	Excess of Cr_2O_3 (Basic.) grm.
25	30	23·50	0·2915	0·0583	0·0059
25	30	23·45	0·2908	0·0582	0·0060
25	30	23·40	0·2902	0·0580	0·0062
25	30	23·45	0·2008	0·0582	0·0060
25	30	23·44	0·2907	0·0581	0·0061

The fact that more chromic oxide is contained in the alum than corresponds to the SO_3 found by the iodide-iodate reaction in the complete hydrolysis of the salt shows at once that this particular preparation of chrome alum, like many ordinary commercial alums, is basic.

Tin.

In experimenting with salts of tin the difficulty is to obtain a salt of definite composition with which to start. The double salt of stannic chloride and potassium chloride was selected as a suitable salt for determining the character of the hydrolysis of stannic chloride. This salt was prepared by adding stannic chloride to a cold saturated solution of potassium chloride. The material was then filtered, washed and dried in a vacuum desiccator.

The tin content of this salt was found by precipitating stannic acid with the iodide-iodate mixture, igniting and weighing the stannic oxide thus obtained. Results of these experiments follow in Table V.

TABLE V.

SnCl$_4$. 2KCl. grm.	KI. grm.	KIO$_3$ cm^3	SnO$_2$ precipitated. grm.	Mean of entire series. grm.
0·25	1·0	15	0·0926	
0·25	1·0	15	0·0933	
0·25	1·0	15	0·0937	
0·25	1·0	15	0·0929	0·0931
0·25	1·0	15	0·0932	
0·25	1·0	15	0·0930	
0·25	1·0	15	0·0934	
0·25	1·0	15	0·5931	

Portions of this salt were placed in the Voit flask with the iodide-iodate mixture, and the mixtures were boiled for 40 minutes in a current of hydrogen to transfer the iodine to the Drexel flask charged with potassium iodide. The iodine thus eliminated was estimated with a standard solution of sodium thiosulphate of approximate N/10 strength. The results are given in A of the following table.

An abundance of iodine is liberated immediately upon the addition of the iodide-iodate mixture without boiling, and in order to see to what limit the action might go at the ordinary temperature of the room, a series of experiments was made in which the iodine was removed at once with sodium thiosulphate, and the solution after standing two hours was titrated with sodium thiosulphate, the total amount of the thiosulphate used being a measure of the iodine eliminated in the reaction and a measure of the tin present.

The results of these experiments are given in B of the table which follows:

TABLE VI.

SnCl$_4$. 2KCl. grm.	KI. grm.	KIO$_3$. cm^3.	Time in minutes.	Approx. N/10 Na$_2$S$_2$O$_3$. cm^3.	I. grm.	SnO$_2$ calculated. grm.	SnO$_2$ precipitated. grm.	Diff. grm.
					A			
0·25	1·0	15	40	24·37	0·3137	·0·0933	0·0931	+0·0002
0·25	1·0	15	40	24·36	0·3135	0·0933	0·0931	+0·0002
0·25	1·0	15	40	24·32	0·3130	0·0932	0·0931	+0·0001
0·25	1·0	15	40	24·33	0·3132	0·0932	0·0931	+0·0001
0·25	1·0	15	40	24·36	0·3135	0·0933	0·0931	+0·0002
0·25	1·0	15	40	24·35	0·3134	0·0933	0·0931	+0·0002
0·25	1·0	15	40	24·34	0·3133	0·0932	0·0931	+0·0001
0·25	1·0	15	40	24·36	0·3135	0·0933	0·0931	+0·0002

TABLE VI (continued).

SnCl₄. 2KCl. grm.	KI. grm.	KIO₃. cm³.	Time in minutes.	Approx. N/10 Na₂S₂O₃. cm³.	I. grm.	SnO₂ calculated. grm.	SnO₂ precipitated. grm.	Diff. grm.
				B				
0·25	1·0	15	120	24·37	0·3137	0·0933	0·0931	+ 0·0002
0·25	1·0	15	120	24·35	0·3134	0·0933	0·0931	+ 0·0002
0·25	1·0	15	120	24·34	0·3133	0·0932	0·0931	+ 0·0001
0·25	1·0	15	120	24·28	0·3125	0·0930	0·0931	— 0·0001
0·25	1·0	15	120	24·31	0·3130	0·0931	0·0931	± 0·0000
0·25	1·0	15	120	24·32	0·3130	0·0932	0·0931	+ 0·0001
0·25	1·0	15	120	24·34	0·3133	0·0932	0·0931	+ 0·0001
0·25	1·0	15	120	24·33	0·3132	0·0932	0·0931	+ 0·0001

These results recorded in A show that stannic chloride is completely hydrolyzed in the presence of the iodide-iodate mixture, and that the iodine liberated on boiling is a measure of the tin present.

The results given in B show that at the temperature of the room complete hydrolysis is also effected by removing from the sphere of action the iodine which at first appears and allowing the mixture to stand two hours before the final titration.

Cobalt.

When cobaltous sulphate is boiled for a considerable time with the iodide-iodate mixture, it is hydrolyzed with the liberation of iodine in amount indicating that the following equation shows the character of the initial reaction.

$$3CoSO_4 + 5KI + KIO_3 + 3H_2O = 3Co(OH)_2 + 3K_2SO_4 + 6I$$
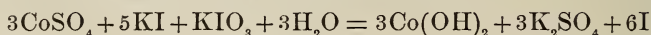
Under the conditions of the experiment potassium iodate is present in excess and exerts an oxidizing influence upon the cobaltous hydroxide, thereby forming black cobaltic hydroxide as follows:

$$6Co(OH)_2 + KIO_2 + 3H_2O = 6Co(OH)_3 + KI$$

After filtering and washing this precipitate and dissolving it with nitric acid, no precipitate was obtained with barium chloride and this solution. This evidence goes to show that the hydrolysis was complete.

The standard of my solution was found by depositing metallic cobalt upon a rotating platinum crucible as the cathode, 3 grms. of ammonium sulphate being used as the electrolyte for 25^{cm3} of the solution of cobaltous sulphate diluted with 25^{cm3} of water, using one ampere for current and continuing thirty minutes. The following table shows these results:

TABLE VII.

$CoSO_4$.	$(NH_4)_2SO_4$	Time in minutes.	Co $=$	SO_3 $=$	I.	Mean of entire series.
cm³.	grms.		grm.	grm.	grm.	grm.
25	3	30	0·0528	0·0710	0·2250	
25	3	30	0·0525	0·0706	0·2237	
25	3	30	0·0524	0·0705	0·2234	0·2242
25	3	30	0·0527	0·0709	0·2247	
25	3	30	0·0526	0·0707	0·2240	
25	3	30	0·0527	0·0709	0·2247	

Subjecting portions of cobaltous sulphate to heat with potassium iodide and potassium iodate in the presence of a current of hydrogen to transfer the iodine to a Drexel flask charged with potassium iodide, the following results were obtained :

TABLE VIII.

$CoSO_4$.	KI.	KIO_3.	Time in hours.	Approx. N/10 $Na_2S_2O_3$.	Iodine value calcu-lated.	Iodine value of $CoSO_4$ taken.	Diff.
cm³.	grm.	cm³.	hours.	cm³.	grm.	grm.	grm.
25	1·0	15	4	17·80	0·2244	0·2242	+0·0002
25	1·0	15	$3\frac{1}{2}$	17·78	0·2242	0·2242	±0·0000
25	1·0	15	$3\frac{1}{2}$	17·75	0·2238	0·2242	−0·0004
25	1·0	15	4	17·79	0·2243	0·2242	+0·0001
25	1·0	15	4	17·79	0·2243	0·2242	+0·0001
25	1·0	15	4	17·78	0·2242	0·2242	±0·0000

It should be observed that the iodine value obtained by the action of the iodide-iodate mixture upon the samples of cobaltous sulphate examined is closely comparable with the iodine equivalent of the cobalt found by the electrolytic deposition of the metal, showing that it is an exact measure of the cobalt present in the completely hydrolyzed cobaltous sulphate of ideal composition.

Nickel.

Nickelous sulphate, like cobaltous sulphate, is hydrolyzed completely, after a considerable time, in the presence of the iodide-iodate mixture, likewise yielding iodine, which may be collected similarly and estimated as a measure of the nickel present. Nickelous hydroxide formed in the reaction remains, however, unoxidized by potassium iodate in neutral solution and therefore the following equation will show the final products :

$$3NiSO_4 + 5KI + KIO_3 + 3H_2O = 3Ni(OH)_2 + 3 K_2SO_4 + 6I$$

The standard of the solution examined was obtained by the electrolytic process. To 25 cm³ in a beaker of convenient size

an equal volume of water and 3 grms. of ammonium sulphate were added, and a current of one ampere was found sufficient to deposit the nickel upon a rotating platinum crucible in thirty minutes.

Below is shown results of these determinations.

TABLE IX.

NiSO₄	(NH₄)₂SO₄	Time in	Ni =	SO₃ =	I.	Mean of entire series.
cm³.	grm.	minutes.	grm.	grm.	grm.	grm.
25	3	30	0·0520	0·0709	0·2246	
25	3	30	0·0523	0·0713	0·2260	
25	3	30	0·0521	0·0711	0·2252	0·2255
25	3	30	0·0523	0·0713	0·2260	
25	3	30	0·0522	0·0712	0·2255	

A portion of 25^{cm^3} of the solution of nickelous sulphate was drawn from a burette into a Voit flask and a solution of 1 gm. of potassium iodide in 15^{cm^3} of the potassium iodate (30 grms. to a liter) was added. This was heated for three hours in the presence of hydrogen to aid in the transfer of the iodine liberated to the receiver—a Drexel flask about half full of water in which 3 grms. of potassium iodide is dissolved. The iodine liberated was estimated with sodium thiosulphate in the presence of starch.

Results of these determinations follow.

TABLE X.

NiSO₄.	KI.	KIO₃	Time in	Approx. N/10 Na₂S₂O₃.	I. calcu- lated.	Iodine value of Ni. table.	Diff.
cm³.	grm.	cm³.	hours.	cm³.	grm.	grm.	grm.
25	1·0	15	3	17·87	0·2254	0·2255	—0·0001
25	1·0	15	3	17·88	0·2256	0·2255	+0·0001
25	1·0	15	3	17·84	0·2250	0·2255	—0·0005
25	1·0	15	3	17·87	0·2254	0·2255	—0·0001
35	1·0	15	3	17·83	0·2249	0·2255	—0·0006

Thus it appears that nickel sulphate may be completely hydrolyzed in the presence of the iodide-iodate mixture and that the nickel of nickel sulphate of ideal composition can be estimated from the amount of iodine liberated in the action of that salt upon the iodide-iodate mixture.

Zinc.

Zinc sulphate is hydrolyzed in the presence of the iodide-iodate mixture and the reaction might be expected to proceed according to the following equation :

$$3ZnSO_4 + 5KI + KIO_3 = 3Zn(OH)_2 + 3K_2S_4 + 6I$$
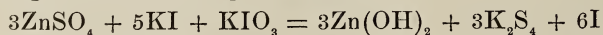
For the purpose of experimenting upon this salt, a solution

was made containing 20 grms. to the liter. The standard was found both by determining the zinc precipitated electrolytically and by finding the weight of barium sulphate precipitated by barium chloride.

In the electrolytic process a portion of 25^{cm^3} was in each determination drawn from a burette into a beaker of convenient size; 3 grms. of sodium acetate and 1^{cm^3} of acetic acid were added and with a rotating platinum crucible as the cathode a current of one ampere was passed for 30 minutes, when the deposit was washed with water and alcohol, dried and weighed as metallic zinc.

Results of these experiments are given in the following table:

TABLE I.

Zinc sulphate. cm^3.	Sodium acetic. grms.	Acetic acid. cm^3.	Current. amperes.	Time in minutes.	Zinc grms.	Equivalent of SO_3 grms.
25	3	1·0	1·0	30	0·1153	0·1413
25	3	1·0	1·0	30	0·1146	0·1405
25	3	1·0	1·0	30	0·1149	0·1408
25	3	1·0	1·0	30	0·1147	0·1406

The entire series gives a mean of 0·1408 grm. of SO_3 equivalent to the zinc.

The content of sulphuric anhydride was found by precipitation with barium chloride as barium sulphate, and the results of these experiments are given in the subjoined table:

TABLE II.

Zinc sulphate. cm^3.	$BaCl_2$ cm^3.	$BaSO_4$ found. grm.	Equivalent of SO_3 grm.	Mean of entire series. grm.
25	10	0·4109	0·1408	
25	10	0·4113	0·1410	0·1408
25	10	0·4101	0·1406	
25	10	0·4105	0·1407	

The determinations of zinc and of the barium sulphate gave in the average the same standard for the combined SO_3.

Portions of this solution subjected to heat with a mixture of potassium iodide and potassium iodate liberated iodine, and the amounts of iodine found by titration with sodium thiosulphate are given in the following table:

TABLE III.

Zinc sulphate. cm^3.	KI. grm.	KIO_3. cm^3.	Time in hours.	Approx. $N/10$ $Na_2S_2O_3$. cm^3.	I. grm.	Equivalent of SO_3. grm.	Mean of entire series. grm.
25	1·0	15	$\frac{1}{2}$	27·8	0·3557	0·1123	
25	1·0	15	$\frac{1}{2}$	28·0	0·3582	0·1130	0·1125
25	1·0	15	3	27·8	0·3557	0·1123	
25	1·0	15	3	27·8	0·3557	0·1123	

From these results it appears that hydrolysis of the salt ceases before all the SO_3 radical is removed.

In another series of experiments similar portions were boiled in an Erlenmeyer beaker with the iodide-iodate mixture until all the iodine visibly liberated in the reaction was expelled, and the precipitate was then filtered, washed, dissolved in nitric acid and treated with barium chloride. The barium sulphate precipitated, filtered off on asbestos, washed, ignited and weighed was found to correspond almost exactly with the SO_3 radical not removed by hydrolysis in the previous experiments.

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

Zinc sulphate. cm³.	KI. grm.	KIO₃. cm³	Time in hours.	BaCl₂. cm³.	BaSO₄ found. grm.	Equivalent of SO₃. grm.	Mean of entire series. grm.
25	1·0	15	$\frac{3}{4}$	10	0·0817	0·0280	
25	1·0	15	$\frac{3}{4}$	10	0·0812	0·0278	0·0280
25	1·0	15	$3\frac{1}{2}$	10	0·0821	0·0282	
25	1·0	15	$3\frac{1}{2}$	10	0·0814	0·0279	

From the results of both Table II and Table III it appears, therefore, that zinc sulphate is not completely hydrolyzed in the presence of the iodide-iodate mixture, and the mean percentage of such hydrolysis is found to be 80·13. So it appears that a one-fifth basic sulphate is formed. The basic sulphate contains 5Zn to 1SO_4 and is so definite that from the iodine liberated the zinc content may be calculated with accuracy.

The reaction of hydrolysis may be expressed by the equation :

$$15ZnSO_4 + 20KI + 4KIO_3 + 12H_2O$$
$$= 3Zn_5(OH)_8SO_4 + 12K_2SO_4 + 24I.$$

Of the various metal sulphates mentioned in this paper zinc sulphate is the only one which is not completely hydrolyzed, more or less easily, in presence of the iodide-iodate mixture.

SCIENTIFIC INTELLIGENCE.

I. GEOLOGY AND NATURAL HISTORY.

1. *The Geodetic Evidence of Isostacy, with a Consideration of the Depth and Completeness of the Isostatic Compensation and of the Bearing of the Evidence upon some of the Greater Problems of Geology;* by JOHN F. HAYFORD, C.E. Proc. of the Wash. Acad. of Sciences, vol. viii, pp. 25–40, May 18, 1906.— The nature of this short paper is well indicated by its title, and instead of merely stating the more conspicuous conclusions, it may be desirable, in order to indicate its great importance, to give a brief historical review of the place of this subject in geological literature and of the problems upon which it bears, the historical side not being developed in the paper itself.

Since the time of Babbage and Herschel the idea has been entertained by certain geologists, that the greater features of the earth's surface were sustained, not by virtue of the internal rigidity, but in large part rested in equilibrium because of a lessened specific gravity of the crust beneath the more elevated masses; the facts leading to this hypothesis having been pointed out by Petit, who in 1849 discussed the deficiency of gravity beneath the Pyrenees,[*] and by Archdeacon Pratt of Calcutta, who a few years later called attention to the striking deficiency of mass found to exist by the Indian Trigonometrical Survey beneath the Himalayas and the Plateau of Thibet.[†]

This conception involves far-reaching consequences in regard to the nature of the earth's interior, implying a superficial heterogeneity of density and a capacity of viscous flowage toward that figure of equilibrium which should tend to bring equal pressures upon all parts of the earth's interior at a certain depth. For this condition of equilibrium Dutton proposed the term of isostacy,[‡] now fully incorporated into geological literature. The acceptance of the principle of isostacy, however, immediately raises the questions as to how deep is the zone within which the heterogeneity of density producing the larger and broader surface features is confined? What is the percentage variation in the density of various parts of this zone? What is the departure from true isostatic adjustment exhibited by the surface features? How quickly will response take place to destroyal of the isostatic adjustment through erosion and sedimentation? What is the initial cause of the internal differences in density which lead to the larger features of the earth's surface and which having once originated, isostacy tends to preserve?

It is seen that these questions involve fundamentally the prob-

[*] Comptes rendus de l'Acad. des Sc., xxix, p. 730.
[†] Phil. Trans. Roy. Soc., vol. 145, p. 53.
[‡] "On Some of the Greater Problems of Physical Geology," Bull. Phil. Soc. of Washington, vol. xi, p. 53, 1889.

lems of continental origin and maintenance, mountain-building and the nature of the earth's interior. On these subjects the long-felt need has been for facts, and it is for these that the present article is especially valuable. Mr. Hayford has utilized the triangulation and astronomic determinations of latitude and longitude within the United States. The preliminary results of the investigation, which is still in progress, indicate that the most probable value of the limiting depth of isostatic compensation is 71 miles and that it is practically certain that the limiting depth is not less than 50 miles nor more than 100 miles. It is certain that for the United States and adjacent regions, including oceans, the isostatic compensation is more than two-thirds complete—perhaps much more.

Internal variations of specific gravity to the extent of three per cent from the mean, both above and below, will account for the ocean basins and plateaus. As a consequence of this limited zone of isostatic compensation it is pointed out that isostatic adjustment involves a subsurface undertow away from areas of sedimentation and toward areas of erosion: this viscous undertow acting as a thrust tending to crumple back the continental margins upon themselves and at least aiding in the formation of mountains. In this connection the reviewer wishes to point out facts not commonly cited, viz.: that Major Dutton perceived as long ago as 1872 the inadequacy of the still popular hypothesis of terrestrial cooling as a sufficient source of mountain-making,[*] and in 1889 suggested the agency of this lateral undertow.[†] The efficiency of this agent must depend upon the depth of the compensating zone, its thickness and viscosity. It is doubtful if Mr. Hayford's figures justify elevating this factor to a major place, but the present limitation of the zone makes it at least a minor factor, and Dutton's suggestion in this respect must stand as an example of remarkable scientific prevision.   J. B.

2. *Pleistocene Deposits of South Carolina;* by GRIFFITH THOMPSON PUGH: A thesis submitted to the Faculty of Vanderbilt University for the Degree of Doctor of Philosophy, Nashville, Tenn., 1905; 74 pp.—This paper is an attempt at ascertaining what must have been the environmental conditions under which lived the Pleistocene mollusca of the state. To that end the species are tabulated, together with the conditions of environment of their living representatives. The conclusion is reached that at least in South Carolina the Pleistocene sea temperature, if differing at all from that of the present, was slightly higher rather than slightly lower. The method of detailed and tabulated investigation is excellent and should be followed out for other localities. The reviewer would point out, however,

[*] A Criticism upon the Contractional Hypothesis, by Captain C. E. Dutton, U. S. A., this Journal, vol. viii, p. 113.

[†] On Some of the Greater Problems of Physical Geology, Phil. Soc. of Washington, vol. xi, pp. 51–64.

that there is nothing to show that the fossiliferous beds concerned were deposited at a time of maximum glaciation, and this possibility must be held in mind in view of the recent tendency to enlarge the estimates of Pleistocene time and to consider it a period of great climatic variability. Such a question has greater force since Collier Cobb has recently made note of finding rounded, subangular and even striated cobbles' on the Atlantic side of Currituck Banks off the North Carolina coast, which he regards as having been transported by icebergs from the New England coast during a period of maximum glaciation.* J. B.

3. *The Geography and Geology of Alaska. A summary of existing knowledge*, by ALFRED H. BROOKS, *with a section on climate*, by CLEVELAND ABBE, JR., *and a topographic map and description thereof*, by R. U. GOODE. Professional Paper No. 45, U. S. Geological Survey, 1906; 327 pp., xxxiv pls., 6 figs.— For all except those who have made a specialty of Alaskan geological exploration, this will be the most valuable volume published by the government on the geography and geology of Alaska, giving a general view of the physiographic provinces and of the present knowledge of the country.

It shows what results may be accomplished in the course of a few years by government support for the scientific exploration of a previously unknown land. Apart from the scientific results, it is doubtless true that from an economic standpoint these explorations have increased the value of Alaska to the United States many times the sum of money spent in the explorations.

J. B.

4. *Geology and Mineral Resources of part of the Cumberland Gap Coal Field, Kentucky ;* by GEORGE HALL ASHLEY and LEONIDAS CHALMERS GLENN, in coöperation with the *State Geological Department of Kentucky*, C. J. NORWOOD *Curator.* Professional Paper No. 49, U. S. Geological Survey, 1906 ; 239 pp., xl pls., 13 figs.—This well written and illustrated report contains 40 pages on the general geography, physiography and geology of the region, followed by 170 pages on the geography and stratigraphy of the coals. The volume contains much of scientific interest and is of great economic value. J. B.

5. *The Pleistocene Deposits of Sankoty head, Nantucket, and their Fossils ;* by J. A. CUSHMAN. Pub. Nantucket Maria Mitchell Assoc., I, 1906, 21 pp., 3 pls.—This paper brings together all that is known regarding the Sankoty Head section, the occurrence of the fossils, horizons, a list of the fauna (86 species, of which 66 are Mollusca), and another of the literature of these deposits. This paper should be studied in connection with an article recently published on the same deposits, in the Journal of Geology, December, 1905, pp. 713–734, by J. Howard Wilson, where about 15 additional species are listed. C. S.

* Notes on the Geology of Currituck Banks, Journal of the Mitchell Society, vol. xxii, No. 1, pp. 17–19.

6. *The Tertiary and Quaternary Pectens of California;* by RALPH ARNOLD. Prof. Paper 47, U. S. Geol. Surv., 1906, pp. 264, 53 pls.—This extensive monograph on the Cenozoic Pectens of California also gives a very valuable "brief outline of the different Tertiary and Pleistocene formations of California" and "their typical fauna as far as known" (pp. 9–40). In order to give a clear definition of the various Pectens and their geologic range, it was necessary to examine "all of the available marine Tertiary paleontologic material from the west coast." The total thickness of these deposits aggregates 21,000 feet. The classification of the Pectens is practically that of Dr. Dall in "Tertiary Fauna of Florida."

The genus *Pecten* and its subgenera *Patinopecten, Nodipecten, Chlamys, Lyropecten, Æquipecten, Plagioctenium, Pseudamusium, Amusium, Propeamusium,* and *Hinnites* are defined on pages 45–50. Of species and varieties there are 93, and of these 50 are new. These are distributed as follows: Eocene 4 (restricted), Oligocene 5 (all pass upward), Miocene 38 (28 restricted, 4 pass upward), Pliocene 37 (10 pass upward), Pleistocene 20 (17 in recent faunas), Recent 25 (16 also fossil).

The illustrations look natural, being nearly all retouched photographs without attempting to show more than the specimens reveal. It will therefore be easy for subsequent workers to identify these species as defined by Dr. Arnold. The work is thoroughly up to date and is indispensable to all students of the Mollusca. c. s.

7. *Cambrian Faunas of China;* by CHARLES D. WALCOTT. Proc. U. S. Nat. Mus., 1906, pp. 563–595.—This is the third paper on the Cambrian material collected by Mr. Blackwelder in China. The final report on the fossils by Dr. Walcott, and on the geology by Dr. Willis, will be published next winter by the Carnegie Institution of Washington.

This paper describes 34 new species and one new genus *Blackwelderia.* The remarkable abundance of Trilobites in the Cambrian is again noticeable in this paper, where 27 species are described. c. s.

8. *Plant Response as a Means of Physiological Investigation;* by JAGADIS CHUNDER BOSE, M.A., D.Sc. Professor, Presidency College, Calcutta. London, New York, and Bombay, 1906. (Longmans, Green & Co.)—In a previous notice of this interesting and suggestive treatise, the promise was given that in a subsequent issue of this Journal a short analysis would be made of the principal chapters. The work is divided into nine parts, which are not of equal rank, some of them being merely convenient headings for minor but generally allied subjects. Thus, for instance, two parts are devoted to the Ascent of Sap and Growth, respectively; topics which are special under larger questions.

Part First considers Simple Response. In this the plant is regarded as a machine responding to external stimuli and giving distinct pulse-records. The sensitiveness of plants is practically

universal ; according to the author, wherever there is a living tissue, no matter how sluggish it may seem, response may be elicited by appropriate means. There are certain conditions which are conspicuously favorable to the exhibition of mechanical response, and these conditions have been carefully studied. Such study has convinced the author that there is no difference, except in degree, between the ordinary and the so-called sensitive plants. The mechanical response in ordinary leaves and the longitudinal response of radial organs have been examined in detail by means of newly-devised apparatus, which appears to possess the power of recording even the slightest possible movement after stimulation of the plant or its parts. The responsive curvature of molecularly anisotropic organs receives a good deal of attention, and the complex phenomena are resolved into their simpler terms or factors. Lastly, under this heading, comes the consideration of the relation between stimulus and response, and also, the effect of the superposition of stimuli. Here tetanus in plants is described.

In Part 2d the author treats of the modification of response under various conditions. Here are studied the theories concerning different types of response, the effects of anæsthetics, poisons, and other chemical agents on longitudinal response. The effects of temperature receive attention in a special chapter, as does also the " death-spasm " in plants. The critical point of death is determined by inversion of the thermo-mechanical curve. In connection with this topic the author examines at considerable length the subject of local fatigue and regional death.

Excitability and conductivity are considered in Part 3. Polar effects, electrotonus, electrotactile and electromotive methods, and the latent as well as the " refractory " periods are fully treated of. Then follows the consideration, in part 4, of multiple and autonomous response ; and the similarities of rythm in animals and plants are clearly stated. The ascent of sap and the general subject of growth are next presented, and the supposed relations of both to certain stimuli are insisted upon. Following come Geotropism, Chemotropism, and Galvanotropism. Near the close of the last chapter in this part the author considers the effect on growth of " electrification " of the soil. To the subject of Heliotropism the author devotes the whole of part 8. He takes up even the effect of invisible radiation and the action of the high frequency Tesla current. Torsional response receives a fair share of attention. Besides this is considered the topic of pulsatory response and the swimming movements.

Part 9 concludes the treatise with general reviews and a final examination of the continuity of physiological response in plant and animal. Three features render this work of great interest: (1) the summaries at the close of the chapters, (2) the descriptions of entirely new types of delicate apparatus, and (3) the fact that the greater part of the experiments were conducted under the most favorable conditions in a tropical climate upon tropical

plants. The treatise is stimulating and suggestive throughout. Even where one cannot agree with the conclusions of the author he must confess deep indebtedness for new lines of thought.

<div align="right">G. L. G.</div>

9. *Heather in Townsend, Mass.*—In this Journal, Oct., 1888, I gave a full description of the occurrence of *Calluna vulgaris* at a locality not far from the railroad station in West Townsend, near the New Hampshire line. On Saturday, July 14, 1906, this place was revisited by me for the purpose of ascertaining what changes might have occurred in the distribution of the plants. In a subsequent notice 1 shall hope to give details regarding the present condition of the heather, but at present I will merely state that the plant has steadily extended over a larger area, and, although in certain spots it has suffered from various agencies, it appears to be so well established as to wage a strong and perhaps successful fight with the contending native plants. The best time to visit this interesting station is early August. At that date, the whole area is said to be a mass of bloom. At this present writing, however, there were only slight indications that the flowers this year would be numerous, but the dried capsules from last year's blossoms were very plentiful. G. L. G.

10. *The Biology of the Frog ;* by SAMUEL J. HOLMES, Ph.D. Pp. ix + 370, with 94 figures. New York, 1906 (The Macmillan Company).—This work is designed particularly as a text-book for students in the college or university who have had some training in elementary biology. A study of this text accompanied by suitable practical work in the laboratory will lead naturally to the study of comparative morphology and physiology. This work is in the broadest sense a natural history of the frog, whose systematic position, relationships, habits, food, enemies, parasites, breeding periods, hibernation, powers of regeneration, movements, and so on are described. Then follow chapters on the external characters, internal structures, development, and general histology. Each of the principal organ systems of the body is then taken up in detail with an account of the functions of each part accompanying the description of the structure. The two concluding chapters deal with instincts and tropisms, and include a brief discussion of the frog's intelligence. The figures and diagrams, which are carefully chosen and well printed, are mainly from standard works, although a few are original. Such a detailed knowledge of the biology of a single animal will meet the needs of the college student who is preparing for the study of medicine, and will form a convenient reference book for teachers of biology in secondary schools. W. R. C.

11. *A Course in Vertebrate Zoology. A Guide to the Dissection and Comparative Study of Vertebrate Animals ;* by HENRY SHERRING PRATT. Pp. x + 299. New York and Boston, 1906 (Ginn & Company).—The plan of the book follows closely the lines adopted by the author in his Invertebrate Zoology, which was published several years ago and has proven a convenient

laboratory guide. As in the earlier work, the type system is followed, a single representative of each of the more important groups of vertebrates being taken up. It contains not merely directions for the work in the laboratory but also short descriptions of parts difficult to study, with brief statements as to function and morphological significance. Each dissection is quite independent of the others, so that the animals can be studied in any sequence. Like its predecessor, this book is sure to form a valuable addition to the already numerous laboratory guides.

<div align="right">W. R. C.</div>

12. *The Life of Animals. The Mammals ;* by ERNEST INGERSOLL. Pp. xi + 555, with numerous illustrations, including 15 colored plates. New York, 1906 (The Macmillan Company).—A popular work, written in an entertaining style, containing a storehouse of facts about the familiar as well as the less generally known animals. These facts of general interest are brought together from widely scattered scientific treatises, books of travel, and reports of hunters. Each of the groups of mammals from the highest to the lowest is taken up in turn with illustrations, descriptions, and anecdotes of some of the representatives. Many of the illustrations are from original photographs and drawings and greatly enhance the value of the work. w. r. c.

II. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Recent Text-books on Astronomy. — A Compendium of Spherical Astronomy*, with its Applications to the Determination and Reduction of Positions of the Fixed Stars; by SIMON NEWCOMB. Pp. viii, 444. New York and London: 1906 (The Macmillan Company).

An Introduction to Astronomy; by FOREST RAY MOULTON. Pp. xviii, 557, with 24 tables and 50 figures. New York: The Macmillan Company. London: Macmillan & Company Ltd., 1906.

Laboratory Astronomy; by ROBERT WHEELER WILSON. Pp. ii, 189, with 89 figures and 7 tables. Boston, New York, Chicago, London: 1905 (Ginn & Company).

The works here noticed meet the needs of students of Astronomy from the Nautical Almanac Office to the High School, except for the computation of orbits and perturbations.

The volume by Newcomb is the most important work in practical Astronomy that has appeared in the present generation and is well worthy of the reputation of its author. Aside from its intrinsic merit, it is the more valuable as " the first of a projected series having the double purpose of developing the elements of practical and theoretical Astronomy for the special student of the subject, and of serving as a hand-book of convenient reference for the working Astronomer in applying methods and formulae."

If Professor Newcomb completes the series it will be a worthy monument both to himself and to American Astronomy and will leave little for other writers to do until the accumulation of new material calls for a new harvest, in the same way that the present work is made necessary by the advance of knowledge since the writings of Bessel, Chauvunt and Oppolzer.

The most urgent want which the present volume supplies is that of improved methods for deriving and reducing the positions and proper motions of the fixed stars made necessary by the period of 150 years through which these positions now have to be reduced. In this and all parts the book is full of new and most valuable material, of which may be mentioned the appendix of 26 tables, most of which can be found in no other text-book, and a chapter on observatories and star catalogues.

Moulton's Introduction to Astronomy has the same justification as Newcomb's volume. It is intended for the student of descriptive Astronomy as a part of general culture, and gives access to the stores of information which have accumulated since Young's unequaled text-books were published, accumulations which frequent revisions of Young's series have not been wholly adequate to keep pace with.

The amount of new material is made evident at a glance by the new cuts which meet the eye wherever the book is opened, such as Chandler's diagram of the variations of the pole, Todd's chart of paths of total eclipses up to 1973, Maunder's figure of the dimensions and distribution of sun spots for 25 years, a spectroheliograph of the sun by Hale, etc.

Both in plan and arrangement the book differs considerably from the conventional form, the design being to use something of the laboratory method throughout, connecting theory as closely as possible with practice and familiarizing the student with the lines of thought and chains of reasoning by which the great theories of the noblest of the sciences have been developed.

It is too much to expect the felicity of statement, the perfection of clearness and conciseness which is found in Young's writings. By comparison the writer seems somewhat prolix and lacking in perspicuity.

Wilson's Laboratory Astronomy is an excellent book to use with the preceding in a course where time permits. It presents a large number of valuable practical exercises for the average student, carefully worked out and requiring such apparatus, largely of the author's own devising, as can be provided in quantities at small cost, so that a large class can be set to work together on the same exercise (e. g. mapping the sun's diurnal motion), under the supervision of an instructor in an ordinary recitation room and from data collected by themselves. w. b.

2. *The Publications of the Royal Society of London.*—A circular recently issued by the Royal Society calls attention to the present method of publishing the Proceedings in two series, viz., A, containing mathematical and physical papers, and B,

those of biological character. Volumes 76–77 of each series have now appeared, of about 600 pages royal octavo, with illustrations. " A main object of this new arrangement was to render the Proceedings more accessible to workers by placing the two groups of subjects on sale separately, at a stated price attached to each separate part of a volume when it first appears. Moreover, with a view to promoting the circulation of the complete series, it has been directed that a subscription paid in advance to the Publishers at the reduced price of 15 shillings per volume for either series, shall entitle subscribers to receive the parts as soon as published, or else the volumes when completed, in boards or in paper covers, as they may prefer." Each number of Proceedings also contains an announcement on the cover of the more recent memoirs of the Philosophical Transactions as published separately in wrappers and the prices at which they can be obtained. It is hoped that this arrangement may facilitate the prompt circulation of the journals of the Society.

3. *Physical Optics;* by ROBERT W. WOOD, Professor of Experimental Physics in the Johns Hopkins University. Pp. vi, 546, with 325 figures. New York and London, 1905 (The Macmillan Co.).—Prof. Wood's book is a remarkably interesting compendium of our present knowledge of Physical Optics. It is very complete and up to date on the experimental side, and while some of the mathematical portion is abbreviated, many results are derived which are found in few if any other books on light. For example, it is proven that, for regular reflection, a surface must be smooth to within an eighth wave length (p. 36), also that Fermat's Law requires that the time be a minimum or a maximum (pp. 55, 61), that the phase is uniform within a quarter wave length over a surface of diameter equal to the wave length divided by the apparent diameter of the source $=\cdot05^{mm}$ for sun light (p. 123); further, Rayleigh's proof is given that the magnification equals the compression of the wave front (p. 65). The reader is surprised to find no reference to Wood's successful diffraction color photographs. Considerable attention is appropriately devoted to the author's work on sodium vapor in the region of the D-lines ; a vapor with a refractive index as high as 1·38 and a dispersion which separates a double line with components twenty times as close as the sodium lines by an amount as great as the distance between the red and the blue of the spectrum formed by a 60° glass prism (p. 346), which shows enormous rotation in a magnetic field (p. 426), which gives a series of fluorescent spectra, corresponding lines in which will appear upon stimulation with proper monochromatic light (p. 408) and which exhibits optical resonance (p. 486) and lateral radiation of the stimulating light (p. 451). There is little to criticise. Misprints are few and not such as to confuse the reader. Does not the graphical explanation of the absence of a back wave (p. 8) assume what is to be proven? The reviewer was unable to find a clear derivation of the condition for resolution. As an American book upon Mathematical

Optics, it is much to be desired that we may have before long Prof. Gibbs' Lectures upon the Electro-Magnetic Theory of Light. ARTHUR W. EWELL.

OBITUARY.

Professor HENRY A. WARD, the veteran mineralogist, scientific traveler and collector, was struck by an automobile in the streets of Buffalo on July 4 and died almost immediately after. Notwithstanding his seventy-two years of age, he was still in full health and vigor. He was born at Rochester on March 9, 1834, studied at Williams College, at Cambridge with Agassiz, and later for four years at the School of Mines in Paris. For six years from 1859 he taught Natural Science at the University of Rochester. The greater part of his time and energy he devoted to travel, with collecting in mineralogy, geology and natural history as the main object and incentive. Throughout his life his interest and enthusiasm for this work never flagged; trips to Europe, Asia, Australia, Africa and South America were repeated at short intervals. Many institutions have obtained their collections through his efforts and the large amount of material he accumulated has been the basis of the Natural Science Establishment which bears his name.

During the later years of his life his interest was particularly aroused by the study and collection of meteorites, the very difficulty of the undertaking serving to stimulate him. One large collection passed from his hands to the Field Columbian Museum in Chicago, and another to Mr. C. S. Bement. His efforts culminated, however, in the Ward-Coonley collection now on deposit and exhibition at the American Museum of Natural History in New York City. Beginning with a small nucleus in 1894, within ten years it had taken the first place among the great collections of the world. This was a unique work calling for all his energy, perseverance and tact, together with liberal expenditure. Could the history of the collection in detail be written it would be full of the interest of travel and adventure; as a typical case may be mentioned his trip to Persia and interview with the Shah, leading to his obtaining a large mass of the remarkable Veramin meteorite.* Up to the day of his death his interest in meteorites and his energy in obtaining new specimens were unabated. He had also accumulated a large amount of material relating to the history and scientific investigation of meteorites, from which he proposed to prepare an exhaustive volume on the subject.

Baron C. R. VON DER OSTEN SACKEN, the eminent Russian entomologist, died in May last at the age of seventy-eight years.

Dr. LUDWIG BRACKEBUSCH, Professor of Geology at Hannover, died recently at the age of fifty-seven years.

* A brief account is given in this Journal, v. xii, p. 453.

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SCIENTIFIC INTELLIGENCE.

Established by **BENJAMIN SILLIMAN** in 1818.

THE

AMERICAN

JOURNAL OF SCIENCE.

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ART. XVIII.—*Abyssal Igneous Injection as a Causal Condition and as an Effect of Mountain-building;* by REGINALD A. DALY, Ottawa, Canada.

CONTENTS.

INTRODUCTION.

The shells of compression and tension in the earth.— Whether the earth, as it cools and contracts, be solid and highly rigid throughout, or whether it consist of a solid crust with an underlying fluid substratum, it is generally held by geologists that there is a "level of no strain" beneath the surface. The depth of this level has been computed for a solid earth by Davison and Darwin, who have made various assump-

tions which are more or less reasonable provided the fact of complete solidity is established. Their estimates for the depth of the zero-strain level vary from 2 miles to 7·79 miles.*
With analogous assumptions Fisher has calculated that there will similarly be a level of zero-strain in a crust overlying the fluid substratum of a globe solidifying from the circumference inwards. He found that "if the time elapsed since a crust began to be formed has been 100 million years, the depth of the level of no strain at the present time will be about four miles."† In any case the depth increases very slowly with the time elapsed since the crust first formed.

Rudski has pointed out that, if the earth's initial temperature were not uniform, the level of no strain would, in a given time, be deeper than by the amount calculated on the assumptions of Davison.‡ It is, in truth, probable that the initial temperature increased downwards. We shall see that there is a grave reason for doubting the conclusion of Kelvin that an initial uniform temperature was secured through the foundering of early crusts. The suggestion of LeConte that it might be secured through the operation of convection currents is not acceptable to those who hold the very probable view that the earth's internal density increases downward, not only because of increasing pressure but because of differences in chemical composition as well.§

All of these calculations have been made on the supposition that the thermometric conductivity of the material of the earth is a constant quantity. It is, however, most probable that this conductivity decreases with rise of temperature and very greatly increases on the passage of liquid magma into solid rock. Forbes showed that the "calorimetric" conductivity of iron decreases with rise of temperature, as illustrated in the following table, which is an abridged form of his experimental results: ‖

* C. Davison, Philosophical Transactions, Royal Society of London, vol. clxxviiiA, p. 231, 1887 ; G. H. Darwin, ibid., p. 242 ; C. Davison, Proceedings of the Royal Society of London, vol. lv, p. 141, 1894. Cf. M. Reade, Origin of Mountain Ranges, London, 1886, p. 121.

† O. Fisher, Physics of the Earth's Crust, London, 2d ed. 1891, appendix, p. 45.

‡ M. M. P. Rudski, Philosophical Magazine, vol. xxxiv, p. 299, 1892.
§ Cf. J. LeConte, American Geologist, vol. iv, p. 43, 1889. It may be noted that, in the above-mentioned calculations, no account has been taken of the special and important contraction characterizing the passage of lava from the liquid to the solid state, nor, except in the case of Fisher's estimates, for the fact that, with a given fall of temperature, liquid lava (diabase) contracts about twice as much as solid lava (Barus, Bull. U. S. Geological Survey, No. 103, 1893).

‖ J. D. Forbes, Trans. Roy. Soc. Edinburgh, xxiv, p. 105, 1867.

Temperature.	Conductivity 1st specimen.	Conductivity 2d specimen.
0°C	12·42	9·21
50	10·63	8·37
100	9·40	7·76
150	8·68	7·38
200	8·14	7·10

Units in centimeter, minute and deg. Centigrade.

Similarly, Weber measured the conductivity of gneiss at 0°C and at 100°C and found the conductivity to be 578/416 greater at the lower temperature than at the higher.[*]

Barus proved that the thermometric conductivity of the substance thymol increased 56 per cent in passing from the liquid to the solid state at the same temperature (possible through undercooling).[†]

It is true that condensation through pressure increases the conductivity for heat, but Arrhenius has pointed out that at depths greater than only a small fraction of the earth's radius, increment of pressure entails no corresponding increment of condensation.[‡] This condition applies to the (gaseous) earth-matter which, at the depth of several hundred miles, has reached its co-volume. At this and at greater depths temperature may be in complete control as regards the conductivity for heat—an increase of temperature with still greater depth involving a slow decrease of conductivity.

These observations and conclusions indicate, first, that experimental studies on the conductivity of rock-matter at different temperatures, in different states of compression, and in the two states of aggregation (if such studies are possible), are urgently needed; secondly, that it is now impossible to calculate the exact position of the level of no strain in the earth's crust. Nevertheless, in an earth composed of a crust floating on a substratum which, because it is fluid and hot, has a lower thermometric conductivity than the solid, cool crust, we might expect the level of no strain to be well within the crust even if the initial temperature gradient were comparable to that now observed in the earth's superficial shell. In a personal letter to the writer, the Rev. Osmond Fisher states that, with a liquid interior, there must be a level of no strain in the crust; and this is apparently true no matter what the initial temperature may have been. He states, further, that "the level of no strain would be the same whatever the conductivity; but the time would not be the same. The position of the level would not fall so rapidly if the conductivity was less."

[*] R. Weber in Landolt and Börnstein's Phys. Chem. Tabellen.
[†] C. Barus, this Journal, vol. xliv, p. 15, 1892.
[‡] S. Arrhenius, Geol. Fören. Stockholm Förhandlingar, vol. xxii, pp. 396–7, 410, 1900.

The shell above the zero-strain level is under tangential compression.   The shells beneath that level, for a considerable distance downwards, are under tension.   On account of the weight of all overlying shells any shell below the zero-strain level tends to be stretched or (using Reade's term) to suffer " compressive extension."   This tendency increases with depth to a maximum in a level computed by Davison for a solid earth to lie 72 miles below the surface.   The corresponding level for an earth with a fluid substratum has been calculated by Fisher to lie at depths of from 30 to 55 miles, depending among other conditions on the temperature of solidification.*

The hypothesis of a crust and fluid substratum.—There are many reasons why the doctrine of the earth's complete solidity is not acceptable to the working geologist.   Some of the cogent arguments against it have been summarized by De Lapparent† and other able writers on the theory of the globe. The strength of these arguments is great and by so much favors the opposed doctrine of a fluid substratum supporting a solid crust.   The astronomic evidence for the hypothesis of complete solidity rested at first on the calculations of Hopkins in his well known paper on the combined effect of tidal pull and internal fluidity upon the precession of the equinoxes. Later analyses by Kelvin and Darwin proved that Hopkins' conclusions could afford no " decisive argument against the earth's interior liquidity."   " Here we have a remarkable instance of the final abandonment of an argument, which, from the portentous difficulties of comprehending it, had proved too hard for geologists to assail."‡

The stronger argument, based by Kelvin and Darwin on the observed and calculated magnitude of oceanic tides, has likewise suffered destructive criticism by Fisher.   The various discussions on this most complicated subject show clearly that not enough is known either of the constitution of matter or of the oceanic tides themselves to permit of certain mathematical determination of the earth's true rigidity.   Fisher's luminous work seems to prove that the geologist may still accept as the best working hypothesis the view that the earth's " crust " is a true crust and rests on a shell of fluid magma.   Fisher has demonstrated that, if the substratum is saturated with water-gas, the bodily tide of the earth may entirely disappear, its place being taken by a density tide in the substratum.   This would be true on account of the compressibility of the substratum.§   Since glass and presumably igneous magma are not only

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* Op. cit., p. 106.

† See the chapters on vulcanism in his " Traité de Géologie."

‡ O. Fisher, op. cit., p. 38.

§ O. Fisher, op. cit., p. 61.

somewhat compressible but almost perfectly elastic, the same reasoning may possibly apply to an anhydrous substratum.* Again, the recently developed view that the great nucleal mass of the earth is composed of true gas immensely compressed, must also be reckoned with in the attempt to prove rigidity by the oceanic tides.

Purpose of the present paper ; acknowledgments.—While the question as to how much of the earth is fluid is now quite open, the hypothesis of crust and fluid substratum has many special points of advantage. Many writers have shown how it agrees with essential observations on the structure and history of the rocks accessible at the earth's surface. It appears, however, that important consequences of the hypothesis, consequences involved in the correlation of subsurface tensions with igneous intrusion, surface deformation and mountain-building, have, so far as known to the writer, never been systematically deduced. This paper is intended to form a brief and but qualitative treatment of the subject.†

The writer has pleasure in acknowledging the great courtesy of Professor F. D. Adams, who afforded much help in discussing such physical constants of rocks as form data required in the following hypothesis. Special thanks are due to Dr. A. C. Lane, who has, by correspondence, discussed anew the relation between subsurface tensions and the gases evolved from the earth's interior; also to the Rev. O. Fisher and to Professor L. V. Pirsson, who, similarly by correspondence, have offered valued suggestions. But, in justice to these investigators, it may be added that they should be clearly absolved from all responsibility in launching this new hypothesis on the sea of discussion, which has borne whole fleets of older hypotheses of mountain-building, has sunk many of them, and still floats the more or less battered but more seaworthy hypotheses. The ribs of this new vessel are few—assumptions which themselves may long have to remain in the workshop of geological opinion ; to these the planks of argument have been fastened and again there is a chance that the vessel is neither tight nor trim. Each postulate and almost every argument of the hypothesis well merits a whole article to itself, but their elaboration or destruction may wisely be left to more skilful hands. This paper is little more than the barest statement of a suggestion which is offered expressly for criticism. The necessary brevity of treatment forbids that constant, explicit reference

* Lord Kelvin states that crystals and glasses probably possess elasticity of volume "to perfection"—art. "Elasticity" in the Encyclopaedia Britannica, 3d paragraph.

† The relative merits of the planetesimal and nebular hypothesis of the earth's origin are not discussed, but the older hypothesis may be regarded as basal to the argument.

be made to the actual facts of outdoor nature which would be essential to a thorough presentation of the hypothesis, but it is true that each argument has been made, as far as possible to the writer, with attention to observations in the field. In fact, it has been the direct call for some kind of explanation of structures and rock-associations in the British Columbia mountains that has prompted this hypothesis. The principle of advancing reasonable deduction beyond the region of observed fact needs no apology. Nowhere in dynamic geology is an appeal to the realm of the unseen more necessary than in the problems of orogeny and igneous intrusion. These problems have already reached the stage where more observations on the visible part of the earth-crust are not so fundamentally necessary as the reference of the abundant, now accessible, and well recorded observations to an intelligent imagining of the gigantic forces and processes resident in the earth's invisible interior. The orology of the future, even more than that of the past, must rest on well-regulated speculation.

The hypothesis is phrased in terms of a solid crust floating on a liquid substratum. It is possible that gases originally absorbed in the substratum, according to the conception of Lane,* should also be considered; but, on a following page, a reason for excluding them from any large share in crustal deformation is briefly noted. On that ground and because of the relative simplicity secured for the hypothesis as set forth, the dynamic influence of the absorbed gases is not discussed. It will be seen, however, that the expansional energy of gases possibly given off during the solidification of the substratum would furnish a condition favorable to the hypothesis.

Thickness of the Crust.—The depth of the level where the fluid substratum is first encountered has been estimated in several ways. Of these estimates, that founded on the most reliable determinations of the temperature gradient and of the relation between pressure and the fusion point, is clearly preferable. Kelvin has shown that for about 25 miles of depth the gradient would be essentially rectilinear in a cooling globe. The generally accepted gradient is approximately one degree Centigrade for 100 feet of depth. This gradient implies that at the depth of about 22·5 miles a gabbroid magma would possess the temperature appropriate to complete fusion at atmospheric pressure; (diabase melts at 1170° C. and solidifies at 1095° C.—Barus). Vogt has recently calculated that the pressure of 22·5 miles of rock would raise the fusion-point about 50°C.†

* Bull. Geological Society of America, vol. v, 1894, p. 259.
† J. H. L. Vogt, Die Silikatschmelzlösungen, part 2, Videnskabs-Selskabets Skrifter, I. Math.-naturv. Klasse, Christiania, 1901, p. 210.

Completely fluid gabbroid magma would therefore not be expected at a depth short of 24 miles even if the temperature gradient were truly rectilinear. Allowing an extra mile of depth to correspond to a possible slight weakening of the gradient at these depths, it follows that a shell of gabbro at the depth of 25 miles might be completely fluid. The enormous predominance of basalt in the world's lava-fields, especially among the lava-floods of fissure eruptions, suggests the strong probability that the fluid material immediately beneath the crust has actually the composition of gabbro. It thus appears permissible to regard 25 miles as representing nearly the thickness of the crust.

The strong compression of the substratum would decrease the average intermolecular distance and thus increase the viscosity, but the material remains a true liquid. Though the viscosity of such a liquid is high, yet the possibility of its infinite deformation and its capacity of transmitting pressures hydrostatically are, in the long periods of geological time, as perfect as if the substratum were comparable to water in fluidity. Its material is a true fluid and not a solid either rigid or plastic. If, however, the substratum material, still preserving its high temperature, is injected into higher levels in the crust, where pressures are less, it may become highly mobile under small stresses. "It is important to remember, too, that the very act of flow of a viscous fluid, by the definition of viscosity, produces internal friction and additional heat and renders it more fluid."[*]

Compression of the substratum; flotation of the crust.— The gabbroid substratum at its upper surface bears a pressure of about 12,000 atmospheres. This vast pressure must compress magma very considerably. Barus has demonstrated that liquid napthalene is about four times more compressible than solid napthalene at the same temperature.[†] If gabbro obeys the same law even approximately under the assumed conditions of pressure and temperature, it is possible to estimate roughly the density of the uppermost shell of the substratum. Let it be assumed, for example, that the specific gravity of crystallized gabbro at 0° C is 3·02 and the volume 100·0. Its density when completely molten at 1250° C. and at 1 atm. would be about 2·54; the volume would be 118·8.[‡] Its compressibility would be about four times that of solid gabbro, which is probably of about the same compressibility as that of glass, viz., nearly ·0000026 per atmosphere. The pressure of 12,000 atmospheres would reduce the volume to 106·4; the density

[*] Quoted from a letter to the writer from Dr. Lane.
[†] C. Barus, Bull. 96, U. S. Geol. Surv., p. 83 ff., 1892.
[‡] C. Barus, Bull. 103, U. S. Geol. Surv., p. 25 ff., 1893.

would become approximately 2·84. Barus has further shown that, so far as density is concerned, temperature and pressure, as these increase with depth on the normal earth gradients, nearly counterbalance each other's effects in glass, though the density should be somewhat increased with increase of depth.* It is not a violent assumption that the same be taken as true for rock-matter generally. The average density of the whole crust is thus nearly equal to the average density of its rocks, provided these are at surface temperature and pressure. The average specific gravity of the visible crust is not far from 2·75; but if the specific gravity of the whole crust were as high as 2·80, it might still float on the compressed gabbroid substratum.

The meagreness of existing experimental data will not allow that statements concerning crustal flotation can be other than in the conditional mood. It is certain that the relation between pressure and the volumetric diminution of a fluid cannot be linear for indefinitely great pressures. Yet the foregoing crude estimates clearly suggest the possibility that crustal foundering could not take place if the crust were even considerably thinner than it is to-day. When the difference in the compressibility of solid and liquid lava at great pressure is, in the future, once determined, it will first become possible really to test Kelvin's view as to the original cooling of the earth. The analogy of Barus's experiments raises the suspicion that the fragments of a foundering primal crust could sink only a comparatively few miles into the liquid interior. They would soon meet therein a level where their own density is matched by that of the more compressible fluid. Solidification by cooling would therefore not progress from the earth's center outwards, but would begin in a surface shell and slowly progress inwards.

Stresses within the crust.—It seems, accordingly, best to conceive of the earth as exteriorly composed of a thin solid shell characterized by tangential compression, a thicker underlying solid shell characterized by tangential tensions, and a liquid, gabbroid, perhaps highly viscous substratum of unknown thickness. This substratum is immensely elastic as to volume and is compressed by the weight of at least 25 miles of crust-rock. Beneath the surface shell of tangential compression the rate of secular cooling and contraction and the consequent tension increase from the level of no strain downwards all the way to the substratum. In his first paper Davison calculates that the average rending stress in the lower shell is, after a given time (if there be no relief by stretching or by cracking), four times the average compressive stress in the upper shell.

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* C. Barus, Bull. 96, U. S. G. S., p. 61, 1892.

So long as folding or overthrusting of the shell of compression does not occur, the two shells are in physical continuity and are strongly bound together.

Secular accumulation of tensions and of cooling cracks.— It is generally agreed that, on the contraction theory of mountain-building, orogenic folding and crumpling is possible through the secular accumulation of compressive stresses in the outer shell. The crucial question has not yet been satisfactorily answered as to whether there may be similarly a secular accumulation of tension and of its effects in the inner shell of the crust. If the crust were a fluid of high though finite viscosity, the accumulation of tension would be impossible to any sensible extent; moreover, the weight of the crust overlying any subshell would necessarily close all cavities almost as fast as formed during the slow secular cooling. But the average rock of the crust is a true solid known to have a very low modulus of plasticity. Pfaff has, indeed, denied even the smallest measure of true plasticity to the average crust-rock, and his experiments seem to prove that massive rocks like granite, gneiss or gabbro would, at surface temperatures, not flow under the weight of even 25 miles of overlying rock.* They would rupture and shear, but the deformation would not reach the perfection of the molecular shearing implied in true flow.

A vertical crack due to cooling contraction would thus tend to be partly closed by shearing in of masses from its walls. The shear-planes would be inclined to the vertical. Each partial bridging of the crack makes further shearing and closing of the crack more and more difficult. A greater weight of crust would now be required since some support of the load is formed through the local meeting of the solid walls. The simple vertical stress becomes partially resolved into a complex network of oblique stresses tending to balance each other in the loci of lateral support. The portions of the crack occurring between these loci of support may remain open because of the diminished shearing stresses along the still gaping walls. It thus appears that, though all rocks at surface temperatures will rupture under the weight of less than 6 miles of crust, yet the complete closing of cracks at the same temperatures would not be expected even under the weight of a much greater thickness of crust. The depth of the shell ("zone") of fracture has been deduced from the crushing tests of stone and from the brilliant experiments of Adams and Nicolson on the deformation of marble enclosed in steel collars. The former tests evidently do not prove anything at all definite as to the pressures required to produce true plastic

* See Adams and Nicolson, Phil. Trans. Royal Soc. London, vol. cxcv, p. 367, 1901.

flow. The flow of marble under confinement has been produced under relatively low pressures, but this is a special phenomenon, the result of movement on gliding planes. A penknife and a few pounds of pressure will cause "flow" in a crystal of calcite. It is safe to say that similar conditions are not found in the average rock of the crust; if it flows at all the mechanism of the flow must be something entirely different.

Deformation within the shell of tension is not to be estimated simply by the ultimate strength of surface rock deformed in the laboratory. The experiments of Spring, Hallock and others show that the rigidity of a solid increases with pressures ranging up to those about twice that borne by our substratum.[*] This experimental law strengthens the belief that cavities may remain open in the shell of tension. On the other hand, the downward increase of temperature tends to lower the internal friction and thus to promote the closing of cavities. The pressure-gradient (1 atmosphere to about 3·7 meters of descent) is, however, steeper than the temperature gradient (1° C. to about 30 meters of descent) and it may well be that rigidity actually increases through the shell of tension down to its bottom layer, where, on account of the high temperature, the change of state, from solid to liquid, is approached.

A further indication that cavities may remain open in the shell of tension is indirect but none the less noteworthy. According to the assumption generally held by those adopting the contraction theory of mountain-building, the shell of tangential compression, free of load and unconfined as it is along its upper surface, can nevertheless for long periods of time endure without deformation a compressive stress perhaps several times greater than the weight of five miles of rock. It is the release of this pressure (which was *not* relieved by simple radial flow and thickening of the shell) that has led to the paroxysmal growth of a mountain-range. If the outer shell can long withstand such pressures, it is reasonable to believe that the material of most of the shell of tension is not perfectly plastic under the weight of overlying crust,—a pressure which is great but, in general, is only a fraction of the accumulated tangential stress of compression.

The same argument seems to apply also to the conceivable closing of cavities through the expansion of the compressed wall-rocks which tend to expand elastically into the opening vertical crack. For the reasons already outlined, this expansion must, under the conditions, take place, through most of the shell of tension, by shearing of mass against mass rather than by molecular flow. The induced partial closing of the cavity would, here again, tend to prevent further shearing and

[*] For references see review by C. F. Tolman, Jr., Journal of Geology, vol. vi, p. 323, 1898.

portions of the crack would remain unclosed. It is important to note that the shearing of mass against mass due to expansion along the walls is not additive to the effect of mass-shearing due to the dead weight of crust; the two kinds of deformation would progress simultaneously, and in proportion as masses moved under the one kind of stress, it would become more difficult for mass-shearing under the other kind of stress to take place. Only at the bottom of the shell of tension where the crust-matter is in the state intermediate between those of plastic solid and viscous fluid, would the cavities be closed entirely.

This part of the argument may now be summarized. On the whole it seems probable that a percentage of the whole tension developed in the lower shell through secular cooling remains, at any time previous to mountain-building, unrelieved by the stretching or cracking of that shell. At the level of zero-strain (which is above or not far below the bottom of the " shell of rock-fracture") cooling tension is at a minimum and resistance to stretching (shearing) is at a maximum. At the bottom of the crust the cooling tension is at a maximum but the resistance to stretching is at a minimum. The accumulation of tension and cooling cracks will therefore be at a maximum at some level near the middle of the shell of tension. The accumulation of compressive strains in the outer shell will be relieved to a certain extent by recrystallization leading to the development of denser minerals in the shell; but geological observation shows that, in a long period of time, enormous compressive stresses are alway stored until relieved by a more catastrophic process. The accumulation of the tensile stresses in the lower shell will be in some direct proportion to the degree in which relief is withheld in the shell of compression. Beneath a crust so diversely stressed, there is a compressed, elastic fluid which is ready, with relative suddenness and with prodigious force, to inject itself into the shell of tension as soon as there is any local relief of pressure or any breaking of the continuity of the shell.

The whole system is evidently in unstable equilibrium. If each shell were of uniform thickness and composition, and if there were no external forces acting on the system, it would be difficult to forecast when or where the strains could be relieved.

Injection of magma into the shell of tension.—But the earth's crust is not perfectly homogeneous; none of the shells is of perfectly uniform thickness; and, thirdly, there are other powerful forces acting on the material of the shell of tension besides those leading to stretching during the earth's contraction. Of special importance is the shearing of the whole crust in the torsional deformation incidental to the contraction, or in the torsion due to tidal stress. Slight as may be the effect

of a single tidal period, for example, it will, in certain lines appropriately oblique to the earth's equator, tend to wrench apart the crust even down through its viscous bottom layer. To such a powerful fluid as that composing the substratum, this viscous layer, suddenly sheared or broken, is relatively a solid mass; to the searching fluid a plane of shearing in the viscous layer is virtually a crack. Into that plane the tidal pulsations will pump the fluid, which instantly exerts its lateral hydrostatic and expansional pressures on a shell already prone to recoil because of the real though mild tension residual in the bottom of the shell. As the fluid thus works its way upward, it encounters rock which is increasingly more rigid and increasingly charged with accumulated tension and cooling cracks. In fact, if we conceive that the viscous bottom layer is once completely penetrated, it is easy to believe that the abyssal dike will be rapidly injected toward the top of the shell of tension. The shearing-in of the solid rock opposes the continued opening of the potential fissure, but this shearing, as the level of no strain is approached, becomes slower and slower and thus more and more powerless to check the rapidly acting wedge of expanding fluid.

The injection might conceivably (following Fisher's idea) be aided by the local removal of the viscous basement through the special attack of upward convection currents in the substratum; for it is clear that the injection is most difficult at its very beginning. Fisher has suggested that water-gas given off from the substratum when it is already injected into a downwardly-opening "chasm" may contribute force tending to widen the crack. However, such gas could not, on this hypothesis (the gas being dissolved in the magma according to Henry's law), segregate except by release of pressure. The release is a slow process. As a means of injection through the viscous layer the solution of magma and water-gas would be more effective than the compressed anhydrous magma, but their activities would be of the same kind. Fisher assumes that the magma is saturated under a pressure of 12,000 atmospheres. This implies that the more rapid the outflow of lava at a vent, the more imposing would be the explosive phenomena. It is obvious that this is not the case in nature. The exceedingly small amount of water in the lavas of fissure-eruptions and of the Hawaiian calderas seems, indeed, to show that the abyssal fluid is essentially anhydrous.* The water actually found in lava and that accompanying explosions of the Vesuvian type may be all or nearly all derived from the shell of rock-fracture. We conclude that it is wisest to find the positive penetrating force of the magma in its own elastic expan-

* Cf. J. D. Dana, Characteristics of Volcanoes, New York, 1891, p. 197.

sion operating wherever a line of diminished pressure is developed in the viscous layer.

It is also manifest that, if torsional or other shear is accompanied by vertical faulting, the abyssal injection will be still further facilitated.

Relief of tensions through abyssal injection.—Whether the foregoing hypothesis be correct in details or not, there is no doubt that abyssally-injected dikes have actually been fed from the gabbroid substratum upward to the vents of fissure eruption. Granting, secondly, that there are cooling cracks and considerable unrelieved tensions in the crust, as already
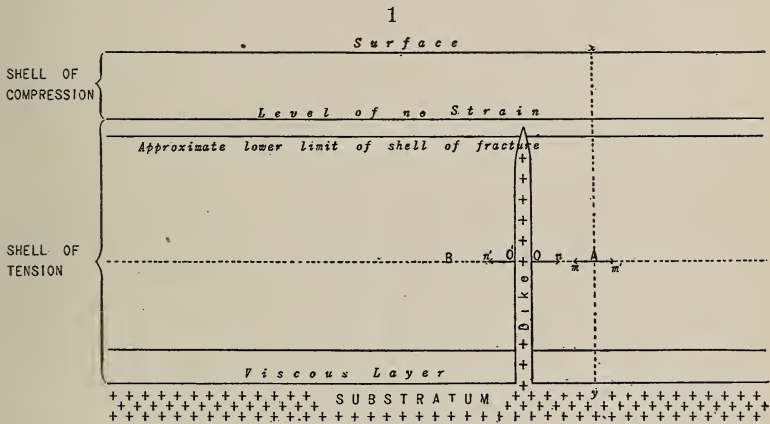
described, consequences of fundamental importance seem to be deducible.

On account of the strong compression at the earth's surface the magma of the abyssally-injected dikes will not in most cases reach the surface. The act of injection produces a great change in the conditions of equilibrium in the shell of tension and therewith in the whole crust.

Let figure 1 represent a sectional view of the system after injection, the earth's curvature being neglected and the dike being shown in cross-section. The level of no strain is represented as about five miles below the surface—a depth somewhat greater than the maximum calculated by Fisher.—The principle of the following argument is not affected if the depth should be a fraction of one mile or as much as six or possibly more miles.

" A " is a particle of the crust within the solid shell of tension. In the stretching of the shell such a particle must move not only radially toward the earth's center but tangentially as well. If the shell is homogeneous, the weight of the overlying crust will tend to shear the particle indifferently toward

m or m' or toward any one of an infinite number of other points lying in the circumference of a horizontal circle circumscribed about the vertical passing through A and with radius Am. The shear-movement of particle A is, however, strictly controlled in direction so soon as a liquid dike is injected. At the level of A the point O in the wall of such a dike bears a combined hydrostatic and elastic pressure from the magma. The former pressure is sensibly equal to the weight of the column of rock Ax; the maximum elastic pressure equals the weight of the column Ay. The total of these pressures, represented by the line On, is equal to the oppositely directed force O′n' on the other wall of the dike. On is not only a positive force compressing the matter between O and A; it is also, and yet more significantly, a *directive* force which determines the direction in which particle A must move as it is affected by the tensional pull of secular cooling and by shear during the compressive extension (stretching) of the shell of tension. As long as the dike remains fluid, particle A will move in the direction of the arrow Am'. The condensation of matter, which, before the dike-injection, had been only potential (being due to the accumulation of tensions and cracks in the shell), now becomes actual. As particle A is forced toward m', a neighboring particle, A_1 on the same level and to the right hand of A, is similarly brought under pressure and moved in the direction of the arrow Am'. A_1 communicates its motion to A_2 and so on. The pressure at O is thus felt within the shell as far away from the dike as the relief of the accumulated tension and the closing of cooling cracks can take place.

The movement of particles A, A_1, A_2, etc., is analogous to the work of a railway engine pushing down a train of cars which had been standing on a grade with each coupling pin at full length because of the grade. Buffer meets buffer, communicating the pressure of the engine. If the train had been nicely poised, just ready to move before the pressure was applied, and if the grade were indefinitely long, a small pressure would set in motion a train of indefinite length. The analogy is not perfect since the creep of the particles in the shell of tension is not free but is controlled by internal friction and by the strong adhesion between the shells of compression and tension. Nevertheless, it is not difficult to believe that lateral creep would be set up at a distance perhaps several times the thickness of the whole crust.

Since the conditions are precisely the same for particles B, B_1 (to the left of B), B_2, etc., there will be similar creep on the side of the dike opposite to A in the direction of the arrow O′n'. The dike is thereby widened. The correlative injection of new fluid magma makes this new system of

motions self-perpetuating until the attainable relief of tensions and closure of cracks is accomplished.

Thereafter, two possibilities are open. The now much widened dike may have lost sufficient heat to solidify. The system of directed creeps or lateral movements will then be exchanged for an undirected compressive extension similar to that which prevailed before the injection. Or, if the dike remains fluid, it will cause an indefinite continuance of lateral creep keeping pace with the differential cooling contractions in the shell of tension. In the former case, the injection of a second and of yet later dikes is possible, and their net effects, provided these dikes are elongated in the same general earth-zone,* are additive to those of the first dike. Tidal or other torsion may locate such a zone of special igneous injection.

Down-warping of the surface as a result of abyssal injection.—We have seen that lateral creep will be fastest somewhere near the middle level of the shell of tension, because it is there that the defect of condensation of matter, shown in cooling crack and in residual tension, is at a maximum. The ensuing condensation of matter in the shell is at a maximum in the immediate vicinity of the zone of injection and gradually decreases to each side of the zone. Since the two shells are still solidly knit together, the enforced creep of matter to right and left of the great dikes involves a strong downward pull exerted on the shell of compression. A down-warp of the earth's surface is thus established. The initial down-warp is of length, breadth and depth dependent on the magnitude of the injected body or bodies. Where the injection is on a large scale the down-warp may be of geosynclinal dimensions.

The down-warping implies, however, that the former nice balance of stresses in the zone of compression is destroyed. Those stresses will henceforth tend directly to increase the down-warp. Sedimentation within the down-warp increases the weight on the creeping material of the shell of tension, which is also now beginning to feel a small downward pressure, a component of the total thrust of the now bent shell of compression. The down-warping of the surface may thus gradually increase even after all magmatic injections in the zone of tension have frozen solid.

The conditions for mountain-building.—The shell of compression is now weakened, as experimentally illustrated by Willis in his memoir on mountain-building.† The weakening is most felt in the two lines where the down-warped surface parts from the spheroidal curve of the earth. If sediment

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* Throughout this paper the word "zone" is used in its proper mathematical sense of a "portion of the surface of a sphere included between two parallel planes."—As prevailingly defined, the "zone of fracture" in the earth may here be profitably called the "shell of fracture."

† B. Willis, 13th Annual Report, United States Geological Survey, p. 217, 1893.

accumulates to the depth of many thousands of feet in a geo-synclinal, the material of the original shell of compression is softened by the rising of the isogeotherms, while the strength of the new shell of compression occupied by the sediments is low because of the poor consolidation of this new formation. For a double reason, therefore, a broad zone of weakness in the shell of compression is developed over the zone of igneous injection. Sooner or later the secular accumulation of com-pressive stresses will express itself in the orogenic collapse of the shell; the building of an alpine mountain range is begun.

The most serious objection to the contraction theory—that the earth's amount of contraction is insufficient for the orogenic
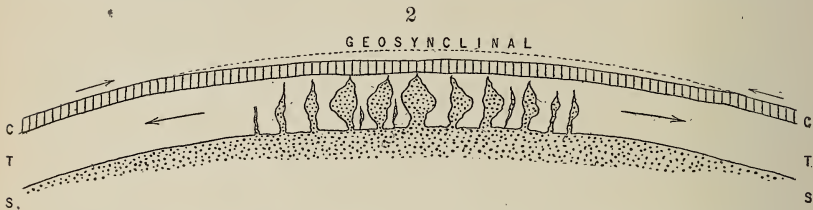
Fig. 2.—Diagrammatic cross-section showing the relation of a geosynclinal to a zone of abyssal injection. C (vertical lines)—shell of tangential com-pression; T (blank)—shell of tangential tension; S (stippled)—substratum. The smaller arrows show the direction of compressive stresses; the larger arrows show direction of rock-creep in the shell of tension. The original position of the surface before the geosynclinal down-warping is shown by the dotted line. Some of the injected bodies of magma are represented as of batholithic size; the same amount of rock-creep in the shell of tension and of down-warping of the surface would have been produced by the injection of smaller bodies, more numerous and also closely spaced in the zone of injection. Scale: about 65 miles to one inch; the curvature of the earth's surface is exaggerated about ten times.

work actually done through geological time—has been founded on mathematical deductions. As with the so-called demon-stration of the earth's extreme rigidity, the deductions are no stronger than the assumptions as to the interior economy of the globe. If the earth's vast nucleus is gaseous, as seems so highly probable, the larger part of the earth may be cooling and contracting according to different laws from those hitherto accepted as a basis for calculation.[*] For example, the con-traction of the nucleus may follow a modified "law of Charles"; secondly, we should expect that, with cooling, there will be, within the globe, the liquefaction of gas as well as the solidifi-cation of liquid—both changes of state possibly being accom-panied with special diminutions of volume. The phenomenon of earth-contraction may thus be much more complicated than it has been assumed to be, but the added complications would probably be favorable to the contraction theory of crustal deformation.

[*] Cf. S. Arrhenius, Geol. Fören. Stockholm Förhandlingar, xxii, p. 395.

Expansion of the earth's outer shell as a factor in mountain-building.—But there is good reason to believe that the contraction theory, as usually stated, carries only half a truth. Both advocates and opponents of the theory have generally spoken of the collapsing surface shell as of nearly constant circumference since the time of original crustification, except for the amount of overthrust and overfold represented in folded and faulted regions. This shell is, indeed, conceived as itself having slightly shrunk through loss of heat during geological time, little or no emphasis being placed on those agencies which tend to counterbalance this shrinking and even
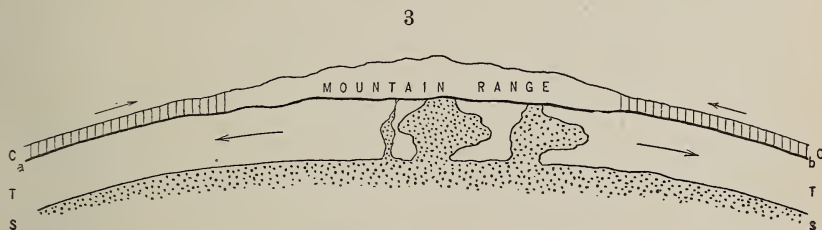
Fig. 3.—Diagrammatic cross-section showing relation of mountain-building to simultaneous and subsequent abyssal injection of magma. Scale and symbols the same as in figure 2. *a–b* (heavy line): the surface on which the shell of compression shears over the shell of tension in the orogenic thrust-movement. Two large batholiths of slightly different ages are represented; the mountain-building is supposed to have been just completed. The igneous bodies injected and crystallized before the epoch of mountain-building are not shown.

produce a net expansion of the shell. Nevertheless, it seems highly probable that the original shell has actually grown larger instead of remaining sensibly of constant circumference, and that a part, perhaps the greater part, of the circumferential shortening observed in the world's mountain ranges is due to this fact.

The outer skin of the earth, including its overthrust portions, may grow areally larger according to two different processes.

a. Local cavities produced in the shell of compression by crustal readjustments may be rapidly filled with magma from beneath or, more slowly, with vein matter deposited from circulating waters. True magmatic injections, such as dikes, laccoliths, "chonoliths,"* etc., and possibly a percentage of batholithic irruptions represent just so much additional matter squeezed into the shell. These wedges when solidified, like all the countless mineral veins, aid in transmitting and increasing the thrusts affecting the shell as it collapses on the shrinking "nucleus" of the earth. This view has been clearly

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* Defined in Journal of Geology, vol. xiii, p. 498, 1905.

enforced and illustrated by Shaler* and must be regarded as embodying a true condition of crustal deformation.

b. Still more important is the consideration that the shell of compression is the home of those metasomatic changes in rocks that lead to expansion of volume. One of the most striking results of Van Hise's researches in metamorphism is his conclusion that in this shell the average effect of hydration, carbonation and oxidation is to cause such expansion on a surprisingly large scale.† For example, if a gabbro were completely altered according to the normal reactions in the "katamorphic zone" (which, in position and depth, is very nearly identical with our shell of compression), there would be a volumetric increment of at least 25 per cent. If the entire shell were gabbroid, and if but 4 per cent of its substance had, in post-Archean time, been similarly hydrated and carbonatized, the volumetric increase would be about sufficient to explain all of the observed overthrusting and overfolding of post-Archean mountain-ranges. The rocks of the continental plateaus are, however, largely composed of quartz and orthoclase, two minerals which do not show volumetric expansion in their alteration. The part of the shell underlying the deep ocean-basins is of unknown composition, but pendulum observations and other general considerations suggest that this greater part of the shell is basaltic, and has, in general, never been exposed to subaerial erosion. Under the deep seas especially the maximum amount of metasomatic expansion and the maximum accumulation of corresponding compressive stress might, accordingly, be expected. It is conceivably to this cause that we may refer the fact that the thrust of mountain-building has, throughout the world, been chiefly from the ocean toward the land. In any case the average result of the alteration of rocks, whether by cold descending waters or by hot ascending waters, or by water trapped within the shell, and with all allowance made for solution of mineral matter which is thus removed to the oceans, is to bring about expansion of volume within the shell. This expansion must be accompanied by tremendously energetic compressive stresses; the process is homologous to the hydration of a bed of anhydrite. Since these chemical reactions take place mainly along more or less vertical cracks, fault-planes, joints, etc., the expansional force will be chiefly directed in planes parallel to the earth's surface. The relief of the strains through simple vertical expansion is resisted by the strength of the unaltered rock lying between the vertical zones of chemical alteration.

* N. S. Shaler, Science, xi, p. 280, 1888.
† C. R. Van Hise, Treatise on Metamorphism, Monograph xlvii, U. S. Geol. Surv., pp. 631 ff.

It is manifestly impossible to test these conceptions quantitatively, thus comparing their calculated effects with the known needs of the orogenic problem. Yet they are worthy of attention as valuable adjuncts to the thermal-contraction theory of mountains. " It may in the end turn out that mountains are the result of a tolerably complicated series of causations, in which secular refrigeration of the earth, the transfer of weight by the operations of erosion and deposition, and the subterranean migrations of matter, all take a part."* The energy for crustal deformation may thus lie in the combination of two immense forces—the force involved in massive readjustments within an entire cooling planet, and the force involved in the molecular readjustments among its recrystallizing ultimate particles. Other causes, such as the torsional shears expected in a planet suffering a progressive change in its rate of rotation, may further supplement those causes which have here been briefly noted as seemingly the most important.

Renewed abyssal injection following mountain-building: development of batholiths.—The extent to which shortening of the transverse axes of the world's mountain ranges has occurred shows that each orogenic revolution has been accompanied by a wholesale shearing of the shell of compression over the shell of tension. The surface of shear is probably not far from the level of no strain.

One effect of the shearing, faulting and crumpling may be to squeeze small bodies of magma up into the upper shell. But the grandest results of igneous intrusion would be felt in the shell of tension. The instant that the two shells are sheared asunder, the tensions that have been accumulated because of the solid continuity of the two shells, and are still residual after the preceding injection of magma, are relieved. The shell of tension is henceforth free to contract on itself. A fluid dike now injected into this shell or a dike injected previous to the shearing but still fluid, would tend, according to the process already described, and especially because of the energetic, spontaneous retreat of the country-rock on either side, to enlarge itself. Opposed to the active retreat and enforced creep of the solid rock of the shell away from the middle plane of the dike, and thus to the ready contraction of the shell, is the friction developed at the surface of shear. Since the shear is directed tangentially with respect to the curve of the earth, the strength of the friction is measured directly by the weight of the shell above the shear-surface. At the upper extremity of a dike which reaches exactly to the shear-surface, the hydrostatic pressure exerted on the dike-wall is somewhat greater than the weight of the shell above the shear-surface. The magma has, in addition, the live energy

* N. S. Shaler, op. cit., p. 281.

of elastic expansion measured by the compression due to the weight of the whole shell of tension.   The net effect of these forces is to permit of the contraction of the shell already prone to movement on account of the sudden relief of tension, and to cause a widening of the dike which may assume batholithic proportions.   It is important to note that the recoil within the shell due to the relief of tensions will characterize the whole of the area over which the shells of tension and compression have been sheared apart; this area may be several thousand miles in diameter.   The piling up of the mountain-mass above would also cause an enhanced rapidity or lateral flow in the shell of tension and likewise widen the magmatic chamber. Injection into the mountain-rocks themselves would only be possible where there is local relief of compression in the now heterogeneous, unequally squeezed, and writhing mass.   Since, in the nature of the case, compression generally dominates, igneous injection will, in this period, afford but small geological bodies as constituents of the range.

At the mountain-roots below the surface of shear there are one or more great bodies of gabbroid magma specially injected as a result of mountain-building.   Through the physical and chemical activity of this magma the acid igneous stocks and batholiths so characteristic of mountain-range of the alpine type, may possibly be explained by the assimilation-differentiation theory.[*]   The cycle of changes which have affected our initial system (compression-shell, tension-shell and fluid substratum) thus began with igneous intrusion and closes with igneous intrusion.   On account of the relief of compressive strains in the superficial shell, the latest and probably greatest intrusive bodies are free locally to flux or stope their way well into the shell of fracture.

With certain assumptions, several authorities have calculated that the level of no strain has always lain at a depth no greater, or but very little greater, than the bottom of the shell in which rocks can readily fracture.[†]   In rising through the shell of tension the gabbroid magma has expanded so much and attained such low viscosity that down-stoping and abyssal assimilation of shattered roof-blocks is now possible.   To the differentiation of the compound magma so produced, the granitic batholiths and stocks, many injected laccoliths, "chonoliths" and dikes, as also many lavas more acid than gabbro, have been attributed.   There are reasons for believing that magmatic stoping is much more potent than fluxing assimilation on main contacts.   If granites, etc., are really secondary after the manner indicated, they can only be formed in the shell of fracture and on the large scale where the tangential

[*] See R. A. Daly, this Journal, vol. xv, 1903, p. 269; vol. xvi, 1903, p. 107; vol. xx, 1905, p. 185.

[†] The limits of the shell of ready fracture, as conceived by Van Hise, are shown in Fig. 1.

compression of the superficial shell is relieved. Otherwise stoping is impossible, for a large magma chamber could not remain open in the zone of unrelieved compression. Granites and allied rocks are, by this hypothesis, primarily mountain-rocks. That this is the fact hardly needs statement.

Vulcanism as a result of mountain-building.—By the inevitable settling-down and block-faulting which follow the orogenic paroxysm, both primary basaltic lava and secondary lavas of indefinite variety may be squeezed out to the surface. Volcanic activity is not, by the hypothesis, necessarily confined to zones of intense mountain-building, but should be specially developed in those zones. The volcanic problem and the orogenic problem are in general both related to the same necessity of understanding the mechanical rearrangements when, for any reason, fluid material from the substratum is injected into the shell of tension.

Summary.

Postulates.—The assumptions on which the foregoing hypothesis has been based are the following :

a. A cooling earth superficially composed of a relatively thin crust overlying a fluid gabbroid substratum of unknown thickness.

b. The substratum so much compressed by the weight of the crust as to be probably able to float the crust.

c. Through differential cooling contraction the development of a level of no strain in the crust not far from the bottom surface of the shell of rock-fracture.

d. The accumulation of pressure in the shell of compression and the simultaneous accumulation of cooling cracks and of some of the powerful tension unrelieved in the shell below the level of zero-strain.

e. A steady or recurrent dislocation of the shell of tension permitting of the forceful injection of the fluid substratum to which even the viscous layer of the shell acts as a relatively solid mass at the moment of dislocation. This dislocation has been referred to the tidal torsion of the earth's crust, but sub-equatorial torsion on the tetrahedral theory of the earth, or crustal deformation due to the play of other cosmical forces or of forces induced by the heterogeneity of the crust, may similarly cause dislocation in the shell of tension.

Conclusions.—1. The abyssal injection involves condensation of the matter in the shell of tension. Cracks are closed and much of the accumulated tension is relieved by an enforced creep of matter away from the injected body. So long as the body remains fluid the stretching of this shell due to continued cooling of the earth is accomplished by creep of matter in the same

directions. The amount of creep is at a maximum above the zone of injection and decreases to a minimum at certain distances to right and left of the middle line of the zone.

2. This lateral creep induces a down-warp of the earth's surface immediately overlying the zone of condensation. The resulting geosynclinal may be the seat of prolonged sedimentation. If so, the weight of the sediment itself tends to increase the lateral creep in the shell of tension and the down-warp slowly deepens.

3. The shell of compression is already weakened at the angles of down-warp; it is further weakened by the sedimentary blanket which, comparatively little resistant itself, causes a softening of its basement through a rising of the isogeotherms. When the filling of the geosynclinal has sufficiently thickened, the shell of compression, owing to its secular accumulation of stresses (which are intensified by metasomatic changes in the shell), begins to collapse. Mountainous forms and structures result.

4. The complete shearing apart of the shells of compression and tension during the orogenic revolution releases the tensions still unrelieved in the underlying shell. Abyssal injection on a large scale is thus initiated or continued in the shell of tension. The relief of compressive stresses in the act of building the mountains first occasions the possibility of magmatic stoping and thus of the extensive assimilation of schists and sediments by the primal gabbroid magma. The differentiation of the compound magmas of assimilation may explain the batholithic central granites, etc. of mountain ranges, along with their satellitic stocks, injected bodies and volcanic outflows.

5. The regional warpings of the earth's crust may be partly at least referred to the varying strengths of abyssal injections from a fluid substratum.

6. The location and alignment of mountain ranges, the location and elongation of geosynclinals, the final development of igneous batholiths and satellitic injections, are all interdependent and related to *special* zones of powerful abyssal injections from the substratum. These zones are, in the large, located by cosmical stresses affecting the earth along special azimuthal lines.

7. Mountain building causes relief of compressive stresses in the superficial shell. The surface outflow of magma either secondary or directly derived from the substratum may therefore be specially pronounced after an orogenic revolution. In general, the theory of vulcanism is also fundamentally affected by the doctrine of the shell of tensions which are not entirely relieved by the compressive extension of that shell.

ART. XIX.—*Some Interesting Beryl Crystals and their Associations;* by W. E. FORD.

THE beryl crystals commonly found in pegmatite veins are prismatic in habit, consisting of a simple combination of the prism of the first order, *m*, with the base, *c*, and as a rule are only semi-transparent, and of a green color. It is the chief purpose of this article to describe several striking exceptions to
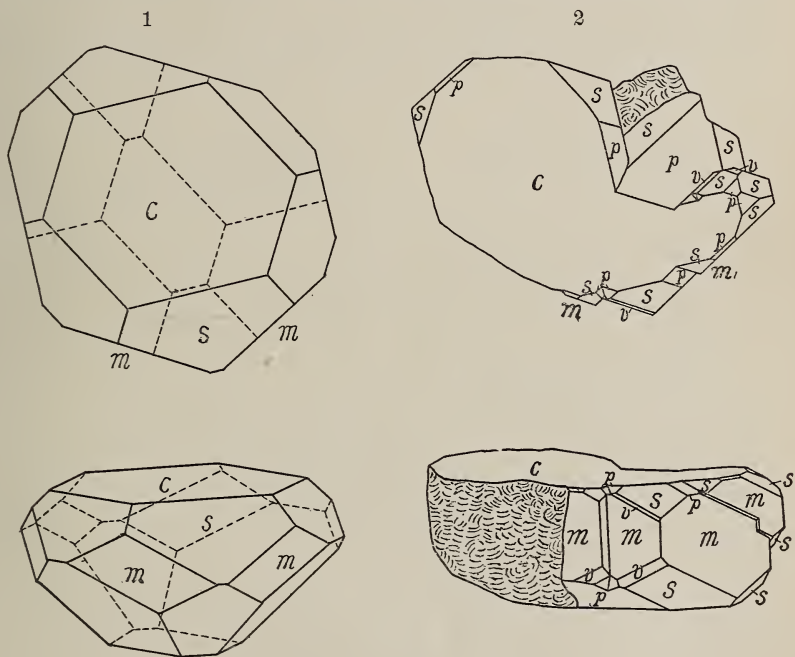
this general rule, and to point out some interesting similarities in crystal habit, color and association shown by a series of beryl crystals from a number of different localities, all of which are noted for the occurrence of variously colored tourmalines of the lithia variety and of gem quality.

The pegmatite deposits of San Diego Co., California, which have become famous on account of their beautiful tourmalines, have lately furnished some beryl crystals of an unusual habit and uncommon color. Figure 1 is of a crystal from the deposit at Mesa Grande, while figures 2 and 3 are of crystals from the locality of Pala. The short prism which they show, especially in figures 1 and 2, together with the large and

prominent development of the pyramid of the second order s ($11\bar{2}1$), give them a habit of crystallization very different from that usually shown by beryl. The crystal represented by figure 2 also shows smaller replacements by faces of the pyramid of the first order p ($10\bar{1}1$) with an occasional face of the dihexagonal pyramid v ($21\bar{3}1$). It is further complicated by several reëntrant angles caused by a repetition of the faces due to parallel growth. The figures are drawn to show as nearly as possible the development of the faces in their true proportions, figure 1 being about natural size while figures 2 and 3 are one half natural size. The crystals are transparent and of a beautiful light rose-pink color : their extraordinary color combined with their unusual habit of crystallization
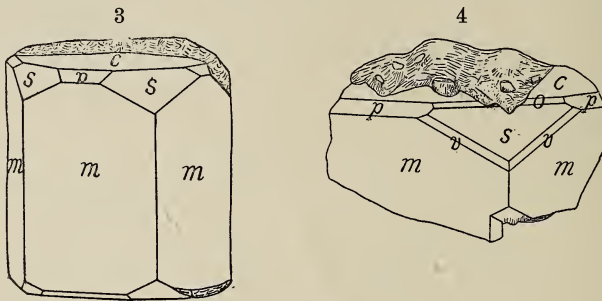
make them especially noteworthy. Figure 1 is of a crystal loaned for study by Mr. Ernest Schernikow of New York and which has since come into the possession of the Brush Collection, while the crystals represented by figures 2 and 3 are in the Tiffany Gem Collection in the American Museum of Natural History, New York.

Figures 4, 5 and 6 are of beryl crystals showing interesting similarities in habit and association with those just described, but from other localities. Figure 4 represents an incomplete crystal found at Mt. Mica, Paris, Maine, now in the mineral collection of the American Museum of Natural History in New York. It shows a short development of the prism m with prominent faces of the second order pyramid s; also small replacements of another pyramid of the second order o ($11\bar{2}2$), of the pyramid of the first order p, and of the dihexagonal pyramid v ($21\bar{3}1$). The crystal is transparent and colorless like pure quartz, and attached to it are plates of lepidolite. Figure 5 is likewise of a colorless crystal from Mt. Mica belonging to the Brush Collection, nearly complete, quite symmetrical in development and about 15^{mm} in diameter. It is characterized by small faces of the prism m and a large development of the pyramid s, while o and v were observed as

small truncations.   Figure 6 is of a crystal in the Brush Collection from the famous tourmaline locality of Haddam Neck which corresponds to these other crystals in having the pyramid of the second order unusually prominent, although on this crystal the prism faces are large and well developed.   This crystal is transparent and has a very pale pink color.   Several other light-colored crystals from Haddam Neck showing a development of faces similar to that of figure 6 are in the mineral collection of the American Museum of Natural History. One very large one, donated to the Museum by Mr. Ernest Schernikow, measures 18 inches in length by 1 foot in diameter.   It is doubly terminated, but so attached that only a portion of its faces are developed.
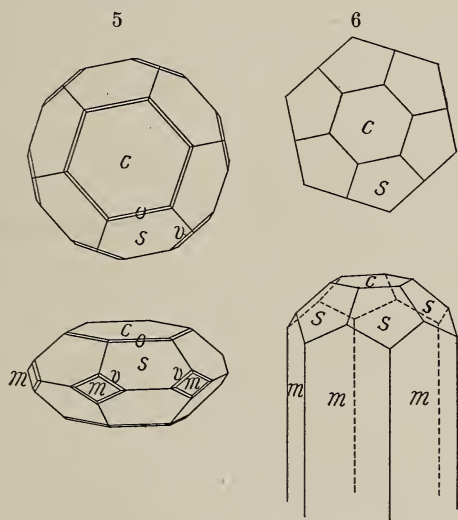
Pink beryls were formerly found at Goshen, Massachusetts, associated with tourmalines of light to dark green color, and were given the name of goshenite by Shepard.*   Specimens of beryl from this locality in the Yale College Collection show only the forms of the prism *m* and the base *c*.   Transparent, colorless and pink beryls are also found in the Island of Elba associated with variously colored gem varieties of tourmaline. A specimen of pink beryl in the Brush Collection from Elba shows a short prismatic development terminated only by the base.   Vom Rath† describes the Elba beryls as being usually transparent and frequently of a light pink color, and although light green and blue crystals occur there as well, they are

* A Treatise on Mineralogy, third edition, 1852, p 229.
† Z. d. d. Ges. xxii, 661.

often only semi-transparent. These crystals are described as having generally a prismatic habit, but he mentions several instances where they are markedly tabular in development.

It is interesting to note the striking similarity in habit, color and association of beryl crystals from these different localities. Many of them are of an unusual crystal habit for beryl, frequently being short prismatic, at times even tabular parallel to the base, and occasionally are highly modified. They are also of unusual color, some of them colorless, others of a light tone of pink, quite distinct from the green or blue-green shades commonly shown by beryl. All of them also were found in pegmatite deposits associated with variously colored green and pink tourmalines of gem quality. Such coincidences of association of beryl crystal of unusual habit and color with tourmaline crystals of light colors and gem quality are interesting and suggestive. To the writer's knowledge, the ordinary green beryl, showing a simple combination of prism and base commonly found in pegmatite veins, occurs rarely at the localities which furnish gem tourmalines. It would seem not at all improbable that the conditions favorable to the formation of tourmalines of gem quality were likewise favorable to the formation of these beryl crystals of unusual color and habit.

The factors which control such matters as mineral occurrence and association are undoubtedly extremely complex, being both physical and chemical in their nature. It would seem probable however, if this association which has been noted is anything but accidental in character, that some chemical similarities might be found to exist between these types of tourmaline and beryl. It has been noted that gem tourmalines are usually characterized by containing about twice as much of the alkali oxides as the ordinary varieties, Li_2O being practically only found in the gem material. The occurrence of small amounts of alkalies, usually Na_2O and Cs_2O, have been frequently noted also in beryl. It was thought therefore that any chemical similarity between the gem tourmalines and the pink or colorless beryls would be in the presence in each of unusual amounts of the alkali oxides. Quantitative tests for alkalies were therefore made on two different beryls, the first being pink material from Mesa Grande, the same as that of the crystal illustrated in figure 1, while the second was a pale pink opaque crystal in the Brush Collection from Haddam Neck. Both of them showed considerable amounts of alkalies, the Mesa Grande material yielding about 3·00 per cent and that from Haddam Neck about 5·00 per cent of mixed alkali oxides. From both of them strong tests for cæsium were obtained by use of the spectroscope. In this

connection an analysis* by H. L. Wells of a clear and color-
less beryl found associated with gem tourmalines at Hebron,
Maine, might be quoted, which yielded Na_2O, 1·13; Li_2O,
1·60, and Cs_2O, 3·60. These few instances would seem to
indicate that these unusually colored beryls are liable to con-
tain several per cent of alkalies, cæsium being characteristi-
cally present. Their association with those tourmaline crys-
tals, which likewise contain unusual amounts of alkalies, can
hardly be considered entirely accidental, and consequently in
this fact of chemical similarity we probably find one of the
conditions which influence the association of this type of
beryl crystals with the gem tourmalines.

Figure 7 is of a transparent green crystal (aqua-
marine) in the Brush Collection from the Mack
Mine, San Diego Co., California, and is introduced
here chiefly for the sake of contrasting it with the
tabular type from the same general locality shown
in figure 2, the two crystals representing the
opposite extremes of development. The crystal is
represented in the figure in its true proportions,
except that its length parallel to the vertical axis
should be four times as great as is shown. The
length of the crystal is approximately fifteen times
as great as its diameter, the actual dimensions being
60×4^{mm}. The faces on the crystal are the prism of
the first order m, the dihexagonal prism i (21$\bar{3}$0),
the pyramid of the second order s and the pyramid
of the first order p, with the basal plane c, and are
developed with almost ideal symmetry.

There are also in the Brush Collection two per-
fectly transparent and yellow colored beryl crystals
from Ramona, San Diego Co., which show remark-
able etchings: These are in the form of depressions
arranged singly in line, figure 9, or in groups, figure
10, in the positions which would naturally be occupied by faces
of the prism m. The prism m, however, does not appear on
the crystals, the groups of pits corresponding in position to
adjacent m faces being separated from each other by a dihexa-
gonal prism. Measurements of a series of the faces forming
the pits were made on a two-circle goniometer and the aver-
ages of the results obtained were used to plot the positions of
the faces on a gnomonic projection, figure 8, the plane of pro-
jection being taken as parallel to m (10$\bar{1}$0). From this pro-
jection figures 9 and 10 were made, which show the character
and arrangement of the etched pits drawn in orthographic
projection upon a plane parallel to m. The faces were all

* Dana's Sys. Min., p. 407.

rounded and gave only approximate measurements, consequently no definite symbols can be assigned to them. The dihexagonal prism designated as *1*, which appears on the crystals and forms prominent faces in the pits, is close to a form having ($31\bar{4}0$) as its symbol. The faces in the pits marked *1* are the same as the right hand prism face ($31\bar{4}0$), also marked *1*, and reflect the light simultaneously with it; and those marked *1′* reflect together with the left hand prism face, ($41\bar{3}0$), designated as *1′*. The bottoms of the pits are usually occupied by two small faces making a very acute angle with one another which correspond to the two prism faces designated as *1″* and *1‴*, figure 9, which lie to the right and left

8   9   10

11

beyond those marked *1* and *1′*. Figure 11, which is a horizontal section along the dotted line in figure 9, illustrates the relations existing between the faces of the dihexagonal prism and the corresponding faces found in the pits. The pyramid of the first order, designated as *2*, which always forms the upper and lower faces of the pits, approximates in its position to ($13\cdot0\cdot\bar{13}\cdot2$). In addition to these faces the etchings show two other forms, *3* and *4*, which in their positions correspond to the faces of dihexagonal pyramids. They are of vicinal character, falling very close to the prism face *m*, as is shown in the gnomonic projection, one averaging only 4° 57′ and the other 2° 13′ from *m*. Because of the uncertainty of the meas-

urements due to the vicinal character of the faces, exact symbols cannot be assigned to these forms. In some places the pits form a single line down the length of the crystal, not encroaching at all on the faces of the dihexagonal prism at the sides, as shown in figure 9. More generally they are in two or more parallel and adjacent lines and interlock with each other in a very complicated manner, as shown in figure 10. The pits average 2^{mm} by $1\cdot5^{mm}$ in size. The crystals show a tendency to taper at the ends on account of the etching and rounding of the prism faces.

Acknowledgment should be made of the courtesy of Mr. Ernest Schernikow of New York and of Messrs. H. C. Bumpus and L. P. Gratacap of the American Museum of Natural History in New York, for furnishing for study the crystals illustrated in figures 1 to 4. The writer also gratefully acknowledges the frequent help, through criticism and suggestion, of Prof. S. L. Penfield during the preparation of this article.

ART. XX.—*Schistosity by Crystallization. A Qualitative Proof;* by FRED. EUGENE WRIGHT.

IN the general theory of the metamorphism of rocks, pressure, especially stress applied in one direction, has long been considered an important factor; and in recent years sufficient evidence has been accumulated by geologists from observations in the field to demonstrate practically its influence on the textures of rocks during their formation. Investigations of the behavior of a body or chemical system under stress have also been made by chemists and physicists, and fundamental laws of equilibrium deduced therefrom which have a direct bearing on the broader problems of metamorphism.

Le Chatelier* discovered a number of years ago, that in a chemical system "any change in its factors of equilibrium from outside is followed by a reverse change within the system." At constant temperatures, therefore, an increase of external pressure tends to produce those changes which are attended by diminution of volume. In the words of Bancroft,† "the system in equilibrium tends to return to equilibrium by elimination of the disturbing element." Most solids dissolve with decrease in volume: when this is the case, the solubility is increased. Riecke and also Hambuechen‡ have proved experimentally an important deduction from this general law, that a body under unequal strain dissolves most rapidly along the line of greatest stress.

In accord with this law of physical chemistry, Van Hise,§ reasoning from the standpoint of geology, has shown that in the deep-seated zone or zone of anamorphism "the deformation in connection with mass mechanical action is mainly accomplished not by mechanical subdivision but by the chemical action of recrystallization;" that "under strains with a stress difference an exceedingly small amount of water at the high temperature is capable of dissolving particles of substance under the greatest stress and depositing them along lines of less resistance, the movement of the solution being slight and

* Comptes Rendus, xcix, 786, 1884; quoted in W. D. Bancroft's "The Phase Rule," Ithaca, 1897, p. 4. Van't Hoff has also derived the same law from the second principle of thermodynamics and expressed it in mathematical terms. Studien zur Chemischen Dynamik, Van't Hoff and Cohen, p. 223.

† "The Phase Rule," Ithaca, 1897, p. 4.

‡ Riecke, E., Nachr. v. d. K. Ges. d. Wissensch. zu Göttingen, Math.-phys. Klasse 1894, iv, 278–284; Hambuechen, C., "An Experimental Study of the Corrosion of Iron under Different Conditions," Bull. Univ. of Wisconsin, No. 42, 1900, p. 255.

§ "Metamorphism of Rocks and Rock Flowage," Bull. Geol. Soc. America, vol. 9, May, 1898; also "Treatise on Metamorphism," U. S. Geol. Survey, Mon. 47, Chap. VII: VIII (1904).

the quantity of substance in the solution at one time being extremely small." Through the superheated water as a medium, adjustment by solution and deposition goes on continuously during the deformation. Under such conditions minerals like the micas and amphiboles, which have a tendency to grow most rapidly in one direction, develop with their longer axes in the direction of least resistance, perpendicular to the line of greatest stress; and the texture of the resultant rock will be characterized by a parallel arrangement of its mineral components.

Since in such metamorphic rocks the recrystallized silicates belong chiefly to the micas, amphiboles and feldspars, all of which cleave well, the cleavage of these rocks is due in large part to the cleavage of their components. In short, the textures observed in metamorphic rocks of this type are characterized by a definite orientation of mineral components recrystallized at high temperatures under unequal stresses.*

Becke† has applied the name Krystallizationsschieferung to this process of recrystallization under stress and has reached conclusions similar to those of Van Hise outlined above.

A recent investigation by G. F. Becker and A. L. Day‡ on the development of crystals under stress shows that although crystals are able to grow in a given direction in spite of a counteracting force, their growth in the plane normal to the pressure is vastly greater, the proportion being about 1 to 1000 or still larger. In their experiments, alum crystals were used which are isometric and which have, therefore, no peculiar direction of elongation. Had substances been tried which crystallize in prismatic or tabular shapes, it is probable that there, also, the direction of most rapid crystal growth would have coincided with the direction of least resistance normal to the active stress, as in the experiments below.

In the Geophysical Laboratory of the Carnegie Institution, several experiments were performed in imitation of this process of nature, and results were obtained which roughly verified the preceding theoretical deductions. The problem which confronted us was to produce crystallization from solution under strain. Purely aqueous solutions could not be used, since in them hydrostatic conditions obtain and stress differences are not possible. A glass, however, from a physico-

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* The arguments given in brief in this paragraph are essentially those of Van Hise developed *in extenso* in his monograph, *loc. cit.*

† Becke, F., Über Mineralbestand und Struktur der Krist. Schiefer; Sitzunsber. Wiener Akad., 7 Mai, 1903. This paper was unfortunately not available to the writer. A brief statement of his conclusions, however, is given by U. Grubemann in "Die Kristallinen Schiefer," i, (1904).

‡ "The Linear Force of Growing Crystals," Proc. Wash. Acad. Sci., vii, 283–288, 1905.

chemical standpoint is an undercooled liquid, and in it the viscosity or internal friction at temperatures at which crystallization may begin is sufficiently great to permit application of unequal stresses. Certain glasses, as those from wollastonite, diopside, anorthite and other minerals, crystallize at temperatures far below the melting point of the mineral, and while still in a state of fair rigidity.

These minerals are, moreover, either prismatic or tabular in habit and possess, therefore, a decided inclination to grow more rapidly in one direction than in another. If made to crystallize under unequal stress, they will, in consequence, tend to develop most rapidly in the direction of least resistance and their favored axis or plane of growth (prismatic or pinacoidal) will be normal to the active stress; while the resultant texture will be comparable to those produced by the recrystallization of a rock under stress.

In our experiments about 50 grams of each of the above minerals were first melted separately in a Fletcher furnace and then chilled rapidly to glass by plunging the platinum crucible containing the melt into water. Cubes of about 1^{cm} edge were then cut from these glasses and subjected afterwards both to heat and stress. Heat was applied by means of an air-gas blast and concentrated by enclosing the preparation in a small reverberatory hood of asbestos. Pressure was produced in two different ways; in the first, a cube of mineral glass, shielded both above and below by thin disks of asbestos, was placed between two short vertical steel rods held in position by a suitable stand and gravity pressure obtained by weighting down the upper rod. By this method the effects of stress in one direction alone were studied, and the similarity of the textures produced compared with those of rocks formed under like conditions of stress.

To obtain stresses acting along two directions normal to each other and thus to imitate the pencilled texture of many amphibolites, a device suggested by Dr. A. L. Day was employed, consisting of a wide metal pipe ring of 12^{cm} diameter, into the sides of which four screws were inserted at intervals of 90°. Steel caps were fitted on the ends of these screws and between them the cube was placed. Pressure was applied by tightening the screws, while heat was derived as above from an air-gas blast.

After complete crystallization under stress, the cubes were immersed in hot Canada balsam and afterwards embedded in plaster of Paris. These precautions were found by experience to be necessary, and were taken in order that satisfactory thin slices could be cut from the cubes, which, after crystallization are extremely brittle and fracture readily. Plates were then

cut after the three faces of each cube and sections ground from them.

If the foregoing hypotheses are applicable in this case, the prismatic minerals crystallizing out of the glass under a stress acting in one direction only, should show in the center of the cube an arrangement along planes which are approximately perpendicular to the line of pressure; while the influence of a second stress at right angles to the first should cause the crystallites to grow along the one line of least resistance and show parallel orientation in consequence. Both of these textures were produced roughly in the cubes and were visible not only under the microscope, but also to the unaided eye.
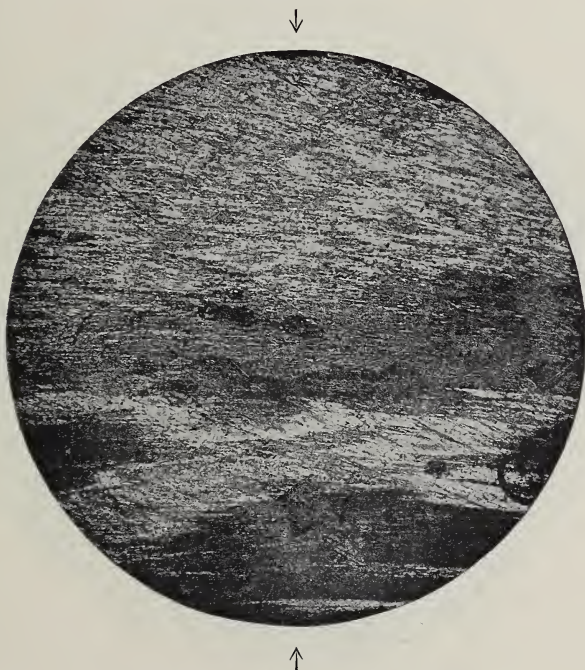
Magnification 25 ×. Nicols crossed.

Fig. 1.—Section parallel to 100 through the center of a cube of wollastonite crystallized from the glass while under stresses acting in the direction indicated by the arrows.

For the sake of convenience in describing the phenomena observed, the cubes will be considered as fixed in position relative to the stresses applied, and the six cube faces as those of an isometric cube; the first stress being applied vertically and perpendicular to the basal planes (001) of the cube; the

second normal to the side planes (010), while the front and back planes (100) remain free in every experiment.

In view of the fact that more extended experimental work on the influence of stress on crystallization under bettered conditions is soon to be carried out in this laboratory, three photomicrographs of simple cases only are reproduced below. The results, here presented, are strictly qualitative and preliminary in character.

Figure 1 shows a plate through the central part of a large cube of wollastonite crystallized from its glass under stress

Magnification 25 ×. Nicols crossed.

Fig. 2.—Section parallel to 010 of a cube of anorthite crystallized from its glass under stresses in the direction marked by the arrows.

normal to 001. The section was cut parallel to 100 and in it the wollastonite fibers are oriented approximately perpendicular to the line of stress. Local variations occur and an individual fiber may occasionally be inclined at an angle of many degrees to the normal plane. Nevertheless, the general effect

of the aggregate is that of an arrangement of the fibers in layers parallel to 001 ; along this plane the cube also showed a tendency to split.

Figure 2 is part of a cross-section parallel to 010 of an anorthite cube crystallized from glass under stress normal to 001. The photograph shows the upper part of a section which was cut nearer the outer edge of the cube than that of the preceding figure. The effect of crystallization proceeding from the outer surface inwards because of the rapid heating and in spite of the counteracting forces, is clearly marked in this section. Only after the conditions of heating had become more uniform could the effect of the unequal stress find expression in the parallel arrangement of the fibers in the central portion of the cube as shown by fig. 1, and the lower part of fig. 2.

Magnification 25 ×.   Nicols crossed.

FIG. 3.—Section parallel to 100 and near exposed surface of a cube of diopside crystallized from the glass under stresses indicated. The prismatic fibers were normal to 100 and are cut, therefore, crosswise by the section.

Figure 3 represents part of a thin slice taken from a crystallized cube of diopside glass parallel to 100 and very close to the exposed surface. The prismatic fibers which were the first to crystallize were normal to the exposed surface and are thus cut transversely by the section.

Résumé.

The schistose and gneissose textures of many metamorphic rocks have been ascribed by Van Hise and others to the orienting influence of pressures with a stress difference acting during the recrystallization of the rock in its new environment,— solution taking place along the line of greatest strain and deposition along the line of least resistance and normal to the maximum stress. In such cases the rock cleavage is due to the parallel arrangement of its mineral components in planes perpendicular to the line of greatest stress.

Conditions of experiment in which crystallization under unequal strains could take place were effected by using cubes of glasses made by chilling melts of different minerals rapidly, and by heating these to the point at which crystallization first began, the viscous glass at that temperature being still in a state of fair rigidity, and capable of supporting a certain amount of unequal strain.

Textures similar to those of certain metamorphic rocks were produced in this way, and an experimental confirmation of the theoretical deductions thus obtained.

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Art. XXI.—*Fractured Bowlders in Conglomerate ;** by
Marius R. Campbell.

During a visit to the Deer Creek coal field of Arizona,
which the writer made in the autumn of 1903, countless num-
bers of fractured bowlders were found on the outcrop of a
coarse conglomerate, which seemed to require unusual and
peculiar surroundings to account for their present conditions.
Accordingly some hasty notes were taken of field relations
and a few typical specimens secured for further study. A
group of these fractured bowlders is shown in figure 2 and
the following descriptions may throw some light on their
mode of origin.

The region in which the phenomenon was observed is an
irregular syncline of Cretaceous and Carboniferous rocks in
Pinal County, about ten miles east of Dudleyville at the
junction of the San Pedro and Gila rivers, better known per-
haps as the Deer Creek coal field.†

The rim of the syncline is in large part formed by the great
Carboniferous limestone which also apparently underlies much
of the central part of the basin, but it is effectually concealed
by a great mass of later rocks consisting of lava, tuff, and beds
of sandstone and shale. These beds are probably of late Cre-
taceous age, and, therefore, there is a great time-break between
them and the underlying limestone, although in most cases the
beds at the contact are apparently conformable.

The rocks immediately overlying the limestone generally
consist of sandstone and shale with some small coal beds.
Above this group there are many beds of andesitic tuff with
interbedded sand and clay and what appears to have been
great surface-flows of andesite. Some 500 or 600 feet above
the base of the Cretaceous rocks is a bed of conglomerate
composed of bowlders of all sizes up to 2 or 3 feet in diameter,
held in a matrix of very soft andesitic tuff, a typical outcrop
of which is shown in figure 1. This view was taken on Ash
Creek just below the limestone box canyon east of Saddle
Mountain and the bedding planes of the conglomerate dip 70
degrees to the left, or toward the center of the basin. The
bowlders represent a great variety of rocks, both crystalline
and sedimentary, but probably those of quartzite are most
abundant.

This bed of conglomerate shows at a great many points, but
in most places the matrix is so soft that the rock breaks down

* Published by permission of the Director of the U. S. Geological Survey.
† For a more detailed description of the region and the geologic relations
see "The Deer Creek Coal Field, Arizona," by the writer. U. S. Geol.
Surv., Bull. 225, pp. 240–258.

when exposed to the atmosphere, leaving only a mass of gravel
and bowlders. The material is all well rounded, and it seems
evident that it has been swept into its present position by
strong currents of water, presumably by surface streams.

1

Bed of Cretaceous conglomerate on Ash Creek, Pinal County, Arizona.
Andesitic tuff matrix.   Dip 70 degrees to left.   Bowlders fractured.

After the deposition of this material, the rocks were dis-
turbed by what seems to have been the upthrusting of huge
masses of igneous rocks, giving to the sedimentary beds the
form of an irregular basin. In some places the movement has
been quite severe, and the rocks are steeply upturned and

faulted, but in other places the movement has been gentle and the rocks dip lightly toward the center of the field.

At a point on the north side of the basin on the old Indian trail across Mescal Mountain to San Carlos, the bed of bowldery conglomerate dips toward the south or center of the basin at an angle of less than 10 degrees. The soft matrix of tuff has been dissolved and the bowlders are scattered over the ground in great profusion. At this place the specimens shown in figure 2 were found. They were not in position, but their original relations are apparent.

Almost every bowlder of the thousands scattered over the ground at this place is marked by one or more bruises where other bowlders have been pressed against it. Considerable movement is indicated by these bruises, for the surface is

2

Fractured bowlders from coarse Cretaceous conglomerate, Pinal County, Arizona. Scale, one-half natural size.

ground and crushed in a way that could only occur under repeated crushing strains. In some instances the opposing bowlder has failed to make an impression, probably because it was composed of softer rock, or because some more resistant bowlder took the strain, relieving the pressure in the surrounding material. The large bowlder shown in the cut has at least six bruises, the two most severe being the one on the front and the one at the left end seen in profile. At these two points the opposing bowlders have been forced into this one until it has been nearly broken to pieces. Great cracks have opened in various directions and the broken parts have been thrust out until it appears like a ball of partly hardened clay that has been squeezed from several directions. The other

bowlders show similar results, the two on the right being marked by especially deep bruises and great cracks which extend entirely through them. The bowlder on top has had another bowlder thrust into it so far that a piece of the opposing bowlder is still contained in the upper part. The bowlders in question are mostly tough quartzite and they present a striking illustration of the enormous pressure that has been brought to bear upon them.

Similar fractured bowlders may be seen in figure 1, but in this case they appear more like fractures due to shearing than the result of one bowlder impinging upon another. A good example may be seen above and to the right of the hammer where a bowlder 8 or 10 inches in length is sheared in three or four places. At first sight it might seem that only a few of the bowlders in this view are broken, but close inspection shows that almost all are more or less affected.

Such pressures as are shown by these bowlders are naturally associated in one's mind with intense folding, but this relationship is questionable. The bowlders shown in figure 1, where the bed is tilted at an angle of 70 degrees, are not so badly fractured as are those shown in figure 2 from the north side of the basin, where the dip is only 10 degrees. It must be stated, however, that where the bed occupies the center of the basin, as for instance at the place where the Dudleyville trail first reaches Deer Creek, a short distance east of the mouth of Little Rock Creek, the bowlders are not fractured, or at least fractures were not observed. The explanation of the phenomenon probably lies in the peculiar conditions under which the bowlders were held. If the matrix had been solid and homogeneous and closely attached to the bowlders, it is probable that no such fractures would have been produced, but under pressure the soft turf acted much like fluid material and all of the strain came upon the bowlders themselves. Not only that, but the bowlders were held so loosely that there was opportunity for the sides to give under pressure and consequently cracks were produced and even the entire side of the bowlder was shoved off to an appreciable extent. A glance at figure 2 makes it plain that the large bowlder could not have been crushed from the spot in front unless there was room for the side to expand on what is now the upper part. If this bowlder had been surrounded by a strong homogeneous cement no such fracture could have been produced.

The conclusion is, therefore, that such fracture can be produced only where the matrix is soft and flows under pressure, leaving the bowlders to take the brunt of the strain, and affording them no lateral support to prevent them being crushed under the strain.

Art. XXII.—*The Exploration of Samwel Cave;* by E. L. Furlong.

Introduction.

The first active work in the exploration of caves in northern California was commenced in the summer of 1902. Though the presence of caves in the region was known for many years, yet no scientific work had been carried on in them. The excellent results derived from the exploration of Potter Creek Cave* stimulated exploration in this region for other caves. Of these the Samwel Cave† has furnished the most valuable results.

The cave investigations have been conducted under the auspices of the Department of Anthropology of the University of California. The exploration of Samwel Cave in 1905 was supported by a grant from the American Archæological Institute.‡

The work has been carried on under the immediate direction of Professor J. C. Merriam, whom the writer desires to thank for material aid in the work of exploration and in the description of the cave fauna. Thanks are due Mr. Walter King and Mr. William Boynton for valuable service rendered in excavating and removing fossil remains under somewhat hazardous conditions.

History of Discovery.

The initial exploration of Samwel Cave in Shasta Co., California, for scientific purposes was carried on in the summer of 1903. An interesting legend, the scene of which was laid in Samwel cave and told by a Wintun Indian, led to its exploration. This story has a double value in making known an important cave, and in the verification of the legend, which now becomes an interesting piece of Wintun history. The Wintuns believe that caverns are of supernatural origin and have used them as places of magic. A courageous Indian, who had any important undertaking in view, such as a long

* The Exploration of the Potter Creek Cave; by Wm. J. Sinclair, Publ. Univ. Calif., North Amer. Arch. and Eth., vol. ii, No. 1.

† Prelim. Note on Expl. of Samwel Cave, Science, N. S., vol. xx, p. 53; E. L. Furlong.

‡ The above is submitted as a part of a report on investigations carried on under a grant from the American Archæological Institute for cave explorations in California, under the direction of Professor F. W. Putnam.

hunting trip, or a war expedition, would hide himself in the cave for a certain period, fasting and meditating on the object desired. It was the belief that through this vigil they would obtain good luck and success.

Following is the version of the legend generally current among the Wintuns :—

Many years ago a woman of strong medicine told three Wintun maidens that this cave contained two pools of Sawame or magic water ; and that if they bathed in these it would insure good luck and make their wishes come true. Acting on the old woman's advice, they entered the cave, lighting their way with pine torches. They found one pool of water in which they bathed, and then went in search of the second pool which contained the stronger Sawame. Following the instructions of the medicine woman, they climbed to the narrow entrance of a large chamber. Seeing no water here, they went hand in hand through this chamber and into the winding passages leading from it. In one of these they came to a large pit. One girl more curious and venturesome than the others went near the edge and looked down. Craning far over, her foot slipped and she fell over the edge. She would have fallen at once to the bottom but for the supporting hands of the other maidens. The overhanging wall at the edge of the pit was slippery and her efforts to regain the top were vain. The two girls above could with difficulty retain their footing and in their bewildered state did not have sufficient strength to lift her. At last, exhausted and slipping slowly toward the edge, they let go their hold and the unfortunate girl fell into the pit. They heard her strike, and then again far below a faint thud. They fled in fright from the cave and spread the news among their relatives and friends.

Some of the Indian braves went to the cave taking with them lengths of grass rope, which they knotted together and lowered into the pit. They seemed unable to touch the bottom with their rope and could do nothing. Hearing no sound below, after a time they left the place. They said the spirits had gotten the girl.

From this time on the cave was held in profound awe and was seldom if ever visited by the Indians. The white people who settled in the country soon after the event thought the tale was but an Indian myth and gave it little credence.

The first descent into the large chamber of the cave was made by Professor J. C. Merriam and the writer in August 1903, the other chambers having been investigated by our party a short time previous to this. The work commenced in 1903 has been continued during the past two summers.

Description of the Cave.

The Samwel cave is in the belt of Carboniferous limestone exposed along the lower portion of the McCloud river. It is situated about sixteen miles above the mouth and on the east bank of the river. The limestone ridge hollowed by the chambers is at the foot of a spur of Bollibokka Mountain.

Fig. 1. Location of Samwel Cave. The main entrance is covered by a group of trees on the face of the highest limestone cliff, and below the arrow. The Quaternary entrance to the lower chamber (chamber II) is in the brushy canyon to the right and below. The elevations of the three lowest terraces are given by the grassy flat to the right across the river, by the small patch of open ground to the right above the lowest terrace, and by the highest point on the limestone.

A small canyon which lies to the south has been cut partly through the limestone at its lower portion and leaves a perpendicular limestone cliff as its northern boundary. From this canyon a small cavern penetrates the base of the cliff about

70 feet below, and considerably to the east of the main entrance of Samwel Cave. As this cavern is closely associated with chamber two, it will be discussed with the deposits in that chamber.
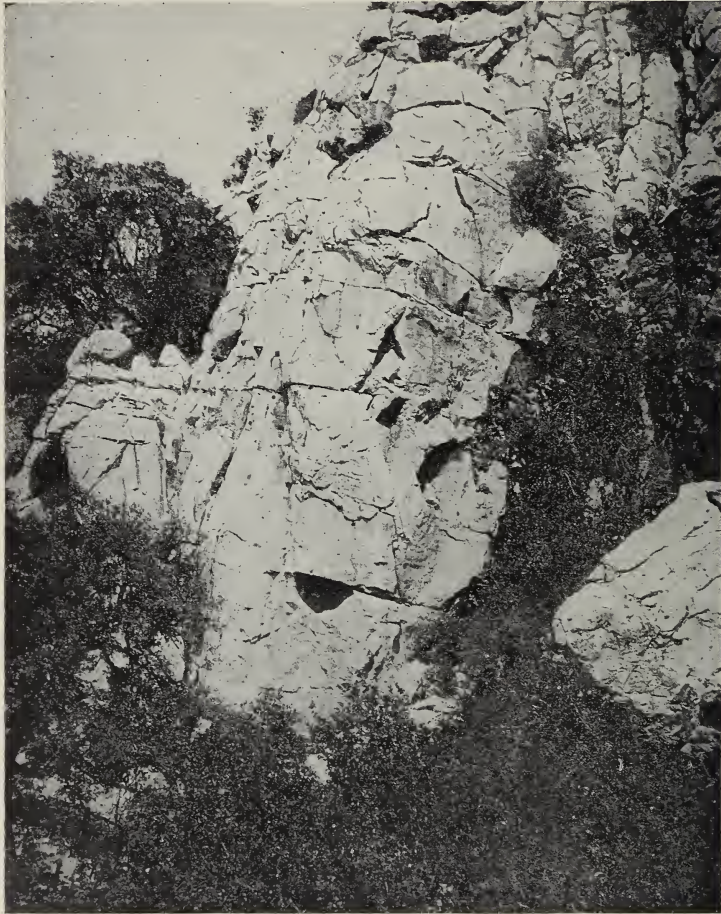
Fig. 2.   View looking toward the cave from the canyon to the south. The existing entrance is behind the trees on a prominent rock shelf projecting to the left from the cliff. The Quaternary entrance to chamber two is behind and below the large fallen block to the right.

The main entrance is on a Quaternary river terrace. The terrace is 355 ft. above the McCloud and 1505 ft. above sea level. It is broad and relatively low and gives access to a large open chamber. The cave as a whole is about 352 ft. long and

exhibits considerable beauty in the curious forms of its chambers and in the numerous stalagmite and stalactite growths contained in them. The entrance chamber is 73 ft. long and 50 ft. wide with an average height of 6 ft. At the extreme northeast end a small opening leads to a long series of lower chambers. Of the latter, the two most important will be designated as chambers one and two.

The lowest portion of the floor of chamber one is 24 ft. below its entrance. From a bench 4 ft. from the floor of the northwest corner a narrow, almost vertical shaft drops a distance of 16 ft. to a winding series of chambers below. The first of these contains the first pool of water referred to in the Indian legend.

About on a level with the entrance to chamber one and its extreme northeastern part, a narrow opening leads to a series of rooms running to chamber two. These have a general trend from south to north. The north chamber contains the chimney-like opening to the chamber below. From the floor of chamber two many small grottoes lead out in several directions. At the southeasterly side a low-arched grotto leads to a passage way which will be discussed later.

Character of the Deposits.

The principal deposits are in chambers one and two. The deposit in *chamber one* partly fills a small fissure-like grotto which leads off from this room. It extends into the chamber and fans out, covering a portion of the floor. This deposit is 29 ft. long, an average of 4 ft. wide and is 8 ft. deep in its thickest portion. The section is as follows :

Reddish clay	·1 to ·3 ft.
Stalagmite capping	·1 to ? ft.
Earth mixed with angular gravel	·3 to 1·6 ft.
Breccia	2· to ?
A floor of stalagmite	·1 to ·3 ft.
Earth grading into breccia	1·2 to 4·4 ft.

The deposit was evidently formed by earth and limestone fragments falling from the outside, through an aperture at the top of the grotto. There is now no sign of such an opening. However, earth can be seen on the fissure walls and projections till the walls meet at the top.

That there was an intermission of sufficient time for stalagmite to form before the completion of the deposit is shown by the presence of the false floor. Probably the aperture was choked for a time and later reopened. All of the material of the deposit evidently came in at one place, as it is as much in the form of a low cone as the fissure will allow. The apex

was near the middle of the fissure with its sides sloping to either end.

FIG. 3.   A portion of the floor of chamber two, Samwel Cave, after the greater part of the fossil material had been removed.   The type skull of *Euceratherium* was still in the stalagmite to the left of the undisturbed skeleton of the Indian woman.

The deposit in *chamber two* has greater surface area but is much shallower than that in chamber one.   Its greatest length is 36 ft. from north to south and greatest width 18 ft.   From north to south it is on an incline plane, the southern end being

5 ft. below the surface level at the north end. It is composed of thin beds, as follows:

Fine-grained reddish clay	·01 to ·4 ft.
Stalagmite capping	·1 " ·4 "
Mixed earth and gravel	1· " 2· "
Stalagmite	·05 "
Fine earth and gravel	·2 "

This shallow deposit was derived from material in the cave chamber, angular limestone gravel, stalagmite formed from dripping, and from very small streams of water carrying in material. The earth and clay were carried in by the water and possibly some part of it was tracked in by animals.

On the southeast side a grotto leading off from the chamber shows the sloping stalagmite-covered surface of a deposit that fills a large space between the outside, canyon entrance before referred to and chamber two. The deposit was tunneled through, thus making open communication between the surface and this chamber. The deposit is 56 ft. long, running approximately southeast by northwest; its greatest depth is 28 ft. Its surface in the canyon entrance is covered by blocks of limestone. The deposit in this portion of the cave has been intermittent in its deposition. Strata of mixed earth and gravel and of red earth occur. In about the middle of the beds, in vertical section, a thick flooring of stalagmite appears. It is thicker at places where there has been drip from the roof.

The material of this deposit was carried in by wash and slide from the entrance during the cutting of the canyon. It filled a former entrance of chamber two.

Method of Excavation.

As in the Potter Creek cave, the deposits were sectioned off in numbered squares of 4 ft. That of chamber one was first excavated. A cut was made in the deposit at the entrance to the fissure and carried through to the inner end. The fossil material was removed from benches a foot deep and each specimen labeled as to horizontal and vertical position. As the digging progressed, the waste material was thrown back to the hard floor in chamber one. It was necessary in working through the breccia to use powder and blast, though this was detrimental to the fossils contained in the breccia.

Previous to the opening of the outside passage way to the grotto in chamber two, a ladder 85 ft. long was necessary to gain access to its floor. For this purpose a rope ladder with wooden rounds was used. Two holes were drilled in the floor of the chamber above. In the holes drills were securely imbedded. Thimbles that were fastened in the free upper ends of the ladder were then dropped over the drills and tied

there. The ladder hung free from its upper fastenings to the floor below.

The deposit in chamber two was also sectioned off and the dirt removed section by section. Specimens were frequently cemented by stalagmite to the hard floor at the bottom of the deposit and had to be freed by the use of gads.

The discovery of specimens imbedded in the surface of a stalagmite-covered slope led to the excavation in the southeast grotto leading from chamber two. A low tunnel 20 ft. long was run through this deposit in a southeasterly direction. At the farther end a space 8 ft. high by 4 ft. wide was hollowed out. Falling blocks of stone and the danger of a sudden caving in of the loose dirt above made a discontinuance of the work at this place necessary.

With the object of ascertaining the distance of the tunnel workings from the canyon outside, Professor Merriam made a series of measurements with compass and a tape line from the far end of the tunnel to the top of chamber two and through the winding passages of the cave to the canyon grotto outside. These measurements indicated that the small cave at the base of the cliff in the canyon was but a few feet from the inner tunnel workings. Work was then commenced in the floor of the canyon cave. A shaft was sunk 4 ft. square by 10·5 ft. deep, at which depth a stalagmite floor was encountered. At this place a strong draught of air which made the candles flicker was noticed coming from a stratum of gravel in the cave. A drift 8 ft. long was run at right angles to the shaft in a northeasterly direction. As the drift progressed the draught had perceptibly increased and become so strong and cold as to make working uncomfortable. On continuing in the same direction an opening was made to a series of two sealed grottoes. The surface of the deposit slope formed the floor of these. Signals had been previously arranged so that a person knocking against the walls in the tunnel from chamber two would be understood if heard by those above. When excavation had reached the sealed grottoes, signals could be distinctly heard close by. In moving about the floor to locate the signals from chamber two, we suddenly heard a voice below warning us to move carefully or we should break through. It was found that a distance of only about one and one half feet intervened between the tunnel and the grotto above, and a moment's work with a shovel opened communication with the chamber below.

Fossil Remains.

The deposits in *chamber one* contained a relatively large quantity of material. Teeth and bones of extinct species were found on the surface. Many complete bones were taken

from the loose earth and gravel, also numerous teeth. Fragments and split bones were plentiful. The breccia layer was exceptionally rich in remains. Most of the specimens are in a fine state of preservation. Those on the surface had a coating of stalagmite of varying thickness. When the stalagmite was removed the bone was found to be white and fresh looking although it contained no organic matter. The specimens from the earth were more or less discolored though in good condition. The bones of young individuals in some cases were in a crumbling condition. In the gravel layers a thin incrustation of stalagmite covered the bones. Some old rodent burrows were dug into the upper layer of earth and in these recent rodent remains were numerous. The fragmentary material consisted principally of split pieces of narrow bones. The pieces were in most instances gnawed around their edges by rodents, the marks of the incisor teeth being distinct. Some fragments show long grooves and roughened places on the surface as if they had been crushed between the teeth of large carnivores.

The fossils in this deposit had access through the same opening as the earth and gravel and were deposited with it. That probably there were two distinct periods of deposition is shown by a slight difference in fauna in its top and bottom layers. In the lowest portion of the deposit ground-sloth (*Megalonyx?*) teeth occur, but they are absent in the top layers. So far there are 20 species recognized; of these 8, or 40 per cent, are extinct.

Following is a list of species from the fissure deposit :—

> *Ursus americanus* Pallas.
> *Ursus*, n. sp.
> *Vulpes*, sp.
> *Putorius arizonensis* Mearns.
> *Aplodontia major* Merriam C. H.
> *Aplodontia* near *major* Merriam C. H.
> *Aplodontia rufa* Rafinesque.
> *Arctomys*, sp.
> *Lepus auduboni* Baird.
> *Thomomys*, sp.
> *Thomomys monticola* Allen.
> *Citellus douglasi* Richardson.
> *Sciurus*, sp.
> *Erethizon epixanthus* Brandt.
> *Euceratherium collinum* Sinclair and Furlong.
> *Haplocerus*, sp.
> *Odocoileus*, sp.
> *Equus occidentalis* Leidy.
> *Elephas*, sp. (tooth fragment)
> *Megalonyx*, sp.

The area of deposit in *chamber two* when first viewed presented an interesting spectacle. Its surface was strewn with skulls and limb bones. Near the foot of the ladder lay a cougar skull. It was covered with stalagmite an inch thick but showed the outlines of skull perfectly. Imbedded in stalagmite, the limb bones of the same individual were lying near it. Near the middle section the skeleton of the unfortunate Indian woman was stretched on its side. The pelvic girdle and skull had a thin film of stalagmite crystals over them, and the remainder of the bones were covered by a soft black mould. Near the human skeleton lay the type specimen of *Euceratherium**. In the surface clay and lying loosely about were several raccoon skeletons. Porcupine and other rodent bones were plentiful. Mammal remains were abundant from the top of the deposit to the hard floor below. In the clay and on the stalagmite capping the fossil remains of several Myriopods were found, the exoskeletal structure and form being perfectly represented.

On some of the higher slopes in chamber two and in most of the grottoes there were a number of small skeletons. Of these, several were porcupines and raccoons. An almost complete porcupine skeleton with the bones lightly covered by stalagmite was found in one of the grottoes. In most instances the enveloping stalagmite tended to keep them in perfect condition. A marked feature of the specimens deposited at this place was the completeness of several skeletons and the unbroken condition of skulls and limb bones. For this reason the supposition of entrance through the opening 85 feet above would be improbable. The presence of entire skeletons of bear, cougar, *Preptoceras* and small carnivores led to the belief that the animals with the exception of the ungulates had free access to the cave at some previous time. The later work of excavating from the southeast grotto to the canyon cave proved the belief to be correct. From the slope in the grotto, where the tunnel was run, to within 8 feet of the surface at the outside entrance, scattered parts of individuals like the animals in the main deposit were found. The well-known hibernating habit of bears readily accounts for their presence in the chamber. At the present time hunters in that region make the rounds of the known caves where bears are in the habit of housing for the winter. It is not uncommon for cougars to use such places for a lair. It is not improbable that bears and cougars used chamber two when entrance was possible. It is true such animals do not care to go far from the light, but it would not have been necessary during the time the cave was inhabited. The deposit filling the old

* Furlong and Sinclair, Bull. Dept. Geol. Univ. Calif., vol. iii, p. 411.

entrance is of considerable extent and fills a large space that when clear would probably permit rays of light to penetrate to some of the deeper parts of the chamber.

That bears and cougars prey on ungulates and smaller mammals is well demonstrated in the present day, and the finding of large quantities of scattered and broken ungulate material, such as deer, *Euceratherium*, *Preptoceras* with many rodents, as rabbits and gophers, supports the view that they were brought in by carnivores. The large carnivore skeletons were found in several cases to be nearly complete and but little disturbed, and the supposition that the carnivores inhabited the cave and were in the habit of dragging their prey to the lair to feast on it at leisure, is probably correct.

Following is a list of the species represented in chamber two and in the deposit leading from the chamber. There are 21 species, of which 6, or 28·5 per cent, are extinct.

> *Ursus*, n. sp.
> *Ursus*, sp.
> *Urocyon townsendi* Merriam C. H.
> *Procyon* near *lotor* Linn.
> *Felis* near *hippolestes* Merriam C. H.
> *Mephitis occidentalis* Baird.
> *Mustela*, sp.
> *Aplodontia* near *major*.
> *Erethizon epixanthus* Brandt.
> *Lepus auduboni* Baird.
> *Lepus*, sp.
> *Microtus*, sp.
> *Neotoma fuscipes* Baird.
> *Neotoma*, sp.
> *Sciurus*, sp.
> *Citellus douglasi* Richardson.
> *Euceratherium collinum* Sinclair and Furlong.
> *Preptoceras sinclairi* Furlong.
> *Odocoileus*, sp.   (*a*)
> *Odocoileus*, sp.   (*b*)
> *Megalonyx*, sp.

Age of Samwel Cave Fauna.

The Samwel fauna through its percentage (over 30 per cent) of extinct species, and its typical Quaternary species, as the ground-sloth, *Equus occidentalis*, *Teonoma spelæa*? *Ursus* n. sp., *Elephas*, *Euceratherium* and *Preptoceras*, establishes its age as Quaternary.

A comparison of the species from chamber one and chamber two shows a greater percentage of extinct species from the former. That the remains may have had entrance to chamber one many years before it was possible for chamber two to be

used by animals or for their remains to reach it, is shown by the relative positions of the two entrances. Though the former entrance to the fissure in chamber one is closely sealed, its outer opening could only be from the top of the cliff the cave is in. The entrance to chamber two from the canyon bed is a hundred or more feet below the point where the fissure entrance was probably located. The additional time required for cutting of the canyon to the depth of the lower entrance would be considerable.

The foregoing reasons, viz: the faunal difference and the probably greater age of the entrance to chamber one, tend to show that the fissure deposit is older than the deposit in chamber two.

While the faunas of Potter Creek Cave and Samwel Cave are both Quaternary and are closely allied, there are some differences that suggest difference in age. *Preptoceras* and the Porcupines are present in Samwel Cave and absent from Potter Creek Cave. *Arctotherium*, *Camelus*, and *Mastodon* are present in Potter Creek Cave and absent from Samwel Cave. These faunal differences are probably to be correlated with a difference in the physiographic relations of the Samwel Cave and indicate that it is of somewhat later origin than the Potter Creek cave. In support of this hypothesis, the river terraces of the McCloud canyon offer some evidence.

On both sides of the McCloud canyon at Samwel Cave several distinct terraces are visible. Across the McCloud, south of Bollibokka, well-defined terraces are cut in Hirtz Mt.; the lowest of these is 27 feet above the river. Above the latter, approximately 150 feet higher, is a smaller terrace. Between this and a terrace approximately 300 feet higher several small benches occur. The 177 ft. terrace corresponds to a level but a short distance below the canyon cave entrance. The 300 ft. terrace is on a level with the top of the cliff over the main entrance to the cave. One of the small benches between the 177 and 477 ft. terraces corresponds to the level of the main entrance itself. It is probable that when the McCloud river flowed at a level 477 ft. higher than its present height opposite the cave, and when making the terraces at that height on Hirtz Mountain, the cave was being partly carved out by solution and subterranean water flow. During subsequent river cutting to the terrace in front of the upper cave entrance, the large chambers were formed. The time represented by the cutting between this last terrace and the one just below the canyon entrance was the period when mammals inhabited portions of the cave and the deposit in chamber one was formed. During the latter part of this period chamber two was opened and occupied. When the river cut to a still lower level and the

canyon on which the lower cave entrance opens was deepened, the lower entrance was gradually filled.

The terrace 477 ft. above the river on Hirtz mountain corresponds to the level of the top of the cliff over the Samwel Cave and probably represents also the present elevation of an early terrace stage mentioned by Dr. Sinclair.* It is 240 ft. above the river level at Baird and is represented by gravel-strewn terraces at that height. This being the case, considerable time must have elapsed after the opening of Potter Creek Cave, which opened at the 800 ft. level and prior to the opening of the Samwel Cave.

Possible Quaternary Artifacts.

In the course of excavation numerous split bones were encountered. Most of these have many marks made by rodents and large carnivore teeth. Some have been gnawed around their entire edge. Split bones were also found that have polished surfaces like some of those described by Sinclair from the Potter Creek Cave.

A piece of chipped lava was removed with some bones a few inches below the surface in the deposit in chamber one. It was found after the firing of a blast and may have fallen in from the surface, though its being covered by a film of stalagmite may support the belief that it was in place.

A chipped obsidian was removed from a bucket of earth and gravel hoisted from a depth of several feet while sinking the shaft through the deposit filling the lower entrance to chamber two.

The description and discussion of the archæological value of these specimens by Professor F. W. Putnam is in press at the time of writing this report.

University of California, May, 1906.

* Univ. Calif. Publ. Am. Arch. and Eth., vol. ii, No. 1, p. 24.

Art. XXIII.—*Occurrence of Unakite in a New Locality in Virginia;* by Thomas L. Watson.

The name unakite was proposed for a unique variety of granite composed of the essential minerals epidote, pink feldspar and quartz, from the Great Smoky Mountains, a portion of the Unaka range of the Blue Ridge, which marks the boundary between Tennessee and North Carolina. The type locality, Madison county, North Carolina, and Cocke county, Tennessee, was first described by Bradley in 1874,[*] and the specimens were from the slopes of the peaks known as "The Bluff," "Walnut Mountain," and "Max's Patch," Cocke county, Tennessee, and Madison county, North Carolina.

Later, a second locality in which this rare variety of granite occurs was noted in the Blue Ridge at Milam's Gap, near Luray in Page and Madison counties, Virginia. Phalen[†] visited and studied the unakite in the Virginia area and, in 1904, published a preliminary paper on the occurrence and petrography of the unakite and its associated rock.

The occurrence of the unakite in the two widely separated areas is somewhat similar, but the unakite-bearing rock is different in each locality. In the North Carolina–Tennessee area the unakite-bearing rock is an epidote-bearing mica granite which, in places, contains little or no quartz and becomes syenitic.[‡] The unakite-bearing rock in the Milam's Gap area of Virginia is reported by Phalen to be a hypersthene akerite. In both localities the epidote of the unakite has been proved by Watson and Phalen to be secondary.[§]

In a recent trip to Ashe county, North Carolina, the writer collected specimens of typical unakite from Grayson county, Virginia, a locality not hitherto reported, so far as the writer is aware. Specimens were collected along the Marion-Jefferson public road, about two and a half miles south of Troutdale, a railroad terminus near the crest of Iron Mountain, in Grayson county, Virginia. Time was insufficient to prove the extent of the area or to study the occurrence and association of the rock. Loose angular masses of moderate size of the unakite were observed for some distance along the roadside and the specimens taken closely resemble those from Madison county, North Carolina. The rock (unakite) is composed of dominant yellow-green epidote, deep pink feldspar and quartz, with no trace of a ferromagnesian silicate indicated.

[*] This Journal, vol. cvii, pp. 519–520, 1874.
[†] Smithsonian Miscellaneous Collections, vol. xlv, pp. 306–316, 1904.
[‡] Watson, Thomas L., Journal of Geology, vol. xii, p. 395 et seq., 1904.
[§] Loc. cit.

Geological Department, Virginia Polytechnic Institute, Blacksburg, Virginia, June, 1906.

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

In the October, 1903, issue of this Journal the writer noted briefly the discovery of insects in the Permian of Kansas. The material is of exceptional interest as giving the most complete record of Permian insect life thus far obtained. Somewhat over two thousand specimens are now at hand and indicate the richness as well as the interesting character of the Permian insect fauna. For the present paper, leading types from the collection are selected for description, a full account of the fauna as a whole being reserved for subsequent monographic treatment. Unless otherwise indicated, the type specimens described are in the writer's collection.

Part I.—*Odonata.*

Odonata have not been obtained previously from the Permian. Several genera are known from the Coal Measures, those from the Commentry Coal Measures of France being particularly well known through the researches of Brongniart.[*] In the Mesozoic the group is fully represented by a rich series of specimens from the Solenhofen deposits. The American Permian specimens give, therefore, a welcome addition toward a fuller history of this interesting line of insect development.

The foundation studies of Comstock and Needham,[†] together with the special study of dragon-fly wing venation by Needham,[‡] have afforded for the classification of the dragon-flies a basis much more secure than has been available heretofore. In seeking types among the living genera with which to compare the fossil forms, I have found it convenient to go repeatedly to Needham's paper, as being, in the absence of a large dragon-fly collection, the most accessible and most reliable source of detailed information regarding the wing venation of the modern forms. I very gladly express my indebtedness to these authors for their valuable investigations, without which a study of the Permian types would have been attended with much greater difficulties.

The following discussion is based, so far as it concerns Permian forms, on the exceptionally well-preserved specimen illustrated by the accompanying figures, 1 to 6. The genus and species are new and I suggest that this type be known as *Tupus permianus.*

[*] Récherches pour servir a l'Histoire des Insectes fossiles des Temps primaires, Charles Brongniart, pp. 394–406, 1893.

[†] The Wings of Insects, by J. H. Comstock and J. G. Needham, Amer. Nat., vol. xxxii, 1898, and vol. xxxiii, 1899.

[‡] A Genealogical Study of Dragon-fly Wing Venation, Proc. U. S. Nat. Mus., vol. xxvi, pp. 703–764, pls. xxxi–liv.
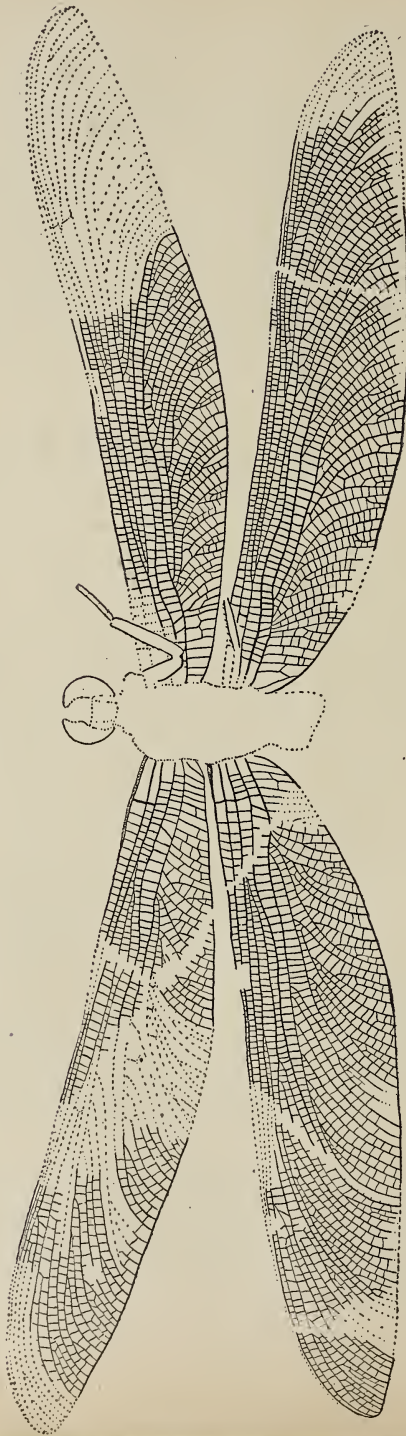
FIGURE 1.—*Tupus permianus* gn. sp. n. Type specimen slightly reduced. The specimen as illustrated is viewed from the ventral side, the base of the wings passing under the body. The strongly outlined structures on the under side of the head are apparently the mandibles, which in this as in European Paleozoic forms are unusually strong. The distal end of the femur, the tibia and a part of the tarsus of the left front leg is preserved, as is also a small part of the tibia of the second pair of legs. The tibia is spinous and the legs appear not to have been strong.

In the description to follow, the wing is considered by areas, as in this way its relations to earlier and to later forms are more readily indicated.

The base of the wing.—The base of the modern dragon-fly wing represents, as is well known, some very characteristic features. The costa is strong and marginal or with merely a narrow expanse of thickened membrane. The subcosta lies at the bottom of a deep fold. The radius and media are fused at the base and lie at the top of a corrugation. The cubitus appears in the basal part of the wing as a strong vein at the bottom of a furrow. The anal, also a strong vein, lies in turn at the top of a fold. Essentially the same features are presented by the base of the wing of Coal Measures and Permian dragon-flies, thus affording a starting point in homologizing the wing veins of Paleozoic and modern types. A clear recognition of the homologous parts at the base of the wing is of great importance in following the further interpretation of the veins throughout the wing, and I introduce here for comparison the base of the wing of a modern dragon-fly with that of the Permian form (figs. 2 and 3).

The costa.—The costa, as indicated, is in essential agreement with that of modern dragon flies. The genera thus far made known from the Commentry Coal Measures have, according to the illustrations of Brongniart, a more distinct precostal area than has *Tupus*. The one genus known from the American Coal Measures, *Paralogus* Scudder, in which this basal area is preserved, has, according to Scudder,[*] the subcosta (mediastinal) close to the margin.

The subcosta.—The subcosta continues simple, reaching usually beyond the middle line of the wing, gradually approaching and merging in the margin. In the modern forms the subcosta terminates at the strong cross vein forming the nodus. This special modification is concerned chiefly with the specialization of cross veins and will be considered under that head.

The radius and media.—The radius and media separate at a distance of from $1\frac{1}{2}$ to 2^{cm} from the base, the media going off at an oblique angle. Radius$_1$ continues as a simple vein to the apex of the wing. The media divides immediately after separating from the radius. The two resulting divisions admit of interpretation as the homologues of the veins marked in all of Needham's figures as M_{1-3} and M_4, the upper division (M_{1-3}) falling into a furrow, the lower (M_4) topping a fold. Their subsequent divisions likewise admit of homologizing in the same way. M_4 runs in

[*] Insect Fauna of the Rhode Island Coal Field, Bull. U. S. Geol. Survey, No. 101, p. 20, pl. 1, figs. *a* and *b*, 1893.

a curved course and reaches the inner border well toward the apex, and has, as is usual with the general run of Odonata,
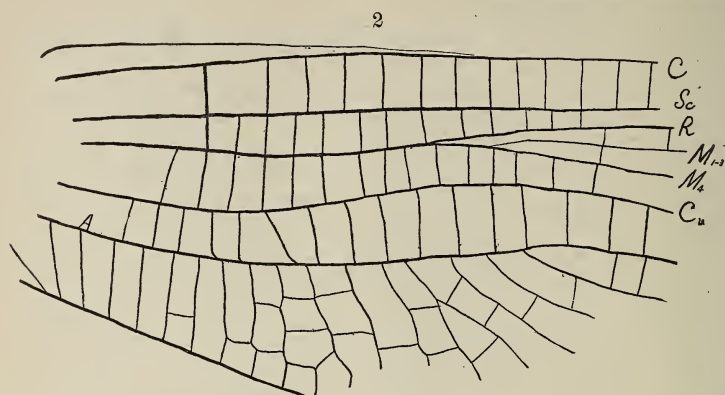

FIGURE 2.—Base of the right front wing of *Tupus permianus*. C, costa; Sc, subcosta; R, radius; M_{1-3}, branches 1 to 3 of media; M_4, fourth branch of media; Cu, cubitus; A, anal. Drawn with the camera lucida; enlarged four diameters.

particularly Odonata Anisoptera, a considerable number of veins from the lower side filling the space between itself and the cubitus. M_3 separates from M_{1-2}, and, again agreeing to a surprising degree with M_3 of Anisoptera, runs in a curved course parallel and close to M_4. No interpolated veins appear between M_3 and M_4. M_{1-2} divides opposite the subnodus; from this point both divisions continue as simple veins, presenting again an unexpected agreement with Odonata Anisoptera.
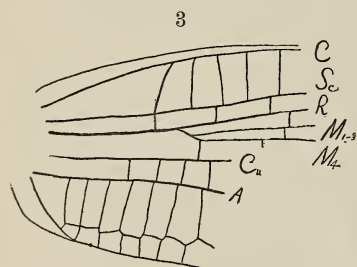

FIGURE 3.—Base of the wing of a modern dragon-fly. Lettering and enlargement as in figure 2. Both wings are viewed from the ventral surface, the body obscuring the extreme base of the wing.

Radial sector, subnodus, and oblique vein. — It is a well-known fact that to recognize the radial sector in the adult dragon-fly wing is often a matter of difficulty. With the Paleozoic forms, the adults only of which are available, we must therefore expect to recognize the radial sector, as a rule, from its relation to other veins rather than from any evidence in the sector itself. Fortunately, however, in most dragon-flies structural evidence bearing on the position of the radius is not wanting even in the adults. The keen observations of Need-

ham emphasized the fact that there exists in the wing of most adult dragon-flies a persistently oblique cross vein lying usually at or just beyond the separation of M_{1-2}; also a similar oblique vein above, uniting the radius and M_1. From the nymph wing it was found that the trachea of the radial sector crosses $M_{1, 2}$, and that the oblique apparently cross veins are in fact parts of the sector. An examination of this region on the Permian genus *Tupus* reveals the presence of such an oblique vein arising from M_2 at a point just beyond the separation of M_1 and M_2; also an equally well-marked oblique vein, the subnodus, connecting the radius and media. Bearing in mind the complete agreement of all other veins of the radio-medial area with those of the same area in modern Odonata, there can
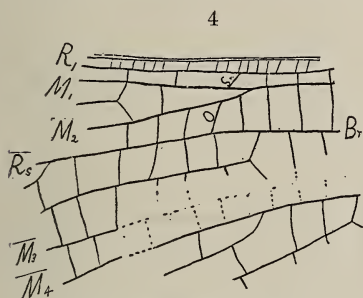
4 5

FIGURE 4.—Enlarged detail of the region of the subnodus of *Tupus permianus*, taken from the right front wing. Sn, subnodus; O, oblique vein; Br, bridge; R, radius: M_1, first main branch of media; M_2, second main branch of media; Rs, radial sector; M_3, third, and M_4, fourth main branches of media. Enlarged 4 diam.: drawn with camera lucida.
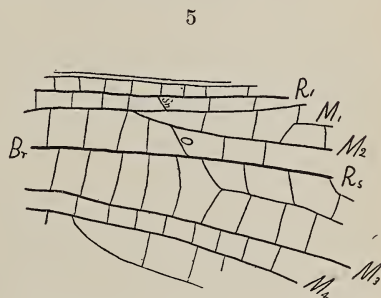
FIGURE 5 —Same area from the left hind wing of *Tupus permianus*. Enlargement and lettering as in figure 4. In this wing there is a slight depression (not shown in the figure) running from the subnodus toward the oblique vein.

scarcely remain a doubt as to the meaning of these two oblique cross veins. They clearly indicate a crossing of the radial sector. The area of the wing in the region of the crossing of the sector is shown enlarged in the accompanying camera lucida sketches. The fundamental significance of the crossing of the sector as a bond or relationship between Paleozoic and modern forms is too obvious to require further emphasis.[*]

It will be observed that in this Permian genus there is apparently a loss of that part of the sector lying between M_1 and M_2.

[*] Handlirsch's statement, Revision American Paleozoic Insects, p. 689, with reference to the Protodonata, that the "intersection of the longitudinal veins" is "still entirely wanting," can not, I feel sure, be maintained in view of the evidence here presented. The agreement of the veins of the entire radio-median area is altogether too complete to admit of explanation on any grounds other than that of strict homology.

In the left hind wing there is a slight depression not shown in the illustration, continuing the subnodal vein and running toward the oblique vein, indicating possibly the position of the vein or trachea. A comparison of the position of the subnodus
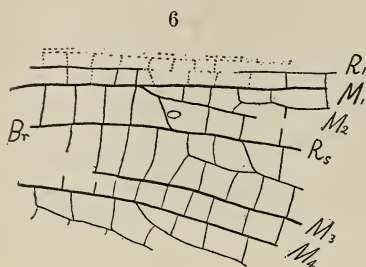

FIGURE 6.—Same area from the right hind wing of *Tupus permianus.* Dotted lines indicate restored border of the wing lost from the breaking of the matrix. Enlargement and lettering as in figures 4 and 5,
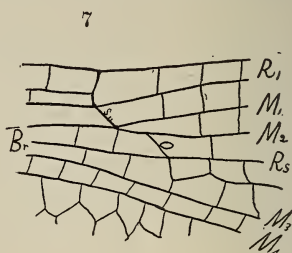
FIGURE 7.—Same area from the wing of a modern dragon fly. Enlargement and lettering as in former figures.

and oblique vein as seen in *Tupus* with the position of the trachea as seen in many modern nymphs is instructive. From the nymphs it will be seen that the trachea often lie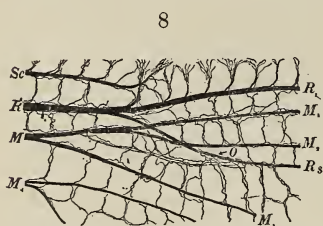s across the media beyond the separation of M_1 and M_2, occupying approximately the position of the subnodus and oblique vein of *Tupus*. In the adult condition of modern dragon-flies the subnodus, as a rule, meets the media just at the point of separation of M_1 and M_2. It is probable that the subnodus has migrated in modern adult dragon-flies to its present position from an earlier primitive position, sometimes beyond the forking of M_{1-2}, sometimes perhaps basad of that point. As a result of its important function as a brace the subnodus is held firmly in place, while the oblique vein, serving no such responsible function, is much less constant in position.

FIGURE 8.—Position of trachea of same area of modern nymph dragon-fly, genus *Didymops;* after Needham. Lettering as above. The indistinct trachea preceding the bridge is present, although not lettered.

The cubitus.—Cu_1 continues from the strong basal origin as a simple sinuous vein meeting the inner border slightly beyond the middle line of the wing. It is observed that the various genera of modern dragon-flies differ not a little among them-

selves in the disposition of the cubitus. With the advanced Anisoptera there is, as demonstrated by Needham, an abrupt bend in the cubitus just back of the arculus, the bend thus made forming the base of the triangle. With the Zygoptera the bend is much less conspicuous and the sinuous or uniformly curved type of Cu_1 is the rule. The Zygoptera have thus retained a cubitus much less differentiated from that of the Permian form than have the Anisoptera. The course of Cu_2 in the Odonata is one of the highly characteristic peculiarities of that unique order. Its distinctive feature lies in the fact that immediately after leaving Cu_1 it fuses with the first anal, continuing that vein and giving in the adult the appearance of a single strong vein from the base of the inner border. In those advanced Anisoptera in which the cubitus is most abruptly bent, Cu_2 is given off at the point of closest approach to the anal. With those more generalized Odonata in which the cubitus has a sinuous course, the basal part of Cu_2 appears as a cross vein. It is hardly to be expected that the particular cross vein representing the basal part of Cu_2 can in all cases be recognized in the fossil genera. It is to be noted, however, that in the Permian genus *Tupus* a cross vein some distance from the base becomes conspicuous by its strongly slanting position (fig. 2). A similar slanting cross vein is seen in Scudder's careful illustration of the Coal Measures genus *Paralogus*.*

The characters thus far discussed are those which concern the distribution of the main veins of the wing, and as such are without doubt the structurally more important characters of the wing. In these characters there is found to exist essential agreement throughout between Paleozoic, Mesozoic, and modern dragon-flies. That there are differences, many and obvious, scarcely needs stating. Such differences as exist, however, are associated almost wholly with the specialization of cross veins and as such are of secondary importance. They are conveniently discussed under the heading of cross veins.

Cross veins.—Specialization of cross veins plays a leading part in the development of mechanical strengthening devices with which the wings of modern dragon-flies are so richly supplied. With the Paleozoic dragon-flies, however, the cross veins are but little differentiated among themselves. Such specialization as has occurred has taken the direction principally of the matching of cross veins and is most advanced in the basal and dorsal part of the wing. In the Permian genus *Tupus* there is observed near the base a strong brace corresponding to the triangular brace at the base of the wing of

* Bull. U. G. S., No. 101, pl. i, fig. a.

many modern genera. Lines of matched cross veins are seen also in the basal part of the wing (fig. 2).

Nodus and stigma.—On the Paleozoic genera thus far known, both nodus and stigma are apparently lacking. Since the nodus is recognized as merely a strongly developed cross vein running from the costa to the radius, at which cross vein the subcosta usually terminates, the existence of a weak nodus on some of the more specialized late Paleozoic genera need occasion no surprise. It is to be expected that the subcosta will in early types reach beyond the cross vein, the nodus appearing simply as a strong cross vein from costa to subcosta, matched with a similar strong cross vein from subcosta to radius. Much the same may be said of the stigma, a strengthening structure thus far not observed to occur on these early Odonates.

The arculus.—A very conspicuous structural feature of the modern dragon-fly wing is the arculus. As is well known, the arculus of this, as of other orders in which it occurs, consists in part of the media directed obliquely at its point of origin from the radius, and in part of a strong cross vein from the media to the cubitus. The arculus, as a conspicuous feature, is absent from the wings of Paleozoic dragon-flies ; yet the elements which compose it are there and in their respective positions. For the formation of a characteristic arculus there is needed scarcely more than a slightly accentuated bend of the media at its separation from the radius and a correlated strengthening of the cross veins bearing the chief stress in the support of the media. Along with this will go naturally the more or less complete disappearance of the now unnecessary accessory cross veins.

Triangle and quadrangle.—The structures known as triangle in the Anisoptera and as quadrangle in Zygoptera result, as in the case of the arculus, from specialized cross veins in conjunction often with a modified course of the adjoining main veins. The base of the triangle of the Anisoptera is formed by the cubitus, and results from an abrupt bend of that vein just beyond the arculus. The sides of the triangle are formed each by a cross vein running from the cubitus to the media. With the Zygoptera, in which the bend of the cubitus is less abrupt, there is naturally a less well-marked structure in this region, and as the arrangement of cross veins gives to this area a quadrangular rather than a triangular shape, Needham has proposed to designate it as the *quadrangle.* As has been noted above, the cubitus of the known Paleozoic forms agrees with that of the generalized modern Odonates in its sinuous, rather than abruptly bent course. With the most generalized of modern Odonates the quadrangle or triangle, as conspicuous

features, can scarcely be said to exist. To this extent they approach the Permian type.*

The bridge.—To the supplementary longitudinal vein interpolated between M_{1-2} and M_3 and connecting with the radial sector, Needham has applied the term *bridge.* The bridge appears as a normal feature in *Tupus.* A part of the bridge is seen also in *Paralogus.* Unfortunately the tip of the wing of that genus is not preserved. The crossing of the radial sector has doubtless promoted the early development of this structure.

Classification.

In the scheme of classification of Paleozoic insects proposed by Professor Samuel H. Scudder, the Paleozoic dragon-flies were disassociated from their modern descendants and placed along with all other Paleozoic insects in the Paleodictyoptera. Brongniart (Récherches des Insectes fossiles) places the Protodonata as a family group under the large order of Neuroptera. Professor Anton Handlirsch, in his recent publication (Revision of American Paleozoic Insects) has advanced the Protodonata to ordinal rank to stand as a Paleozoic order coördinate with the Odonata of Mesozoic and modern times.

It will be remembered that Professor Scudder, in defense of his general plan of classification, has urged repeatedly that the insects of the Paleozoic were more closely related *inter se* than to their descendants of the Mesozoic and later times. A classification based upon Scudder's principle must, in the nature of the case, break down with the advance of knowledge of extinct forms, for as the life history of the various lines of descent is continuous, it necessarily follows that the artificially placed dividing line between the Mesozoic and Paleozoic can remain a distinct break only so long as there remains time for a considerable development between the earliest known Mesozoic and the latest known Paleozoic representative of that particular line. In Scudder's classification emphasis is thrown on the interrelation of associated but diverging groups, or what may be called the lateral relation of organisms, rather than on the lineal or phylogenetic relations. In this connection I have urged a principle of classification[†] by no means new in its application, as follows:—"Any natural group of organisms should be recognized as extending back in time until a point is reached at which that group coalesces with a group or groups of coördinate rank, or unites with the parent stock." The principle proposed by Scudder necessitates breaking phyla,

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* As a genus with cubitus unexpectedly similar to that of *Tupus,* compare *Pseudophœa.*

† This Journal, vol. xviii, p. 121, 1904.

the earlier members to be grouped with the parent or associated phyla, while the later stand in our classification under distinctive names. The line selected as the point at which to break the various insect phyla was the imaginary line dividing Paleozoic and Mesozoic—a line subject to change with the advance of stratigraphy and paleontology and in any case confessedly a line of convenience. A more natural classification is attained by recognizing under a single head an entire phylum. Difficulties will be met in applying the principle, owing to the near approach of the first ancestor of a phylum to the parent phylum (unless the origin of phyla should prove to be much more sudden than has been heretofore generally supposed). In practice it is clearly safe to recognize a phylum under a common head as far toward its point of origin as the evidence available permits the line to be with certainty determined. Thus, with the dragon-flies, there is apparently no doubt of the origin of the phylum as a distinct line in Carboniferous or pre-Carboniferous time and continuing to the present time. They are therefore entitled to a group name distinctive of the phylum as a whole.

Regarding the relative rank to be assigned the Protodonata, whether ordinal as proposed by Handlirsch[*] or subordinal, I would urge again what has been shown above, namely, that the main veins of the wings of the Coal Measures and Permian dragon-flies present an arrangement in agreement in their major characters with that of both Mesozoic and modern dragon-flies. The differences found are due to the specialization of cross veins, with which are associated minor changes in the direction of some of the main veins. These secondary differences are to my mind insufficient characters on which to base ordinal rank. The characters which are now known to exist entitle the Protodonata in my view to not more than subordinal rank. According to this view the order Odonata consists of three suborders, as follows: Protodonata, Zygoptera, and Anisoptera. The term Odonata is thus still available as an ordinal term, covering the Odonate phylum as a whole.

[*] Revision of American Paleozoic Insects, Proc. U. S. Nat. Museum, vol. xxix, p. 689, 1906.
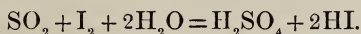
Art. XXV. — *The Analysis of Dithionic Acid and the Dithionates ;* by R. Harman Ashley.

According to the method of analysis employed by Dymond and Hughes[*] in the examination of potassium dithionate, obtained by these investigators as a product of the interaction of potassium permanganate and sulphur dioxide, a weighed amount of the dithionate is dissolved in water, the solution is introduced into a partially vacuous closed flask containing hydrochloric acid, and, after heating, iodine is run in to determine the sulphur dioxide. In this action of hydrochloric acid decomposition takes place according to the equations

$$BaS_2O_6 + 2HCl = H_2S_2O_6 + BaCl_2$$
$$H_2S_2O_6 = H_2SO_4 + SO_2.$$
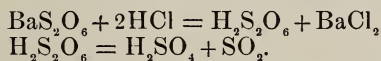
The sulphur dioxide formed is calculated in accordance with the expression

$$SO_2 + I_2 + 2H_2O = H_2SO_4 + 2HI.$$

It is to be noted, however, that the procedure of Dymond and Hughes according to which iodine is introduced into the solution of sulphur dioxide was long ago criticized by Finkener,[†] and for it has been substituted the method suggested by Finkener and elaborated by Volhard[‡] according to which the solution of sulphur dioxide or the sulphite is introduced slowly from a burette into the iodine solution, the purpose being to obviate the establishment of a secondary reaction

$$SO_2 + 4HI = 2HO_2 + S + 2I_2.$$
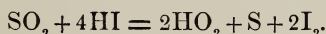
It seemed desirable therefore to study the decomposition of dithionates by boiling with hydrochloric acid under conditions which would permit the estimation of the evolved sulphur dioxide by bringing it into action in small amounts upon an excess of iodine, in accordance with the principle of the Finkener-Volhard process.

Barium dithionate was chosen as a suitable salt for investigation. It was prepared in the following manner : Manganese dioxide suspended in water was treated with sulphur dioxide gas in a vessel surrounded with melting ice. After this treatment the solution was made alkaline with an excess of barium hydroxide to remove sulphates and sulphites as

[*] J. Chem. Soc., lxxi, 314–318.
[†] Finkener-Rose, Quant. Anal., vi Auf., p. 837.
[‡] Ann. Chem. Pharm., ccxlii, 94.

well as to convert the manganese dithionate to barium dithionate. The excess of barium hydroxide was removed by introducing carbon dioxide and boiling to break up any acid barium carbonate which might have been formed and the solution was filtered. The filtrate from the barium carbonate contained pure barium dithionate, which was obtained in solid form by evaporating this solution.

The salt so prepared gave all the reactions of dithionic acid and had a composition corresponding to the formula $BaS_2O_6 \cdot 2H_2O$. In determining the composition of the salt two methods were used. In the first, the barium was precipitated by sulphuric acid and weighed as barium sulphate; in the second method the salt was introduced into a platinum crucible and blasted to drive off water and sulphur dioxide, the residue being weighed as barium sulphate.

A salt of the formula $BaS_2O_6 \cdot 4H_2O$ is said to be formed by slow evaporation.[*] According to my experience, however, the salt crystallized by evaporation over a flame and that by evaporation at the ordinary temperature in a vacuum over concentrated sulphuric acid had the same composition and both preparations gave on analysis figures corresponding to the formula $BaS_2O_6 \cdot 2H_2O$, the results coming within 0·3 per cent of theory. Crystals of barium dithionate are supposed to effloresce, but no evidence of such action was found in my preparations when the crystals were kept in a weighing bottle at ordinary room temperature.

In studying the decomposition of barium dithionate under the action of hydrochloric acid, crystals of the salt were weighed out and transferred into a Voit flask provided with a separating funnel sealed on. The outlet was connected to a Drexel receiver containing a known amount of standardized iodine, and the outlet of this receiver was provided with a trap containing a solution of potassium iodide. Water was first run into the Voit flask through the separating funnel and the salt was dissolved by the aid of heat. Acid was next run in through the separating funnel and the whole was boiled, a current of carbon dioxide being employed to sweep the sulphur dioxide into the iodine. Hydrochloric acid was added from time to time through the separating funnel to keep up the volume of the liquid and the concentration of the acid. After the operation had proceeded for the times noted, the whole was disconnected and the iodine remaining was determined by means of sodium thiosulphate with starch as an indicator. Results of experiments conducted in this manner are given in Table I.

* Watt's Dict., vol. iv, p. 696.

TABLE I.

Decomposition of barium dithionate by boiling with hydrochloric acid.

No.	S_2O_5 taken. grm.	I value of S_2O_5 taken. grm.	I taken. grm.	I value of $Na_2S_2O_3$ required. grm.	S_2O_5 found. grm.	Errors in I. grm.	Errors in S_2O_5. grm.	Time. min.
1	·0854	·1898	·5721	·3782	·0872	+ ·0041	+ ·0018	90
2	·1298	·2885	·5846	·2920	·1316	+ ·0041	+ ·0018	90
3	·1429	·3177	·5778	·2607	·1426	— ·0006	— ·0003	45
4	·1042	·2317	·5765	·3468	·1033	— ·0020	— ·0009	60
5	·1031	·2293	·5884	·3557	·1047	+ ·0034	+ ·0016	60
6	·0704	·1564	·5751	·4228	·0685	— ·0041	— ·0019	60
7	·0778	·1729	·6194	·4637	·0700	— ·0172	— ·0078	60
8	·1043	·2319	·5726	·3395	·1048	+ ·0012	+ ·0005	30
9	·1043	·2319	·5892	·3548	·1054	+ ·0025	+ ·0011	60
10	·1042	·2317	·6110	·3849	·1017	— ·0056	— ·0025	105

The irregularity of these results may conceivably be due to one or more of three different reasons. In the first place, it may be that the decomposition of the dithionic acid is not complete, and that this may be so is shown by the fact that after the liquid in experiment 10 was boiled for an hour and three quarters and filtered from the precipitated barium sulphate, the addition of sulphuric acid caused further precipitation of barium sulphate. Secondly, it may be that some of the sulphur dioxide escapes absorption in the receiver if the current of carbon dioxide is passed through the system too rapidly. Thirdly, the concentration of the hydrochloric acid in the receiver tends, as is well known, to render the titration of the residual iodine by sodium thiosulphate less exact and the starch iodide less delicate as an indicator.

To eliminate the concentration of acid in the receiver, in the following experiments sulphuric acid was substituted for hydrochloric acid in the Voit flask. A weighed amount of barium dithionate was introduced into the Voit flask and there dissolved in water. Sulphuric acid was run in through the separating funnel and the mixture then boiled, the sulphur dioxide being collected in the Drexel receiver, trapped as before with potassium iodide. A slow current of carbon dioxide was driven through the system to sweep the sulphur dioxide into the iodine and to prevent any sucking back. When boiling had been carried so far that fumes of sulphuric acid began to appear the operation was stopped and the excess of iodine remaining was determined by means of sodium thiosulphate, starch iodide being used as an indicator. Results of experiments carried out in this manner are given in Table II.

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

Decomposition of barium dithionate by boiling with sulphuric acid.

No.	S_2O_5 taken. grm.	I value of S_2O_5 taken. grm.	I taken. grm.	I value of $Na_2S_2O_3$ required. grm.	S_2O_5 found. grm.	Errors in I. grm.	Errors in S_2O_5. grm.	Time. min.
1	·1039	·2310	·5759	·3435	·1045	+ ·0014	+ ·0006	20
2	·1046	·2326	·5708	·3372	·1051	+ ·0010	+ ·0005	28
3	·1039	·2311	·5740	·3435	·1037	— ·0006	— ·0002	34
4	·1033	·2297	·5701	·3387	·1041	+ ·0017	+ ·0008	45
5	·1721	·3827	·5712	·1876	·1726	+ ·0009	+ ·0005	35
6	·1719	·3820	·5702	·1894	·1713	— ·0012	— ·0006	50
7	·1726	·3838	·5734	·1898	·1726	— ·0002	·0000	12
8	·1724	·3832	·5727	·1885	·1728	+ ·0010	+ ·0004	10
9	·1721	·3826	·3727	·1886	·1728	+ ·0015	+ ·0007	10
10	·0692	·1539	·3130	·1599	·0689	— ·0008	— ·0003	12
11	·0350	·0777	·3109	·2323	·0354	+ ·0009	+ ·0004	4
12	·2061	·4582	·6205	·1632	·2057	— ·0009	— ·0004	15
13	·2402	·5340	·6215	·0862	·2408	+ ·0013	+ ·0006	15

These results show that dithionic acid may be determined by boiling with sulphuric acid and estimating the sulphur dioxide liberated, while when hydrochloric acid is used the results are far from satisfactory.

There are three reasons why sulphuric acid should work better than hydrochloric acid in this process :

First, when sulphuric acid is added to the solution of barium dithionate, barium sulphate is precipitated and dithionic acid is left in free condition, this reaction proceeding at once to completion because the barium sulphate formed is removed from the system. It would seem that when hydrochloric acid is used the dithionic acid is completely liberated only by a gradual change in the conditions of equilibrium.

Second, when the solution containing sulphuric acid is boiled, the water is driven off, the concentration of the solution increases and the high temperature of the fuming point of sulphuric acid is reached. Under such conditions the decomposition of the dithionic acid is rapid and complete, the time being dependent upon the original dilution of the solution. In one case, No. 11, the operation was ended in four minutes.

Third, no appreciable amount of acid distils over from the Voit flask into the receiver containing the iodine to interfere with the back titration with sodium thiosulphate, the only acid present being that produced by the oxidation of the sulphur dioxide. Under these conditions the starch indicator acts sharply, which is not the case when hydrochloric is used.

SCIENTIFIC INTELLIGENCE.

GEOLOGY.

1. *Ueber Parapsonema cryptophysa Clarke und deren Stellung im System;* von TH. FUCHS. Centralbl. f. Min., etc., 1905, pp. 357–359.—In 1902, Clarke (54th Ann. Regents Rept. N. Y. State Mus., pp. 172–178) described a most perplexing and highly interesting fossil, under the title "Paropsonema cryptophya : A peculiar echinoderm from the Intumescens-zone (Portage beds) of western New York." Fuchs reviews Clarke's paper and adds that "the entire organization is wholly different from all known Echinodermata and can not be readily compared with any. According to my view, we here have the remains of quite another animal, namely, a medusa, related to *Porpita*."

A very excellent cast of one of Clarke's finest specimens was presented by him to Peabody Museum of Yale University. It does not possess unmistakable echinoderm structures, although the radial parts, with their numerous transverse divisions, do in a way recall the ambulacra of Paleozoic echinoids. Unlike these, however, the radial parts of *Paropsonema* are bifurcated, in adult specimens, as many as four times. Then, too, the upper surface is wholly unlike the lower and is not made up of plates. Further, associated with this fossil crinoids occur and in these the calcareous plates are preserved, while in *Paropsonema* there is nothing other than a cast or the infiltrated filling of the cavities. Fuchs states that the lower surface "has a great number [60 to 80] of arched folds that increase by division or intercallation of new radii and carry the individual polyps. . . . Should it prove that my view is the correct one, we then have in this organism, as far as I am aware, the first evidence of a fossil siphonophore related to *Porpita*."

The present writer likewise thinks it more probable that *Paropsonema* is related to *Porpita* and *Velella* (see Agassiz, "The Porpitidæ and Velellidæ," Mem. Mus. Comp. Zool., Harvard, VII, No. 2, 1883) rather than to any echinoderm.   c. s.

2. *Phylogeny of the Races of Volutilithes petrosus;* by BURNETT SMITH. Proc. Acad. Nat. Sci. Phila., 1906, pp. 52–76, and one plate.—This interesting paper gives the results of a study based on many specimens of *Volutilithes petrosus* derived from nine localities, and on four other species. The forms of *Volutilithes* first appear in non-normal marine deposits (Lignitic), having radiated from the outer deeper normal marine waters. These peripheral races undergo "a course of evolution which was a direct reflection of their unfavorable environment. . . . The senility becomes more and more extreme with the course of time." The normal, slow and even development takes place in the more open favorable environment.   c. s.

3. *Notes on some Jurassic Fossils from Franz Josef Land, brought by a Member of the Ziegler Exploring Expedition;* by R. P. WHITFIELD. Bull. Amer. Mus. Nat. Hist., May, 1906, pp. 131–134, 1 pl.—The notes relate to Ammonites, Mollusca, and land plants.

Samuel Lewis Penfield, Professor of Mineralogy in the Sheffield Scientific School of Yale University, died August 12, at Woodstock, Conn., where he had been passing the summer. He was in the 51st year of his age. He had been for some time in bad health. A notice of the life and work of this distinguished mineralogist will appear in a near number of this Journal.

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Art. XXVI.—*The Lime-Silica Series of Minerals:* * by
Arthur L. Day and E. S. Shepherd, with Optical Study
by Fred E. Wright.†

Part I. Introductory.

Anyone who has followed the work of the eminent Norwegian scientist, Prof. J. H. L. Vogt, during the past three or four years, must realize that an extraordinarily effective weapon has come into the service of petrology, the full power of which cannot at once be understood or appreciated. We refer to the methods and established generalizations of physical chemistry. The older science of chemistry has made such strides under these new theories of solutions that we really have little more to do than to apply them ready-made to our own problems, like a smooth and powerful machine tool of guaranteed effectiveness. Mineral solutions, as Bunsen long ago maintained, are after all only chemical solutions over again with slightly different components and a different, a very different, range of temperatures and pressures. There is no need to disparage the difficulties involved in operating at high temperatures and under great pressures; they are very great, probably even greater than most of us appreciate, but they are certainly not insuperable, and when they are overcome, not only will a new era in the science of petrology have been inaugurated but an important return service will have been rendered to physics and physical chemistry in extending the scope of their generalizations.

There is, therefore, no question of where to begin. Roozeboom, Vogt, and many others have seen and appreciated and indicated to us with great clearness the various ways in which

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* Full text of a paper of this title read before the American Chemical Society at the Ithaca meeting, June 28, 1906.

† The authors are indebted to Prof. A. C. Gill of Cornell University for a number of microscopic examinations of our earlier products, and for many helpful suggestions.

mineral and rock formation can now be competently studied. The question is now, rather, how much of it all can we actually carry out? Vogt has already shown us,[*] in a paper published only a few months ago, that a great deal can be accomplished by a judicious treatment of existing observations, particularly the more trustworthy of the mineral and rock analyses, when combined with extensive field experience.

It has been the purpose of this laboratory to attempt this task by a direct application of the principles and methods of quantitative physics and chemistry, or, in a word, to study mineral and rock formation by direct measurement at the temperatures where the minerals combine and separate like the solutions of ordinary chemistry under ordinary conditions. We further determined, wherever possible, to prepare chemically pure minerals for this purpose in order that such conclusions as we might reach should not be dependent upon dangerous assumptions regarding the harmless character of the five or ten per cent of "impurities" not infrequently present in hand specimens from natural sources. It is at once obvious that in order to succeed, the first experiments must be restricted to the simplest reactions, and that these will not always be the most important or the most interesting, but the results will always be in definite terms and final when the materials used are pure. Furthermore, the accumulated experience obtained from simple cases will safely and surely lead to successful methods of a scope to meet the more complicated problems of rock formation.

This plan was really entered upon several years ago in a small way and with very limited resources. The first paper, which was published in 1904–05, contained a laboratory study of a typical isomorphous pair, the soda-lime feldspar series, carried out in the spirit of the above plan. The second, which appeared in February of the present year, was a very careful study of enantiotropic mineral inversion between the mineral wollastonite and the pseudo-hexagonal form which has been obtained by several observers but which appears not to have been found in nature. The present paper, which is the third of the mineralogical series, undertakes to carry through a fairly complete set of measurements upon a typical eutectic pair—the lime-silica series. It is still incomplete in some particulars, notably at the ends of the series. Mixtures very rich in lime possess temperature constants which are beyond the reach of existing apparatus, while on the silica side the extreme viscosity and consequent inertness which were encountered in the soda feldspars, effectually veil or prevent the development of the phenomena which occur there. Some approximate measurements have been made even in these

[*] J. H. L. Vogt, Physikalisch-Chemische Gesetze der Krystallisationsfolge in Eruptivgesteinen, Tschermak Min. u. petr. Mitth., xxiv, 437, 1906.

regions (represented by dotted lines in the diagram fig. 3), but they have not the same accuracy as those portions of the curve which are represented by full lines. All the mixtures used were prepared with the greatest care and were chemically pure within one or two tenths of one per cent.

Lime-Silica Minerals.—Of the lime-silica series only one well-defined mineral is known—wollastonite—which when melted usually crystallizes in a pseudo-hexagonal form of the same composition. This mineral has already been carefully studied by Allen, White, and Wright,[*] and the relation between the natural mineral and its second crystal form thoroughly cleared up. Pursuing the conventional methods of reasoning, we might also expect to have an intermediate mineral for the trisilicic acid, $2CaO,3SiO_2$ an åkermanite analogue, $4CaO,3SiO_2$; an orthosilicate, $2CaO,SiO_2$, and a tricalcic silicate, $3CaO,SiO_2$. All of these minerals are deducible from the various hypothetical silicic acids. We have undertaken to prepare and study the entire series of mixtures of lime and silica.

Boudouard's Measurements.—So far as known, there has been only one serious attempt to determine the constitution of this series of minerals.[†] According to Boudouard, the freezing point curve for the lime-silica minerals consists of four eutectics and three maxima (compounds), the maxima corresponding to the metasilicate, the orthosilicate and the tricalcic silicate. Unfortunately, the method used by Boudouard was a very inaccurate one. He prepared small cones of the various mixtures and placed these in a furnace alongside of Seger cones. The furnace was then heated and allowed to cool down again, after which the crucible was opened and the cone observed to see whether or not the mineral had melted. It is a common method in industrial practice, but has rarely been thought accurate enough for original determinations.

This method is peculiarly unsuited for such investigations for several reasons: Suppose the mixture to contain an eutectic with a greater or less excess of one of the components. The cone would begin to weaken as soon as the eutectic began to melt, and its further progress would be governed entirely by the relative quantity of eutectic present and its viscosity *after melting.* No information whatever regarding inversions in the solid or of the component in excess could be obtained, and errors of more than 500° would certainly occur (in fact did occur in Boudouard's case) in the interpretation of the softening temperature in some parts of the lime-silica curve. Let us illustrate by a perfectly obvious hypothetical case (fig. 1): Assume first that the melting-points change rapidly following a steep liquidus AB

[*] E. T. Allen, W. P. White and Fred Eugene Wright, "On Wollastonite and Pseudo-Wollastonite, Polymorphic Forms of Calcium Metasilicate," this Journal. xxi, 89, 1906.

[†] Boudouard, Journ. Iron and Steel Institute, 1905, p. 339.

(see also fig. 3, curve DE). The amount of eutectic in concentrations X and Y will be so great as to soften the cone long before the melting-points Z and W are reached. If, on the other hand, the liquidus slopes gently (AC), the amount of liquid eutectic as compared with the solid phase is smaller and the temperature of softening of the cone will approximate more closely to the change in melting-point.

Furthermore, if the cones are made up from the initial components ($CaCO_3$ and SiO_2, for example), the heat of combination is liberated as the cone approaches the melting temperature and raises the temperature of the cone above that of the furnace, producing sudden fusion of which the neighboring Seger cone can receive no record.

Incidentally, one finds here the explanation of Hoffman's experiments[*] on the temperature of formation of slags. Contrary to the statement that the "temperature of formation is above the

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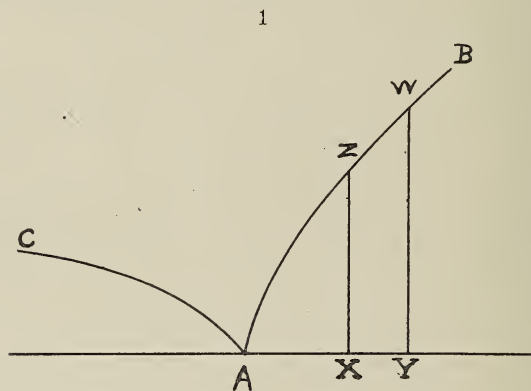
temperature of fusion," just the reverse is true. Under normal conditions these mineral combinations occur at temperatures lower than the melting point, the exceptions occurring only when the materials are so coarsely ground or poorly mixed that combination is retarded until the melting point of the slag is passed. The orthosilicate of calcium is a very good instance of the formation of a compound below its melting temperature. We shall show later that while this compound melts at about 2080° C., it is possible to prepare it below the melting point of platinum, in fact in platinum vessels, by heating the finely ground material in the Fletcher furnace, regrinding, mixing and reheating. By this process it is possible to obtain a compound which gives the optical tests for the orthosilicate and is entirely without free lime or silica.

Apart from the criticism which this particular application of cones appears to us to deserve, it is also well known that the

[*]H. O. Hoffman, Trans. Amer. Inst. Min. Eng., xxix, 682, 1899.

time factor is always very important in dealing with a Seger
cone. Boudouard himself states (p. 343): "A very small differ-
ence in temperature, or *a few minutes additional heating,**
often suffices for the softening stage to pass into one of complete
fusion." If this statement was made understandingly, the
method merited rejection by Boudouard himself. Furthermore,
the use of Seger cones for exact work will always be unsatis-
factory because it depends upon the judgment of the operator
to say when a cone has "fallen" sufficiently to be considered
melted, and different observers almost always obtain widely
different results under like conditions. As has been pointed
out by Day and Allen,† any method of measurement which is
not based upon some reasonably sharp physical change must be
expected to give different results in different hands.‡ Suppose

* Italics are ours.

† Arthur L. Day and E. T. Allen, "The Isomorphism and Thermal Properties
of the Feldspars;" this Journal (4), xix, p. 93, 1905. Zeitschrift f. Phys.
Chem. liv, p. 1, 1905. Publication of the Carnegie Institution of Washing-
ton, No. 31.

‡ Since the text of this paper was written, a very recent paper by Doelter
(C. Doelter, "Die Untersuchungsmethoden bei Silikatschmelzen," Sitzungs-
ber. d. Wien. Akad. cxv, 1, May, 1906) has come to our attention in which he
reaffirms his confidence in and preference for subjective methods for the
investigation of silicate solutions,—more particularly the viscous silicates.
This question of methods of attack in problems of wide scope and considera-
ble difficulty is not an academic one ; it is a matter of the very first importance,
particularly in view of the increased attention which is coming to be paid
to the minerals as solutions. We have preferred to avoid subjective methods
wherever possible on the general ground that no observation so made is
exactly reproducible. Subjective observations are therefore always much
more satisfactory to the observer than to any one else. Prof. Doelter has
probably had a greater and more varied experience in the observation of
mineral melting points than anyone now living, and he is therefore able to
form consistent judgments upon the changes which he observes. But even
under his exceptionally competent hand we have seen the "melting points"
of the feldspars rise a little higher each year in his successive publications
upon the subject, and the feldspars are very viscous minerals of the type to
which he finds the optical methods especially adapted.
Doelter then criticises the thermoelectric methods in use in this laboratory
on the ground of inexactness, i. e., because the recorded time-temperature
curves contain no period of absolutely constant temperature, although he
appears to be very familiar with the fact that the phenomena themselves are
not sharp. This seems to be unfortunate and unproductive criticism. Under
fair conditions a phenomenon is obviously the same, whether observed by
looking at the charge or by exposing a thermoelement in it. If the supposed
melting "point" does not occur at a point, it cannot be recorded as such.
So far from failing in its purpose, therefore, the thermoelement has revealed
to us a hitherto unfamiliar phenomenon with great fidelity. Our principle
in the choice of methods is therefore diametrically opposed to Doelter's. If
the change of state were sharp and well marked, it would really matter very
little how it was determined. If, on the other hand, it is a slow change, we
should greatly prefer the unprejudiced record of a thermoelement if it could
be obtained. Nothing is so difficult of observation or gives rise to so much
difference of opinion between observers as a slow-moving phenomenon. An
interesting example of this is to be found in this (Doelter's) paper itself (p.
12). Nearly all observers of the constants of silicates are now completely
agreed that the glasses are merely undercooled liquids which of course have
no melting point but change *continuously* from a hard amorphous to a soft

this method were to be applied, for example, to the determination of the melting temperature of orthoclase or albite, or even pure quartz, which have been shown to possess a viscosity entirely comparable in magnitude with the rigidity of the solid crystalline mineral; almost any conclusion could have been reached under these conditions.

It is stated by M. Boudouard, for example, that all mixtures of lime and silica between 30 and 90 per cent of lime melt below 1500°. This certainly cannot be the case. Pure orthosilicate of calcium when heated in a platinum crucible will stand without showing the slightest trace of melting while the platinum containing vessel melts down. The temperature must therefore be at least as high as the fusion point of platinum (1720°). We found no lime-silica mixtures richer than 60 per cent in CaO which could be melted in platinum vessels.

Apart from the uncertainty in the temperature measurements offered by Boudouard, we shall undertake to show in its proper place that there is no pure lime-silica compound corresponding to åkermanite and no tricalcic silicate. We are, therefore, somewhat at a loss to explain in any satisfactory way how the published curve which has attracted so much attention in England was really obtained.

Part II. Experimental.

In this kind of investigation it is always desirable to begin with a careful determination of the physical properties of the pure components, although in the present case it must be admitted that this was the most inaccessible and difficult portion of the field over which we worked.

amorphous condition. The use of subjective methods has misled Prof. Doelter into picking out points upon these curves to which he attaches great importance in the determination of eutectics.

Apart from this general criticism, the particular optical methods which Doelter employs appear to us rather limited in scope for the work they will be required to perform. In the case of a mineral combination which is neither an eutectic nor a pure compound, they are open to all the objections of Boudouard's method (see above) and furnish no trustworthy information whatever. It is also difficult to see how they can be used effectively to determine unknown conditions of equilibrium. Doelter's method 4 (p. 6, loc. cit.), in which he places greatest confidence, appears to us to promise immediate and serious difficulties of another kind. It consists in observing directly with the microscope tiny grains of the substance to be studied as they lie upon a tray of amorphous silica (quartz glass) in the furnace. The glass tray, which is, of course, also heated, is in very unstable equilibrium and therefore ready to enter into solution with almost any oxide or silicate in contact with it at relatively low temperatures, and to produce what may appear to be a melting point but which of course has no necessary relation to that of the pure substance examined. Joly's old method of examining mineral fragments on a platinum strip was much more trustworthy for melting point work, although inversions in the solid state could perhaps be advantageously studied in the new apparatus.

For these reasons it does not seem to us wise to employ the subjective methods when others which are reproducible by any observer are available.

Lime.—Calcium oxide melts at a temperature so high that it is not yet possible to make a satisfactory determination of its melting point. It can be fused in the electric arc under favorable conditions to a clear liquid of low viscosity which crystallizes readily into a well developed cubic structure. Near its fusing temperature, lime either becomes quite volatile or the carbon of the arc reduces it to the metal, which volatilizes and is immediately reoxidized outside of the heated zone. We are unable to offer conclusive evidence in favor of the one hypothesis or the other, but the fact that pure lime at 2000° shows no signs of a high vapor pressure points rather to the second explanation as the correct one.

For experiments with lime fusion, we obtained some artificial graphite* practically free from all impurities, so that no contaminating substance was introduced into the fused lime from the electrodes. To further guard against possible contamination, only that part of the cake which formed above the (horizontal) arc was used in determining its physical properties.

Density of CaO.—The density of fused calcium oxide was determined as follows: A selected portion of the crystalline mass was finely ground, ignited to drive off adsorbed water, and weighed in carefully dried turpentine after the method of Day and Allen. The results are not in very good agreement, due probably to the difficulty of weighing out the product without its becoming superficially hydrated or absorbing CO_2.

<div align="center">

Fused CaO. H_2O at $25° = 1$.

3·313

3·307

3·329

————

Mean density, 3·316 (25°)

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This crystallized lime is much less readily attacked by water than is the amorphous oxide. It is, however, not indifferent to water. Five grams of the crystals when ground and mixed with a small quantity of water in a test tube scarcely raised the temperature at all, but upon standing for some five minutes, the charge exploded with considerable violence. Unpowdered blocks of the crystalline oxide when placed in cold water dissolved slowly without appreciable heating. Hot water attacks them more rapidly, but the action of the water is slow in both cases as compared with the amorphous lime.

The hardness, according to Mohs's scale, is between 3 and 4.

Silica.—The melting temperature of silica has been variously estimated at from 1200 to 2000°, but so far as known no

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* Prepared by the International Acheson Graphite Company, Niagara Falls, New York.

careful determination of it has ever been made. Since this oxide melts to an extremely viscous liquid, attempts to determine the melting temperature by observing the softening of the charge are wholly misleading. The molecular deorientation proceeds very slowly, extending over a considerable range of temperature, as albite and orthoclase have been found to do,[*] but with the disadvantage that this temperature region is too high to be reached with a thermoelement, and no other method of temperature measurement possesses sufficient sensitiveness in this region to locate the melting temperature by the heat absorbed during slow fusion. Determinations of the freezing-point are out of the question, owing to the inertness of the viscous melt.

An approximate determination of the melting temperature was made in this way: A gram or two of finely powdered quartz was placed in a small iridium crucible and heated in an iridium tube furnace (see p. 286). (Experience has shown that melting and inversion phenomena in very viscous substances take place much more readily if the material is finely divided.) A tiny fragment of platinum foil was then laid on the top of the charge and the furnace slowly heated until the foil was observed to melt. Upon removing the charge from the furnace and examining it microscopically, evidence of fusion was found throughout the mass. The crystal grains had inverted to tridymite and the superficial liquefaction had caused them to sinter tightly together, but no displacement of the grains had taken place. At the temperature of melting platinum, therefore (1720°), silica shows positive evidence of fusion. Other similar charges were then prepared and the operation repeated with longer exposures and temperatures slightly below the melting point of platinum, the temperatures being measured with a Holborn-Kurlbaum optical pyrometer[†] focused on the platinum fragment. By repeating this process at short temperature intervals and with about 20 minutes exposure, melting was definitely established as low as 1625° C.

The iridium furnace is unfortunately not adapted for long-continued heating, and the platinum coil furnace will not reach this temperature, so that an effort to discover a definite temperature below which the solid is stable and above which it will melt if given time enough, was abandoned. If the heating is moderately rapid, the crystalline solid will persist far above the melting point of platinum; if slow enough, it liquefies completely at 1625° or even lower. It is probably a fair assumption, that pure silica begins to melt at about 1600,° and will continue to complete fusion if given time enough,—

[*] Day and Allen, *loc. cit.*
[†] Holborn and Kurlbaum : Ann. d. Phys. x, p. 225, 1903.

above that point the higher the temperature, the more rapid the melting. A charge of quartz was heated for a long time in a platinum furnace at 1555° without producing a trace of fusion.

There is little satisfaction in pursuing an inquiry of this kind. As has been stated elsewhere with reference to an entirely similar case,[*] the term "melting point" does not appear to be well applied to cases of this character, in which the crystalline structure persists for days or weeks at temperatures above the point where melting begins.[†] If the change of state is to be defined by the absorption of heat, and the absorption of heat extends over a wide range of temperatures and conditions, our forms of expression should be revised somewhat to include these hitherto unrecognized cases.

Tridymite.—The relation between tridymite and quartz appears to be a simple one, although the literature of the subject is unsatisfactory. But few trustworthy observations have been recorded and the conclusions drawn from them are vague and contradictory. So far as known, quartz has never been crystallized as such from mineral fusions except where catalyzers were present. Tridymite has probably been obtained by several individuals through the accidental crystallization of fused silica vessels,[‡] but no especial attention appears to have been given to the circumstances in which it occurs, and its identification has not always been positive.

Like the melting temperature, the inversion of quartz to tridymite and the crystallization of fused silica are very difficult phenomena to study, owing to the extreme inertness of the material, but a number of experiments have been success-

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[*] Isomorphism and Thermal Properties of the Feldspars, Publication 31, Carnegie Institution of Washington, p. 74 (3).

[†] Doelter has recently offered a new general classification of silicates (loc. cit. p. 3): "Einfacher konstituierte Silikate (Gruppe A) haben scharfen Schmelzpunkt, geringere Viskosität und grösseres Kristallisationsvermögen. Komplexere Silikate (Gruppe B) haben ein grosses Schmelzpunktsintervall, grosse Viskosität, geringere Kristallisationsgeschwindigkeit."

Such information as we have been able to gather in our work with pure minerals does not substantiate this generalization. We have encountered no mineral more viscous than quartz, which has the simplest of compositions. Anorthite, wollastonite and diopside differ radically in simplicity of formula but melt and crystallize at very nearly the same rate and with very nearly the same sharpness.

[‡] Prof. Dr. L. Holborn of the Physikalisch-Technische Reichsanstalt; Dr. M. Herschkowitsch of the firm of Carl Zeiss in Jena; Dr. Küch of the firm of Heraeus in Hanau; and the Rev. Theodor Wulf, S. J., formerly of Göttingen, in the preparation and use of quartz glass vessels have noticed that the glass devitrifies at high temperatures in the presence of water vapor or after long usage. So far as we are aware, all of these observations have remained unpublished. Hahn, in the Int. Cong. f. Angewandte Chemie, Berlin, 1903 (vol. 1, p. 714), notes the devitrification of a quartz glass tube at 1100°. He also identified the crystal formation under the microscope as tridymite.

fully carried out which appear to clear up the situation, even though the inversion temperature cannot be determined with any great accuracy.

First of all, we heated a large charge of finely ground quartz and followed the temperature curve carefully from 400° to 1600°. It was found after the experiment that the quartz crystals had for the most part gone over into tridymite and the change in the volume accompanying the inversion had generated enough pressure to completely shatter the open platinum crucible which contained the charge. The change was so gradual, however, that no record of it appeared upon the thermal curve. Subsequent experiments in which we endeavored to change crystalline quartz into tridymite at lower temperatures were successful as far down as 1100°. To be sure, entire crystals showed no change whatever after six hours' exposure at 1400°, but powdered quartz is completely changed into tridymite after a few hours at that temperature. On the other hand, if finely divided amorphous silica, i. e., fused ("quartz glass"), or better, precipitated silica, be allowed to remain for a short time at any temperature above 1000°, it changes promptly to tridymite—the precipitated material very rapidly, the quartz glass much more slowly. Neither the glass nor the precipitated silica ever crystallized as quartz at temperatures above 1000°, nor is there any difference in the optical properties of the tridymite obtained at the different temperatures, either from the quartz crystals or the amorphous silica. The rate of change is much influenced by the fineness of the powder, although there is no difficulty in recrystallizing large blocks of solid quartz glass at the higher temperatures. In our experiments in the preparation of quartz glass,[*] we frequently obtained isolated spherulites of tridymite several millimeters in diameter, even with rapid cooling, which appeared to have been started by a grain of graphite or carborundum powder accidentally falling into the melt. On one occasion the entire block was coated with tridymite to a depth of a millimeter or more.

We have therefore succeeded, by direct experiment upon pure silica, in establishing the fact that tridymite, and not quartz, is the stable crystalline form of silica for all temperatures above 1000°.

At lower temperatures than this it is impossible, in view of the inertness of the substance, to obtain any further reaction, even with the finest precipitated silica, within the time available for a laboratory experiment. A month's exposure at 900° produced no change. We therefore followed the example of

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[*] Day and Shepherd, ''Quartz Glass,'' Science, xxiii, p. 670, 1906.

several distinguished predecessors in this field, and tried various catalyzers.

Formation of Quartz.—Hautefeuille thought he had produced quartz crystals by fusing amorphous silica with sodium tungstate at 900°, but the methods of high-temperature measurement commonly employed in his time were very imperfect, and the temperature is undoubtedly too high. He has also stated that he obtained it by fusion with lithium chloride. Both Hautefeuille and Margotet have recorded the fact that in the presence of lithium chloride amorphous silica changes to tridymite at high temperatures and to quartz at low temperatures. We obtained quartz crystals from glass by the use of a mixture of 80 per cent KCl with 20 per cent LiCl at all temperatures below 760°, while at temperatures of 800° and higher only tridymite crystals appeared. The same results were obtained with vanadic acid and with sodium tungstate. The inversion point

$$\text{quartz} \rightleftarrows \text{tridymite}$$
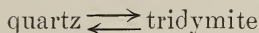
therefore occurs at about 800°. This conclusion is subject to the assumption that the inversion temperature is not lowered by the catalyzing agent—an assumption which seems to be justified by the fact that the quartz crystals obtained in this way (judged by the optical properties) appear to hold none of the reagent in solid solution.

The situation is then, briefly, this : Both quartz and amorphous silica at high temperatures change to tridymite. Quartz is consequently the unstable form of silica from 800° upward, and will go over into tridymite whenever conditions favorable to the change are present. The melting temperature of silica is therefore properly the melting temperature of tridymite and not of quartz as it is commonly described. We have once or twice succeeded, by extremely rapid heating, in melting quartz as such, or more correctly speaking, in carrying a quartz charge past the melting temperature of tridymite, melting a portion of it and finding a residue of quartz afterward which had neither inverted nor melted. It would hardly be possible by any known method, however, to obtain a separate melting temperature for quartz independently of tridymite.

The reverse operation, showing that tridymite inverts to quartz at temperatures below 760°, cannot be carried out in the laboratory without the use of catalyzers on account of the extreme slowness of the change. In the presence of the mixture of 80 per cent KCl and 20 per cent LiCl, quartz began to appear from tridymite in quantities sufficient for positive identification after an exposure of five or six days, at about 750°.

No effort was made to invert an entire charge on account of the slowness of the change and the fact that its character was now fully established. The glass crystallizes to quartz below 760° and to tridymite above 800°, crystalline quartz goes over to tridymite above 800°, and tridymite to quartz at 750°; the change is therefore enantiotropic and not monotropic.

Incidentally, a sufficient reason has been given for the complete failure of experimenters to produce quartz without catalysis. If dry silica at 900° is so inert as to undergo no reaction at all during a month's exposure under favorable conditions, how can we expect reaction below 800° where the viscosity is even greater? Silica must be crystallized below 800° to produce quartz.*

Density of Silica.—The density of the silica used and obtained in our experiments was determined with the following results, the aggregate impurity being not over one-tenth of one per cent:

Purified Natural Quartz.	Quartz Glass.		H_2O at $25° = 1.$
2·655	First preparation,		2·209
2·653	"	"	2·215
2·654	"	"	2·212
	Second	"	2·213
	"	"	2·215
———			———
Mean, 2·654 (25°)			Mean, 2·213 (25°)

It will be noted that there is a difference of more than 16 per cent between the density of the glass and that of the quartz crystals.

A charge of powdered crystalline quartz heated for several days at 1200° appeared under the microscope to be homogeneous tridymite. Some observations of its density are contained in the subjoined table under the heading "tridymite from quartz."

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* E. Baur (Zeitschr. f. phys. Chem. xlii, p. 575, 1903) appears to have obtained tridymite and quartz side by side from a mixture of 5^{grms} SiO_2, $4·3^{gr}$ AlO_2Na and 12^{cc} water heated for six hours in a closed steel bomb at 520°. We find it very difficult to reconcile this result with our experience. That tridymite is not the stable phase at this temperature under the conditions of the experiment appears to be established beyond reasonable doubt by our own work, although we have never studied a mixture of exactly this composition. We should therefore not expect it to form in such a melt, certainly not in the presence of quartz. If tridymite came to be present by accident as a result of some previous operation, or by the temperature in the furnace having been too high, it might revert gradually to quartz and thus explain the presence of both forms in such a charge. Until we are in position to repeat Baur's experiment, therefore, we are unable to explain the simultaneous appearance of quartz and tridymite except by assuming that two operations have taken place: (1) a formation of tridymite, and (2) a partial reversion to quartz, or some unchanged silica may subsequently have formed a quartz at a lower temperature.

A similar charge obtained by crystallizing the glass at 1200° (three days) also showed no residual glass under the microscope. Its density is given under the heading "tridymite from glass." A second table contains confirmatory measurements upon a second preparation heated to a slightly different temperature.

<div align="center">

Tridymite.

(H_2O at 25° = 1)

</div>

First Preparation, (1200°).		Second Preparation. (6 days at 1160°).	
From quartz.	From glass.	From quartz.*	From glass.
2·325	2·316	2·327	2·319
2·330	2·318	2·325	2·318
2·325	2·316		2·316
	2·319		

Mean, 2·326 (25°) Mean, 2·317 (25°) Mean, 2·326 (25°) Mean, 2·318 (25°).

Whether the quartz had not completely changed to tridymite, or the glass was incompletely crystallized, or perhaps both, is of little moment. It is a very slow change and the agreement between the values obtained by the two methods is sufficiently good, when considered in the light of their identical optical properties, to establish the absolute identity of the tridymite formed from the glass and from the quartz crystals.

The Lime-Silica Series.—Having determined the properties of our two component minerals, we are prepared to enter upon the study of their relation to each other in mixtures of various proportions. It will be borne in mind that inasmuch as we found no proper melting-*point* for pure silica on account of the inertness (if we may so describe it) with which it resists molecular deorientation when heated, so compositions which are immediately adjacent to the silica end of the series may be expected to show the same property and to yield but little information from a direct application of the usual pyrometric methods. Similarly, pure calcium oxide and its immediate neighbors are well out of reach of accurate measurement by any existing pyrometers. But even without these important measurements, we have been able to obtain sufficient information in the more inaccessible portions of the curve to enable us to describe all the reactions involved with little probability of error. Inasmuch as lime is one of the most refractory minerals known, it will require no apology if we simply leave its thermal constants until greater perfection in pyrometric measurements shall have been attained.

Preliminary Orientation.—Given chemically pure and *well mixed* (by grinding and *repeated melting*) preparations, it is

* This preparation was afterward found to contain some unchanged quartz.

not a difficult matter to secure a preliminary survey of a field
of this kind. The mineral wollastonite is known, and more
than that, is known to possess a melting temperature lower than
either lime or silica. There is therefore immediate reason for
anticipating eutectic relations somewhere in the series. If
wollastonite forms a eutectic with components on one or both
sides of it, mixtures containing slightly more lime or slightly
more silica than wollastonite will have lower melting tempera-
tures than it. A simple and effective mode of preliminary pro-
cedure is therefore to take a tiny pinch of a number of the
percentage mixtures adjacent to wollastonite, place them in
order upon a narrow platinum ribbon which can be heated
electrically to uniform brightness, and observe the order in
which they melt. No temperature measurement is worth
while; the information obtained can serve only for orientation
and must be verified by more reliable pyrometric methods.

If a eutectic is present on either side of the compound, it
will be the first to melt, and the compound last; the interme-
diate mixtures are not important. If the materials are not too
viscous the melting will be sharp and the material will crystal-
lize again on slow cooling. A few repetitions, or the intro-
duction of intermediate compositions in doubtful cases, will
usually enable a preliminary curve to be drawn in which the
compounds and eutectics which are within reach will be cor-
rectly located. In fact, for many substances they can be very
exactly located in this way. Intermediate compositions, on the
other hand, may be very misleading, depending upon the
behavior of the eutectic present after the melting temperature
of the latter has been passed. (In applying this method, very
small particles ($0\cdot2^{mm}$) must be used in order to obtain com-
parable results.)

Proceeding in this way, a eutectic will be readily located
between silica and wollastonite at the composition 63 per cent
SiO_2, 37 per cent CaO, and another on the other side of wollas-
tonite at the composition 46 per cent SiO_2, 54 per cent CaO.
We will allow the other component of this second eutectic to
remain unidentified for the moment, as no stable lime-silica min-
eral richer in lime than wollastonite is known. If we continue
our platinum ribbon experiment with continually increasing
percentages of lime, we shall find that after one or two steps
beyond this second eutectic the platinum ribbon will burn out
without melting the little grains. In other words, the melting
temperatures of lime-silica mixtures richer in lime than 60 per
cent are all higher than that of the platinum. To meet this diffi-
culty we built a small but very serviceable piece of apparatus
the essential portion of which is a thin ribbon of pure iridium
about 2^{mm} wide and 10^{cm} long, stretched between electrodes

under constant tension. Immediately beneath the ribbon and supporting its weight was a slender block of selected magnesite. The ribbon and its supports were then enclosed within concentric glass tubes between which cold water was kept flowing. The atmosphere immediately surrounding the ribbon was nitrogen.[*] With this ribbon we proceeded as before, laying out a whole series of compositions from 60 per cent CaO on. With

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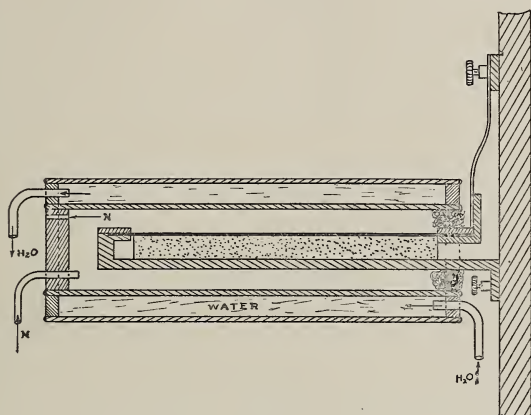
this little apparatus, of which fig. 2 will convey a fairly clear idea, we promptly discovered a third and very sharp eutectic with the composition 67 1/2 per cent CaO, 32 1/2 per cent SiO_2, and a maximum indicating a probable compound at 65 per cent CaO, 35 SiO_2, which corresponds to the anticipated orthosilicate. No other points were obtained up to 2100° C.

Thus in a very short time and in this simple and expeditious way we were able to locate three eutectics (37, 54 and 67 1/2 per cent CaO) and two compounds (48 and 65 per cent CaO) between lime and silica, canvassing for the purpose practically all the compositions from pure lime to pure silica at intervals of 1 or 2 1/2 per cent, and all temperatures from 500° to 2100° C. Beyond 75 per cent lime and below 32·5 per cent the method yields no information, for reasons which have been elaborated elsewhere. All the important determinations were verified by numerous repetitions.

If we now compare the compounds obtained by this preliminary investigation with those which we were led to anticipate from Boudouard's observations, as well as from the hypothetical

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[*] Even with this precaution, the iridium volatilized so rapidly that the magnesite was black after *thirty minutes* heating.

silicic acids, we find that we have located two—the metasilicate and orthosilicate—and missed two—the åkermanite analogue $4CaO, 3SiO_2$, and the tricalcic silicate. The next step was therefore obviously to bring all our resources to bear upon these particular compositions in order definitely to ascertain whether such compounds can exist when the components are pure, and if so, under what conditions and with what properties.

The Åkermanite Analogue.—The åkermanite analogue ($4CaO.3SiO_2$) was first taken up and the neighboring concentrations investigated at intervals of 1 per cent with the greatest care. A large charge of this particular composition was repeatedly melted and examined under the microscope, but it failed to show homogeneous structure or any characteristic property of a compound. On the other hand, the pseudo-wollastonite and the orthosilicate appeared in the proportion appropriate to its place in the series. Furthermore, since the melting temperatures of these mixtures were within the reach of our platinum furnaces, and therefore of our most sensitive pyrometric measurements, we were able to hold the temperature constant at any desired point and then by rapid cooling (quenching in mercury) to fix any phase which might have been present and become unstable below that temperature. Here again we found that pseudo-wollastonite and the calcium orthosilicate were the only phases which could be separated from this or any mixture of the pure components in this neighborhood. It is our belief, therefore, that the åkermanite mineral cannot exist between the pure components and is only possible when other substances are present. This is further indicated by the fact that the metasilicate of calcium in the presence of magnesium forms a solid solution of which the limiting concentrations are relatively wide and which would easily account for the åkermanite mineral produced from the fusion of the three components.

The Orthosilicate of Calcium, $2CaO,SiO_2$ (65·00 per cent CaO).*—It has long been known that the orthosilicate of calcium, although not found in nature, can be formed by the fusion of the pure components. The temperature of fusion is very high and the crystalline material obtained disintegrates spontaneously at the lower temperatures. The cause of the disintegration has not been carefully studied heretofore, and optical determinations of it are difficult, owing to the extreme fineness of the disintegrated product. Our investigation establishes the fact that the orthosilicate of calcium can exist in

* The metasilicate of calcium has been made the subject of a special paper by Allen, White and Wright (loc. cit.) and will not receive detailed consideration here.

three polymorphic forms in enantiotropic relation to each other, which we have designated as a, β and γ, in the order in which they form from fusion. The a-form is the only modification which is stable in contact with the melt. Its specific gravity is about 3·27, determined in methylene iodide solution upon fresh crystals. Its hardness is 5–6, Mohs's scale ; crystal system, monoclinic.

Below 1410° the a-form changes into the β-form, of which the density 3·28 (measured by comparing the indices of refraction) is but little different from that of the a modification. The substance was too unstable for determinations of the density to be made in the ordinary way. It crystallizes in the orthorhombic system. The inversion point between the a and β varieties is well marked and distinguishable over almost the entire range of compositions of which the orthosilicate is a component, as indicated in the diagram (fig. 3, line MN). The inversion of β into γ occurs at about 675° with a large increase of volume which at once explains the disintegration of the material. The temperature at which this inversion occurs is somewhat variable, and it is not readily reversed. It is much too slow a change to admit of pyrometric determination, but it is possible to locate it approximately by quenching the material from selected temperatures in the neighborhood of the inversion point. The usual procedure was to take a small portion of the disintegrated material, fold it tightly between thin strips of platinum and place these in the furnace. The temperature was then raised to any chosen value and maintained constant for periods of time varying from six hours to three or four days. At temperatures far enough removed from the inversion point, the transition from one form into the other was fairly rapid, but as the temperature of inversion approaches, equilibrium is attained with increasing difficulty. After the furnace had remained at this constant temperature for a length of time, it was opened, the platinum strips containing the orthosilicate were removed and quickly plunged into mercury. In this way, from temperatures just above the inversion point, it was possible to fix the β-form long enough to allow of its optical determination.

The disintegration on cooling appeared to depend considerably upon whether or not the a-form had first been allowed to change into the β-form. For example, if a small portion of the orthosilicate is fused before the oxyhydrogen blast and then plunged directly from the flame into mercury, the quenched material will usually be stable for a considerable time. If the flame is removed but a moment and the slightly
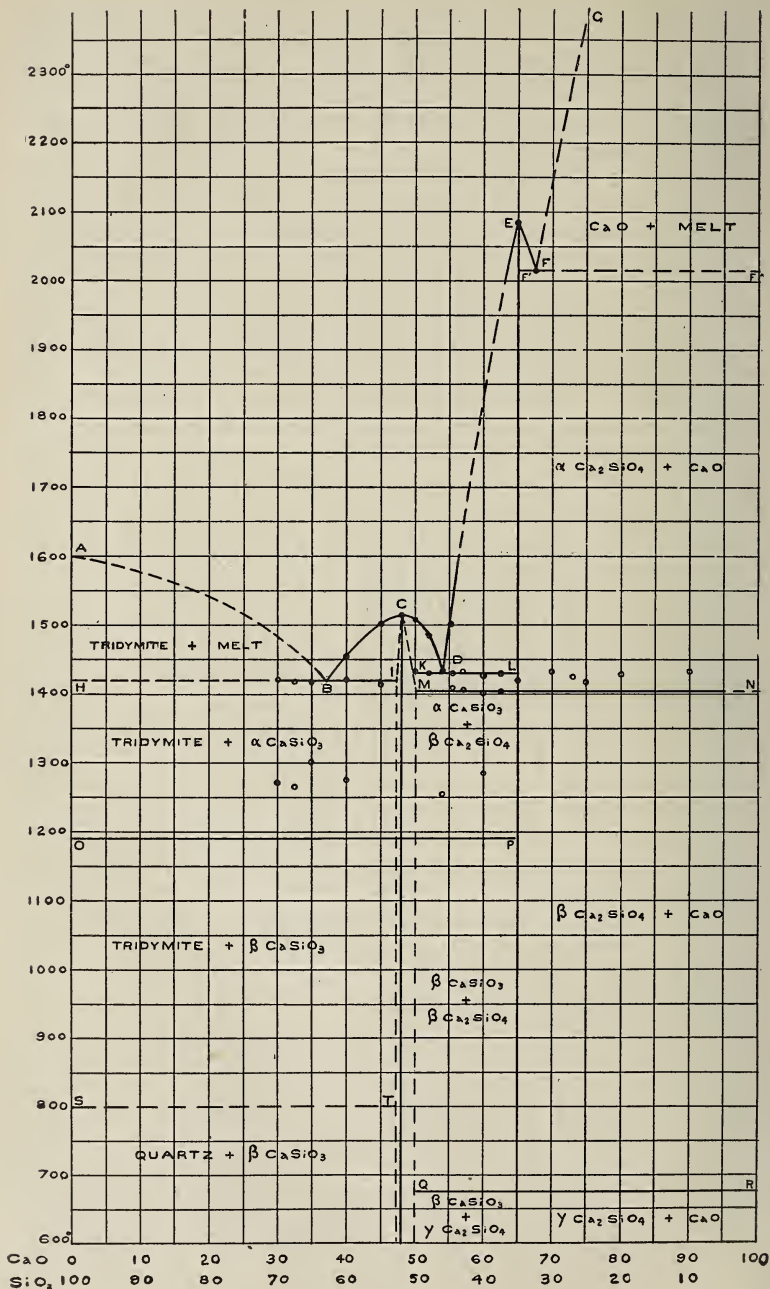
cooled specimen plunged from white heat into mercury, disintegration is immediate. This phenomenon was further verified by fusing the material and dropping it into a furnace held at about 1200° C. After a few moments the charge was then removed and quickly plunged into mercury. Treated in this way, all of a goes over into β, which in turn will disintegrate completely with little or no delay after reaching the $\beta \rightleftarrows \gamma$ inversion temperature. One will sometimes get the a-form by slow cooling, but never the β-form.

The γ-form of the orthosilicate crystallizes in the monoclinic system. Its density, determined in turpentine, by the picnometer method, is

$$2\cdot973$$
$$2\cdot975$$
$$\overline{}$$

Mean, $2\cdot974$

The difference in volume between the γ and a or β forms is therefore nearly 10 per cent, and since the a and particularly the β-form goes over into the γ at low temperatures with the greatest readiness, the disintegration of the fused orthosilicate is readily explained.

Neighboring mixtures containing the orthosilicate as a component disintegrate beginning with compositions containing only 51 per cent of lime. The disintegration of this preparation is, however, very slow, and usually does not take place at all unless the mixture has been held for some time at a relatively high temperature. The 54 per cent mixture can also be readily obtained without disintegration, but with more than 54 per cent of CaO, disintegration always occurs under the ordinary conditions of preparation.

If the orthosilicate be heated to temperatures only slightly above QR (fig. 3) so as to produce the β-form without sintering, disintegration does not appear on cooling for the reason that the change in volume is not apparent in the powdered material. If the charge be heated to about 1400°, or above 1410° where the a modification appears, it sinters tightly together and the disintegration phenomenon is again observed. Charges sintered together at 1400° to 1500° and held continuously at any temperature above QR do not disintegrate so long as this temperature is maintained, but as soon as the temperature drops below QR, disintegration recurs, but not at a constant temperature nor at any characteristic rate, the change being very dependent upon the conditions obtaining at the time.

The orthosilicate is easily attacked by water, giving an alkaline reaction, even when the water is cold, while with boiling water

it is possible to wash out as much as 10 per cent of lime. This probably accounts for the absence of this mineral in nature. Ammonium chloride solution even when cold decomposes all the mixtures of CaO and SiO_2.

The tricalcic silicate, $3CaOSiO_2$. — This silicate owes its supposed existence mainly to those investigators who have found it necessary to postulate such a compound in order to explain the constitution of portland cement. So far as the literature shows, no one has ever isolated and described a pure and homogeneous compound of this composition or defined its properties.[*] Many and varied attempts to make it have uniformly resulted in mixtures in which poor optical properties have made the conclusions insufficiently positive.[†]

We began the investigation of this composition by fusing the components in the proper proportions and examining the fused product microscopically as others had done. Most previous investigators, however, appear to have depended for microscopic evidence upon the ordinary optical figures and interference colors. Now, it so happens that this mixture when fused crystallizes in an extremely fine structure in which the interference colors are quite different from those of the orthosilicate to be sure, but this is merely the result of the fine state of division and the overlapping of the crystals, and not to another compound. If one examines any of the compositions in which the tricalcic silicate might be expected to figure, using the very sensitive index of refraction as a test of homogeneity, he will find that in every preparation containing more lime than 65 per cent (orthosilicate composition), there is an excess of free lime which can be positively identified. We have fused the tricalcic silicate composition, cooled it rapidly and slowly in various ways, without once failing to find free CaO present in quantity. Through the kindness of Dr. Clifford Richardson we were also given an opportunity to examine some of the tricalcic silicate prepared and described by him, and while its

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[*] It is sometimes described as "nearly homogeneous."

[†] A moment's consideration should suggest that there is no real necessity for assuming the existence of the tricalcic silicate in order to explain the nature of portland cement. It is at least a three-component system with a great number of possibilities. The real difficulty appears to have been that crystallized lime is relatively inert and does not readily give the reactions common to ordinary lime, consequently the tests which were thought to demonstrate the absence of free lime in these preparations have proved very misleading. For example, we have found that crystals of CaO are but very slowly attacked by water (see p. 271). Another argument which is freely offered—that there can be no free lime present " because if free lime is added the cement dusts spontaneously," is obvious fallacy. Free lime does not cause the dusting and if it did the fact that the *addition* of free lime caused dusting would be no proof that none was present. (Cf. 52 per cent CaO, 48 SiO_2.)

ordinary appearance under the microscope differed from that of the orthosilicate, a study of the index of refraction showed the supposed tricalcic silicate to be a mixture of the orthosilicate with free lime. Having failed to obtain a single tricalcic silicate which did not contain free lime, and because every specimen which we examined, including many which had been prepared by others, also showed the orthosilicate to be present, we were forced to conclude that the tricalcic silicate has no real existence. We also tried fusing the tricalcic silicate composition with a flux, but the product was always the orthosilicate of calcium with free lime.

Although we are anticipating pyrometric studies which follow, a single glance at our diagram, fig. 3, will show that we have found and measured the $\beta \rightleftharpoons \alpha$ inversion of the orthosilicate in all the compositions up to 90 per cent lime, which we could never have done with a tricalcic silicate intervening unless the tricalcic silicate be assumed to possess an identical inversion,—which would be rare coincidence. We have, therefore, complete optical and pyrometric evidence of the persistence of the orthosilicate throughout the supposed tricalcic silicate region, and no compound of tricalcic silicate composition can exist there.

By way of completing the search for hypothetical compounds, we also examined compositions corresponding to the trisilicic acid, but found that the mixtures of lime and silica from which the salt of this acid might be expected to crystallize did not give any new phases. These mixtures showed well developed pseudo-wollastonite with the tridymite eutectic, and neither rapid cooling nor crystallization of the glass at low temperatures gave any indication whatsoever of the hypothetical compound.

Thermal Apparatus.—The thermal measurements to be detailed in the pages which follow were obtained for the most part in furnaces and by methods which have been described in sufficient detail elsewhere.* The work which has been done with the apparatus since that time has exposed one weakness which will be given detailed consideration at a more appropriate time and place, but will be outlined here for the use of others who may have occasion to employ this extremely useful and accurate apparatus. For certain reasons of convenience rather than of necessity, the platinum coils which we have heretofore employed for heating purposes have usually contained 10 per cent of iridium. It has now been found that even in a nitrogen atmosphere this iridium sublimes slowly at temperatures above 1200° and enters and contaminates the wires of the thermoelement, if they are exposed, even in the

*Day and Allen, *loc. cit.*

colder parts of the furnace. Unglazed porcelain offers no protection against this iridium. The effect of this contamination is to make the thermoelements read too low. The error is noticeable after a single hour's exposure (perhaps $1/2°$), and will gradually increase to fifty degrees or more in a few weeks of continuous usage, the amount depending considerably upon the temperatures employed. The remedy is simple and sure,— *use no iridium in the furnace.* An element once contaminated in this way can only be restored by cutting off the exposed portion.

Above 1600° the platinum coil and the thermoelement gave place to the iridium tube furnace and the Holborn-Kurlbaum optical pyrometer. The adjoining diagram (fig 4) contains
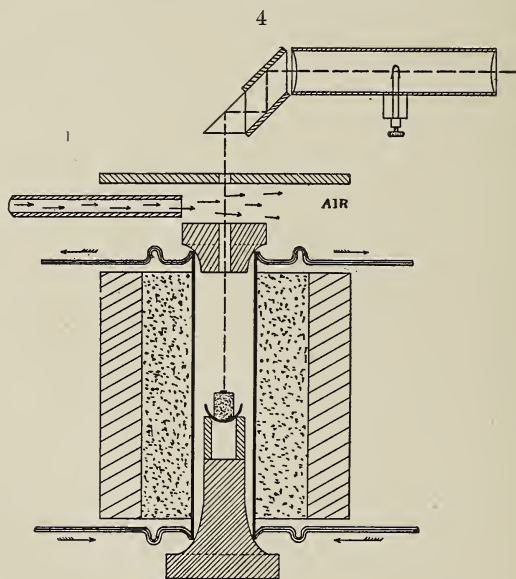
sufficient details to show almost at a glance the operation of the system. A straight iridium tube about 18^{cm} long and 4^{cm} in diameter is fed by an alternating current of low voltage, led in through platinum and silver flanges at the ends. Fused magnesia serves as insulating material and a base of magnesia supports a small iridium crucible in the position indicated. A small opening in the magnesia cover enables the pyrometer to be sighted on any point within.* The furnace will reach temperatures of 2100° C. and is almost indispensable at very high temperatures where an oxidizing atmosphere is important.

*This furnace was made for us by Dr. Heraeus of Hanau, Germany, to whom, as well as to his associate, Dr. Küch, we are indebted for many courtesies.

The Holborn-Kurlbaum pyrometer is a very simple telescope consisting of two cheap lenses, in the focus of the first of which (eye-piece) is placed a small incandescent lamp in which the current and therefore the brightness of the filament can be varied. The operation of measuring then consists merely in focussing the telescope upon the hot body of which the temperature is required and changing the current in the filament until the latter can no longer be seen against the hot object observed. The current then passing through the filament is a measure of the temperature. Monochromatic light (preferably red) only is used. The calibration of this instrument is arbitrary. It requires merely to be directed at a hot object of which the temperature is known, and the current observed. The relation between current and temperature for several temperatures can then be elaborated into a curve for purposes of interpolation or extrapolation. One condition must not be overlooked in the use of such an instrument,—the radiant energy sent out at a particular temperature is different for different substances unless they are enclosed within a hollow body of uniform temperature, in which case all bodies radiate alike and perfectly. Such a hollow body with a small opening has been called by Kirchhoff a "black body" or perfect radiator, and the radiant energy passing through the opening, black radiation. A fair working test for the "blackness" of radiation within a furnace, for example, is obtained by observing whether objects within can be distinguished. When all detail disappears within a furnace, its radiation is reasonably black. This is approximately true at the center of nearly all enclosed electrical resistance furnaces in which no combustion is going on, but if the temperature is high it is usually not entirely uniform even for small areas, and the radiation is consequently not black.

For purposes of comparing the thermal constants of different substances of unknown radiating power, therefore, we first obtained small incandescent lamps which had been calibrated upon a black body at the Reichsanstalt and verified the calibration upon a similar body in our own laboratory for the purpose of comparing standards. We did not deem it safe to assume the approximate blackness of charges within the furnace, although the conditions sometimes appeared sufficiently good to warrant it. We took two trustworthy fixed points, the melting temperature of anorthite (1532°) and platinum (1720°), both being in the region in which we proposed to apply the method, and observed the radiation from a tiny fragment of iridium ribbon at those temperatures. In this way we obtained two points slightly below the black body curve and passed through these an empirical curve parallel to

the standard curve. Our temperatures were measured in terms of this empirical curve. Since differences of less than five degrees can hardly be distinguished by this apparatus at such high temperatures, the assumption here made that the radiation from iridium is of uniform quality throughout the region between 1600° and 2100°, will hardly be called in question. After the temperature scale was established in this way the iridium fragment was laid on the top of each charge during the measurement and all determinations were made in terms of the radiation from it.

With this pyrometric apparatus we undertook to examine all the mixtures within reach from lime to silica which the microscopic study had shown to be important. The mixtures were first examined in charges of 100 grams between 500° and 1600° in a furnace of the type described by Day and Allen (*loc. cit.*), supplemented where necessary by observations at higher temperatures in the iridium furnace with the optical pyrometer. The relative sensitiveness of the two methods is roughly one to ten, i. e., the smallest temperature changes which the optical pyrometer can detect are fully ten times as great as those which can be readily measured with the thermoelement. Furthermore, the optical pyrometer is merely a device for estimating temperatures by observation from without the furnace. It enables an observer to heat a charge to a certain temperature but not to tell whether anything takes place there except by removing the charge from the furnace for examination. It is not adapted to the determination of thermal constants by direct observation except in the case of the melting temperature of pure compounds or eutectic mixtures which melt sharply into a thin liquid.

It has been our universal experience that changes of state which are subject to lag are much more easily and certainly determined from heating than from cooling curves. Undercooling in these ultra-viscous media cannot be prevented with certainty by any of the usual methods. Superheating is also unavoidable at times, as we have already noted in the case of quartz and elsewhere. In these cases the change of state required by conventional definitions simply cannot be determined as a point. Where the inertness is not so great as to be prohibitive of all measurement, our uniform experience has been that the melting temperature can often be established with confidence, where solidifying temperatures cannot. Similarly, inversions in the solid state can usually be fixed upon a curve of rising temperatures with greater certainty than upon a cooling curve.

The temperature constants.—We have now definitely located the compounds of lime and silica which can exist between the

pure components together with the eutectics which they form. It only remains to study their thermal properties somewhat more consistently with the help of the apparatus which has been described. It was not found possible to determine the presence of the eutectic (Line HBI, fig. 3) in the 10 and 20 per cent compositions, for reasons which will have become sufficiently clear already, but the microscopic evidence shows the tridymite to be normal, whether it forms from pure silica or in the presence of lime, so that the eutectic must extend over to the silica axis. From 30 per cent on there was no difficulty in observing it pyrometrically. The observations are included in Table I.

TABLE I.

Eutectic. *Tridymite + Pseudo-wollastonite.*

(Line H I, fig. 3.)

Percentage of CaO.	30	32	35	40	45
Eutectic melts	1420°	1417°	1120°	1421°	1419°
		1419	1423	1420	1419
			1414	1422	1406
			1416	1420	1406
Mean	1420°	1418°	1418°	1421°	1413°

The liquidus AB (fig. 3) has been drawn as a dotted line. The value assumed for the melting temperature of silica is based upon considerations which have been elaborated elsewhere (p. 272). It requires no further comment except perhaps to call attention to the fact that it is much lower than the temperature usually assigned to it. As the mixtures grow richer in lime, the melting of the excess of silica seems to be considerably facilitated, but there are no points sufficiently sharp to serve any purpose as quantitative determinations until we reach the composition $30CaO, 70SiO_2$. The microscopic evidence is however both satisfactory and sufficient as to the nature and continuity of the curve.

Along the branch BC (fig. 3) of the liquidus, the pseudo-wollastonite is the solid phase. It crystallizes from these mixtures in laths between which an extremely fine-grained, almost sub-microscopic eutectic appears.

It may be remarked in passing that the "eutectic structure" in minerals is by no means so characteristic as in the case of the alloys. Owing to the great viscosity of these melts and consequent slowness of diffusion, it is evident that there is no opportunity for the formation of the characteristic grain structure which we have come to associate with the eutectics of alloys. This almost complete absence of diffusion in silicate melts makes it necessary to proceed with great caution in applying to minerals the methods which are easily and effectively applied to the alloys. For example, in alloys it is possible to crystallize out a portion

of the solid phase, then to separate the mother liquor and, by analysis of the two, to determine the composition of the solid phase. In the case of mineral mixtures, the segregation of the eutectic is, for laboratory experiments at least, very indefinite. We have repeatedly examined different regions of a charge in which the eutectic was known to separate, in the hope of finding it segregated towards the middle of the charge, as commonly happens with alloys, but in no case were we able to detect more of the eutectic in one part of the charge than in another. It is usually finely divided and intimately mixed with the primary crystals.

The properties of the pseudo-wollastonite which separates along the branch BC are not quite identical with those of the compound when prepared pure, from which it is evident that a certain amount of silica must be taken up by it in solid solution. The amount thus held in solution is certainly less than 2 per cent, but its exact determination microscopically is very difficult indeed. Furthermore, this pseudo-wollastonite when changed to wollastonite still shows a slightly different optical character from the pure material, showing that the solid solution apparently continues after the inversion. For brevity, the pseudo-wollastonite has been designated a-CaSiO$_3$, and wollastonite β-CaSiO$_3$ in fig. 3. The branch of the liquidus CD was readily determined, as well as the beginning of the branch DE. It was not possible, however, to follow the branch DE beyond 57 per cent owing to the steepness of the curve, which rapidly carries it out of the range of the accurate thermoelectric methods.

TABLE II.

Curve of Melting Points.

(Curve A B C D E F G, fig. 3.)

Percentage of CaO	40·0	45·0	48·2	50·0	52	54	55·5	65	67·5
Component in	1457°	1504°	1512°*	1505°	1484°	1435°	15.16°	2077°	2015°
excess melts	1457	1504		1510	1483	1437	1489	2085	
	1445	1497		1509	1485	1434		2083	
		1494			1484	1435			
					1483	1435			
					1482	1432			
					1488	1432			
						1435			
						1433			
						1430			
						1429			
Mean	1453°	1500°	1512°*	1508°	1484°	1433°	1503°	2082°†	2015°†

* Determined by Allen and White (*loc. cit.*).

† Determined with the Holborn-Kurlbaum optical pyrometer in the iridium furnace.

Observations along the curve of melting points are contained in Table II. The eutectic KL (pseudo-wollastonite + a-calcium orthosilicate, Table 3) was found in all compositions containing more than 50 per cent and less than 65 per cent CaO. Not a trace of it could be detected in the 65 per cent composition, though diligent search was made for it. A great many determinations were made of it of which the values are given in Table III.

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

<div align="center">*Eutectic. Pseudo-Wollastonite + a-Calcium Orthosilicate.*</div>

<div align="center">(Line KL, fig. 3.)</div>

Percentage of CaO	50	52	54	55·5	57	60	62·5
Eutectic	1428°	1432°	1435°	1427°	1419°	1431°	1426°
melts	1435	1428	1437	1428	1428	1422	1431
	1432	1428	1434	1427	1428	1425	1429
		1428	1435	1428	1430	1426	
		1429	1435	1427	1429	1426	
		1428	1432	1428	1429	1426	
		1430	1432	1429	1433		
		1433	1435	1431	1434		
		1426	1433	1430	1434		
		1433	1430	1430	1441		
		1427	1429		1438		
		1431			1435		
		1430					
		1426					
		1430					
		1431					
Mean	1432°	1430°	1433°	1429°	1431°	1426°	1429°

The properties of the metasilicate separating along CD are also slightly different from those of the pure pseudo-wollastonite, and up to 50 per cent the mixture appears homogeneous, so that the metasilicate probably takes up about 1 per cent of orthosilicate in solid solution. The melting point of the orthosilicate determined in the iridium furnace was found to be

<div align="center">

2077°
2085°
2083°
_____

</div>

<div align="center">Mean   2082°</div>

Another charge observed at 2035° was found entirely unmelted. Optical methods of temperature measurement are not competent to determine the melting temperature of the

orthosilicate in the presence of the eutectic for reasons already explained (p. 267), but the eutectic or the compound is readily measured by itself once the composition has been determined. Applying the method to the $67\frac{1}{2}$ per cent mixture, therefore, it was found to melt very sharply at 2015°. Neither the orthosilicate nor the 70 per cent CaO composition showed any trace of fusion at this temperature. Since the microscopic properties of the orthosilicate remain unchanged in the presence of an excess of lime or of silica, it follows that the orthosilicate does not form solid solutions with either lime or silica. Both eutectics will therefore continue up to the orthosilicate. Above the lime-orthosilicate eutectic the pyrometer affords no further information regarding the melting point curve.

The line MN (fig. 3) represents the temperature at which the inversion to β-orthosilicate occurs. It will be noted that the inversion is frequently delayed by superheating, especially in the region remote from the eutectic, but it was always possible to show by quenching the material from above and below these temperatures that the variation is merely due to the inevitable lag of the reaction. Between 50 and 65 per cent of lime, the two heat changes at MN and KL lie so close together that it was very difficult to separate them. The pyrometer shows two points plainly, but each is somewhat influenced by the presence of the other. We were able, however, to distinguish them beyond possibility of confusion by holding the furnace constant at 1425° and quenching the charge in water. These conditions yield a-orthosilicate + pseudo-wollastonite, while if the temperature is held at 1390–1400°, β-orthosilicate + pseudo-wollastonite results. The inversion temperatures are contained in Table IV. Mean values lose much of their significance in determinations of inversion temperatures where superheating can occur and are accordingly omitted from the table.

Table IV.

Inversion β-Orthosilicate to a-Orthosilicate.

Percentage of CaO	55·5	57·0	60·0	62·5	65·0	70	73	75	80	90
Inversion temperature.	407°	1395°	1404°	1396°	1426°	1409°	1426°	1415°	1407°	1433
	1414	1412	1411	1397	1421	1405	1425	1421	1429	1432
	1403	1419	1411	1405	1415	1412	.		1432	1433
	1411	1415	1398	1398	1414				1425	
		1406	1402	1408	1412					
		1406	1404	1407	1413					
		1404	1405	1401	1417					
			1388		1423					
					1411					

The scattered points lying below 1300° (fig. 3) occur only in the compositions in which the metasilicate is present, and correspond, as a microscopic examination at once shows, to the change from wollastonite to the pseudo-hexagonal form. With falling temperature, the points occur very much lower or are lost, since the inversion does not occur quite as readily on cooling. Allen and White observed that this inversion could be brought about only with great difficulty with the pure metasilicate, but in the presence of an excess of either lime or silica, we found it to occur with comparative readiness (Table V) in many compositions.

The line QR is the temperature at which the reaction β into a takes place. As observed in the discussion of the properties of the orthosilicate, this reaction does not occur promptly, but is liable to very serious superheating or undercooling.

<div align="center">

TABLE V.

Inversion β-Metasilicate to a-Metasilicate.

</div>

Percentage CaO	30	32·5	35	40	45	57
Temperature of inversion.	1273°	1274° 1263	1257° 1399 1323 1328	1288° 1266	1254°	1286°

<div align="center">

Part III.   Optical Study.

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The different members of the lime-silica series are well characterized optically and can generally be distinguished under the microscope without difficulty. Occasionally, however, the preparations are extremely fine-grained and require repeated examination before the minute details of each substance in the product are fully appreciated. In actual practice, experience has shown that the best results can be obtained by examining the preparations in powdered form rather than in thin sections cut from larger fragments. The chief advantage of thin sections over the powdered material is a textural one, since by breaking any given preparation into small particles its original texture is practically destroyed. Although problems of textural differences in artificial products are not to be disregarded, actual determinations can best be made with the powder, since with it the crystallites can usually be examined separately and the optical phenomena of a single individual observed rather than those of an aggregate of overlapping and interlacing crystals, as is often the case in slides; furthermore, by embedding the fine grains in a viscous liquid, such as Canada balsam, they can be rolled about in the liquid and their optic properties in any desired direction ascertained; the refractive indices of a substance can also be determined directly

on powdered particles by Schroeder van der Kolk's method of refractive liquids and numerical constants thus obtained on grains measuring even less than ·001^{mm} in linear dimensions.

Optically, four different compounds were recognized in the lime silica series; three of these appeared in different polymorphic modifications according to the conditions of formation. Pure silica crystallized either as quartz or tridymite; calcium metasilicate ($CaSiO_3$) either as wollastonite* or pseudo-wollastonite; calcium orthosilicate (Ca_2SiO_4) in three forms, *a*, *β*, and *γ*; and calcium oxide only in one form, so far as known. The experiments indicate that for each compound the different modifications bear enantiotropic relations to one another.

Calcium oxide.—Well-developed crystals of this substance are rare and were observed only in preparations from large melts in the furnace. In intermediate mixtures between the oxide and the orthosilicate it occurs usually as small rounded colorless grains which are easily recognized under the microscope by their high refractive index and isotropism. The crystals are colorless to pale yellow, transparent, and crystallize in unmodified cubes of the isometric system. Their hardness is between 3 and 4. Attempts were made to etch these crystals by immersing them in water, but the etch figures obtained were not sufficiently distinct to be of value. They pass rapidly into Aetzhügel which cover the entire etched face. The crystals cleave perfectly after the cube (100). Their refractive index, 1·82, was determined by immersing fragments in a high refractive liquid solution of arsenic sulphide in arsenic bromide. Owing to rapid superficial decomposition, the crystals soon became coated with a thin crust which tends to decrease the accuracy of this determination of the refractive index. Optical anomalies were observed occasionally, and were due probably to internal strains. On exposure to air and moisture, the crystals slowly become hydrated and disintegrate.

The orthosilicate.—The microscopic examination of the various preparations of this compound revealed the existence of three distinct forms, *a*, *β*, and *γ*, which are stable over different temperature ranges. The optical properties of the *a* and *β* forms are similar and their microscopic discrimination is a difficult problem, while the γ-form, which is stable for temperatures below 675°, differs considerably from the *a* and forms and can be recognized with ease.

(a) *The a-form* is stable only at temperatures above 1410° and on cooling has a strong tendency to invert to the *β* and *γ* forms. It was found by experiment that if chilled very

* Compare this Journal, xxi, 89–108, 1906.

rapidly, this change could be checked, in part at least, for a considerable period of time. The *a*-form belongs either to the monoclinic or triclinic crystal system, probably the former, and shows prismatic development, with good cleavage after a face in that zone. The crystals are transparent and colorless and occur as fine aggregates so intricately intergrown that the precise determination of their optic properties is practically impossible. Twinning is a characteristic feature of this form, and is often extremely complicated. Different sets of the twinning lamellae cut each other at various angles and the sections then resemble plates of microcline or leucite. Extinction angles measured along the prism axis were noted as high as $c : a = 18°$, although smaller angles appear more frequently. The hardness is between 5 and 6. The refractive indices were measured by the method of refractive liquids: $a = 1·714 \pm ·003$; $\beta = 1·720 \pm ·004$; $\gamma = 1·737 \pm ·003$. Birefringence about ·02. The optical character is positive; $2\,V = 81°$; $2E > 180°$. This optic axial angle was measured on a section nearly perpendicular to an optic axis by the graphical method recently described by Becke.[*] The method is founded on the difference in curvature of the dark hyperbolic bar which passes through the optic axis, for different axial angles in the diagonal position. In place of the revolving drawing table of Becke, a different type of instrument which can be clamped directly to the microscope was used in this laboratory with satisfactory results. This method is only an approximate one and the figures obtained by its use may vary considerably from the actual values, a condition recognized by Becke himself in the original paper. The plane of the optic axes is about parallel to the direction of elongation of the crystals.

(b) *The crystallites of the β-form* are stable between 675° and 1410°; they are also prismatic in shape and show good cleavage parallel to the prism axis. They are colorless and transparent, and are orthorhombic in crystal system. Their hardness and density could not be determined directly, as this form, at low temperatures, inverts rapidly to the γ-form and can furthermore be obtained only in powdered condition. The least ellipsoidal axis c is parallel to the c crystallographic axis and the plane of optic axes lies in the direction of elongation of the crystals. The optic axial angle is very large. The refractive indices, $a = 1·722 \pm ·003$ and $\gamma = 1·733 \pm ·003$, were determined by the method of refractive liquids. The birefringence is not strong, about ·01. The β-form is distinguished from the preceding *a*-form most readily by the absence of twinning and by its parallel extinction. The pro-

[*] F. Becke, Tscherm. Min. u. pet. Mitth. xxiv, 1905.

gressive paramorphic change of this form into the γ-form can be followed under the microscope and is interesting to watch. Shortly after cooling, irregular interference colors appear, as though induced by internal strains, and soon the mass resembles a crystalline aggregate of minute fibers. Toward the end of the process, the larger masses usually disintegrate as fine powder owing to the enormous increase in volume (about 10 per cent) during the inversion.

(c) *The γ-form* is stable at low temperatures and into it the preceding forms usually pass on cooling to ordinary temperatures. It is noteworthy that the properties of this form are unlike those of the above, particularly in specific gravity and refractive index. The density of the a and β forms is about 3·27, while that of the a-form is only 2·97. As a result, on paramorphic change in the solid state a great increase in volume takes place which at once shatters the larger fragments of the original material and causes the preparation to "dust." The γ-form can be had, therefore, only in the form of powder. It is prismatic in habit, cleaves well parallel to the long direction, is colorless and transparent, and occasionally shows indications of twinning with small extinction angles; $c : \mathfrak{c} = 3°$ was measured in one instance. The form is probably, therefore, monoclinic in system. The twinning is recognized only rarely, and the extinction usually appears parallel. The refractive indices were determined by the method of refractive liquids: $a = 1·640 \pm ·003$, $\beta = 1·645 \pm ·003$, $\gamma = 1·654 \pm ·003$. The birefringence is weak, about ·014; biaxial with an optic axial angle in air $2E = 52°$, measured by the graphical method of Becke on a section nearly normal to an optic axis; optical character negative; plane of optic axes perpendicular to the prism axis in contradistinction to the a and β forms. Compared with the a and β forms this form is readily distinguished by its lower refractive index, its optical character, optic axial angle, and position of the plane of optic axes to the prism axis.

The metasilicate occurs in two enantiotropic modifications, one of which corresponds to the mineral wollastonite. The second form has been called pseudo-wollastonite, and is stable above 1200°. Both these forms have been discussed so thoroughly in a preceding paper[*] that repetition here is unnecessary. The properties of the artificial wollastonite counterpart those of the mineral, while the pseudo-wollastonite is pseudo-hexagonal, probably monoclinic in crystal system. It is optically positive and nearly uniaxial; its refractive indices, $a =$

* Loc. cit.

1·615 $\gamma = 1$·636; its birefringence is strong and considerably higher than in wollastonite.

Silicon dioxide.—In nature this oxide occurs in at least two modifications, quartz and tridymite, both of which were produced artificially in this laboratory. As a result of the experiments, the fact is well established that quartz is the stable form below about 800° and tridymite over the range 800° to the melting temperature 1600°; that, on heating, the inversion of quartz into tridymite is so extremely sluggish that quartz crystals may be heated 700° or 800° above the inversion point without changing. Quartz glass, however, can be made to crystallize to tridymite as low as 1000°.

The microscopic examination of the different artificial preparations of tridymite and quartz proved satisfactorily their identity with the natural minerals. By using the method of refractive liquids it was found possible to discriminate between quartz, tridymite and amorphous quartz with ease, even though many of the preparations were cryptocrystalline and scarcely determinable by other ordinary methods. The refractive index of amorphous quartz, obtained by precipitating silica from solution, was measured by the immersion method at 1·459±·003; later the same constant was determined more accurately on a polished face of quartz glass[*] on an Abbe total refractometer in sodium light with the result, 1·460.

(a) *Quartz.*—The best crystals of quartz were obtained as a byproduct from a mixture of magnesium-ammonium chloride, sodium metasilicate and water heated for 3 days in a steel bomb at 400–450°. This mixture was used by Dr. E. T. Allen of this laboratory to synthesize one of the polymorphic forms of magnesium metasilicate and to procure measurable crystals of the same. The quartz crystals thus procured were colorless, water clear, doubly terminated and well developed crystallographically. The larger crystals attained a maximum length of 2^{mm}, but were usually coated with a thin film of foreign matter and were less suited to goniometric measurement than smaller ones. The crystals are often barrel-shaped with short rhombohedral terminal faces which pass by oscillatory development into steeper rhombohedrons and finally into the prism which shows the characteristic striae of the mineral quartz. In a few of the crystals, the positive rhombohedron only was developed and the crystals were terminated by its three faces above. Several crystals were measured on the two-circled goniometer and the forms $(10\bar{1}0)$ $(10\bar{2}0)$ $(10\bar{1}1)$ observed. Other forms were noted but gave indistinct and multiple reflection signals and are not listed in consequence.

[*] Obtained by fusing quartz in the electric furnace under pressure.

The angle between the prism faces and the rhombohedrons ($10\bar{1}0 : 10\bar{1}1$) measured $37° \, 48'$ and differs appreciably from that of pure quartz, which is given by Dana, $38° \, 13'$. The three rhombohedron faces from which this angle was obtained gave perfectly sharp reflection signals, and although the observations on the goniometer were made with the reducing attachment, the difference no doubt exists and is due probably to a solid solution of quartz with some other ingredient of the original mixture. The hardness of the crystals is 7; their specific gravity, 2·650 determined in Thoulet solution, and their refractive indices $\epsilon = 1·654 \pm ·002$, to $\omega = 1·644 \pm ·002$; measured by the method of refractive liquids, their birefringence is about ·01. The crystals are unaxial and optically positive, and extinguish parallel to the prism edge, which was found to be the direction of the least ellipsoidal axis c.

Quartz could not be produced by direct crystallization from silica glass, since at low temperatures at which it is stable the viscosity of the glass is too great to allow sufficient molecular mobility for the rearrangement. Fluxes or solutions were therefore used to increase this mobility, and with satisfactory results. Quartz crystallites were formed at temperatures below 760° and tridymite above that point in the same flux.

The chief effect of such crystallizing fluxes or crystallizers seems to be that they tend to increase the molecular mobility of the crystallizing material and thus procure greater freedom and power for crystallization. In many experiments performed in this laboratory it has been noted that crystals obtained directly from silicate melts are usually minute and ill-formed; while the addition of a few per cent of a second substance improves both size and quality of the crystals to a remarkable degree, even though the added substance may solidify as glass and enter apparently in no wise into the composition of the crystals.

(b) *Tridymite.*—In the experiments, well developed crystals of tridymite of sufficient size for goniometric measurements were not obtained, and optical properties alone were relied upon for its identification. The refractive index γ was measured $1·485 \pm ·003$ on one preparation and $1·483 \pm ·003$ on a second by the method of refractive liquids. These values are slightly higher than that given for natural tridymite, which is 1·478. No reason has yet been suggested to explain this discrepancy. The birefringence is extremely low, apparently not over ·002. The crystallites are biaxial with an optical axial angle so large and indistinct that the optical character could not be determined satisfactorily. In some of the crystals an elongation in a direction diagonal to the positions of extinction was noticeable. The best preparations of tridy-

mite were obtained by allowing large melts of quartz glass to cool slowly. On the surface of these melts radial spherulites of tridymite frequently formed and in one instance coated the entire charge with a film 1^{mm} thick of crystalline material. The preparations, however, were without exception fine-grained and so intricately intergrown and affected by optical anomalies that the exact determination of its optical constants is not possible. The same conditions obtain in the mineral tridymite and appear to be characteristic of this phase of silicon dioxide.

Intermediate mixtures.—The preparations from mixtures between pure silica and wollastonite varied greatly in texture and, with the exception of those mixtures which approached the metasilicate in composition, were found to be inhomogeneous and to consist of tridymite and one of the forms of the metasilicate. In products with less than 37 per cent of calcium oxide,—the eutectic composition of silica and calcium metasilicate—crystallites of tridymite were observed, often arranged in systems of lines intersecting at 90°, 60° and less angles or in rosettes and radial spherulites. The rosettes are finer grained than the crystallites and frequently appear as mere dust particles. The metasilicate is also fine-grained, without crystal outline, and includes the larger phenocrysts of tridymite. It can be distinguished from the latter most readily by its higher refractive index and stronger birefringence. The eutectic itself is extremely fine-grained and tridymite occurs then only in minute dust-like particles without discernible crystal outline.

Preparations ranging in composition between the eutectic and the metasilicate contain large, clear, lath-shaped crystallites of the metasilicate, often in parallel orientation and interrupted by a finely crystalline, less clear mixture of tridymite and the metasilicate. The optical properties of the metasilicate in these intermediate products differ slightly from those of the pure mineral, a condition which is due undoubtedly to the presence of silicon dioxide taken up in solid solution by the metasilicate. In these products the form equivalent to the mineral wollastonite was found to differ from true wollastonite chiefly in its lower refractive index and smaller optic axial angle; a measured in one instance 1·485 instead of 1·521, the a of pure wollastonite. The smallest value for the optic axial angle in air was found to be about 30° in air in place of the 70° of pure wollastonite.

The second form of the metasilicate corresponding to pseudo-wollastonite showed similar variations; its refractive indices were also lower, $a = 1·490$ having been measured in one instance, a value ·025 lower than a for pure pseudo-wol-

lastonite. The optic axial angle was found to increase and reached a maximum of about 25° in air, whereas pure pseudo-wollastonite is nearly uniaxial. In many of the preparations hexagonal outlines of this phase are noticeable, and two sets of imperfect cleavage lines intersecting at an angle of 120° . can then be seen on sections normal to the acute positive bisec-trix. Mixtures containing over 45 per cent of calcium oxide appear homogeneous, and the crystals from the preparations show a continuous variation in their optic properties from that point on as the composition of the metasilicate is approached.

The microscopic study of the preparations ranging in com-position between calcium metasilicate and calcium orthosilicate showed that the metasilicate is capable of absorbing a consid-erable amount of the orthosilicate and still appear homogene-ous, the resultant crystals expressing the fact of solid solution by the change in their optic properties. The limit of homo-geneity of the mass appeared to be reached at about 50 per cent lime and in crystals from fusions of that composition the refractive index a was found to have increased from 1·615 of pure pseudo-wollastonite to about 1·630 ; the optic axial angle was also larger (2 E about 20°–30°); the plane of optic axes was normal to a direction of cleavage in contrast to its position in crystals of solid solutions of the metasilicate and silica in which the plane of optic axes was observed parallel to the direction of cleavage. In the 50 per cent preparations, twin-ning lamellae with small extinction angles can often be seen on sections normal to the acute positive bisectrix, thus demon-strating their monoclinic or triclinic nature, notwithstanding the hexagonal outline of the basal section and systems of cleavage lines intersecting at angles of about 120°.

In products containing a little more than 50 per cent of cal-cium oxide the fine-grained eutectic begins to appear in small patches between the crystallites of the metasilicate. Fusions from mixtures of about 55 per cent lime and 45 per cent silica are usually fine-grained, and differences in size between crystals of the meta- and orthosilicate are less apparent.

Preparations with more than 55 per cent lime ordinarily disintegrate to fine powder on cooling, due to the great increase in volume of the orthosilicate on inverting to the γ-form at low temperatures. Studies in texture could not there-fore be made in the loose powder, and evidences of solid solu-tion near the orthosilicate were sought for by means of optical constants alone. The refractive indices of the minute crystal-lites from the products approaching the orthosilicate in com-position were not observed to differ appreciably from those of the orthosilicate.

The products whose composition extended from the ortho-silicate to pure lime were not homogeneous and contained both end members in variable amounts. If quenched quickly, the melts consisted of fine grains of the high refracting calcium oxide and the *a*-form of the orthosilicate ; if allowed to cool slowly, the *a*-form inverted ordinarily to the *γ*-form with attendant shattering or " dusting " of the product.

Thermal evidence showed that the eutectic for the orthosili-cate and calcium oxide is very close in composition to that of the orthosilicate. Preparations of this composition were examined under the microscope but no definite eutectic struc-ture was observed. In such cases thermal evidence alone must be relied upon to determine the eutectic point, as the optical data are entirely inadequate.

Summary.—There are only two definite compounds of lime and silica capable of existing in contact with the melt. They are :

(1). The pseudo-hexagonal metasilicate melting at 1512° and inverting into wollastonite at about 1200°. The metasilicate is able to take up a small amount of either lime or silica in solid solution.

(2). The orthosilicate of calcium, which melts at 2080° and possesses three polymorphic forms :

The *a*-form, which crystallizes in the monoclinic system, has a density of 3·27 and a hardness of between 5 and 6.

The *β*-modification crystallizes in the orthorhombic system and has a density of 3·28.

The *γ*-modification has a density of 2·97, and also crystal-lizes in the monoclinic system. The disintegration or " dust-ing " of the orthosilicate and of all lime-silica mixtures above 51 per cent lime is due to the 10 per cent volume-change accompanying the $\beta \rightleftarrows \gamma$ inversion.

The inversion point *a* to *β* occurs at 1410°, *β* to *γ* at 675°.

There are three eutectics in the series :—tridymite+the metasilicate at 37 per cent CaO, 1417° ; the metasilicate+ orthosilicate at 54 per cent of lime, 1430° ; and orthosilicate+ lime at 67½ per cent of lime, 2015°.

The orthosilicate is readily attacked by water, which dis-solves out the lime in large quantities. This is probably the reason why it is not found as a natural mineral.

The density of fused CaO is 3·32 ; its hardness 3+. It fuses in the electric arc but its fusion temperature is not accu-rately measurable. Lime crystallizes in the isometric system and possesses no polymorphic forms.

Silica begins to melt at about 1600° to an extremely viscous liquid, so that an exact melting point cannot be determined. It has been shown that for all temperatures above 1000° pure

quartz changes into tridymite, and pure quartz glass crystallizes as tridymite; so that above this temperature tridymite is unquestionably the stable phase. In the presence of fused chlorides silica crystallizes as quartz at temperatures up to 760° and as tridymite above 800°; crystalline quartz inverts to tridymite above 800° and tridymite goes back to quartz at 750°. The inversion temperature is therefore about 800° and the change is enantiotropic. The density of artificial tridymite was found to be 2·318, and that of quartz glass 2·213. The pure natural quartz used had a density of 2·654, the artificial crystals, 2·650.

Neither the salt of the trisilicic acid, $Ca_2Si_3O_8$, the åkermanite analogue, $4CaO,3SiO_2$, nor the tricalcic silicate, $3CaOSiO_2$, can exist in the two-component system.

The optical evidence gained by the microscopic study of the crystallized products of mixtures of silicon dioxide and calcium oxide in variable proportions confirms the pyrometric measurements in the following particulars: (1) That silica, calcium metasilicate, calcium orthosilicate and calcium oxide are the only compounds in the series; (2) that two different modifications of silica exist and correspond in their properties to the minerals quartz and tridymite; that the metasilicate crystallizes in two enantiotropic varieties, one of which is identical with the mineral wollastonite in its characteristics; that three enantiotropic phases of the orthosilicate exist and are stable at different temperatures; (3) that the metasilicate forms solid solutions both with silicon dioxide and with orthosilicate over limited ranges.

The experience gained in the course of the examination of these and other laboratory preparations indicates that the best results can be obtained by observing them in powdered form and immersed in liquids of different refractive indices and not in thin sections embedded in Canada balsam. In a liquid whose refractive index is equal to that of one of the component substances of the product, the differences in homogeneity in the product are more readily discerned than in a thin section, and at the same time one of the optical constants of the substance is ascertained.

Geophysical Laboratory,
    Carnegie Institution of Washington, June, 1906.

Art. XXVII.—*Analysis of "Iron Shale" from Coon Mountain, Arizona;* by Oliver C. Farrington.

In the account recently published by Messrs. Barringer and Tilghman* of their investigations at Coon Mountain, Arizona, they call attention to a magnetic oxide of iron, locally known as "iron shale," which they state occurs in considerable quantity upon the mountain. The distribution of the shale is stated to be around the rim of the "crater," especially on and in its northern portion and near by on the plain. In the form of minute particles, either as fragments or as spherules, it is also said to occur over the surface of the surrounding country concentrically around the crater for perhaps several miles. Beneath the surface large fragments are found, at varying depths, the greatest depth noted being twenty-seven feet. The pieces reported by these authors varied from one to thirty pounds in weight. No quantitative analysis of the shale is given, but qualitatively it is said that all the specimens examined contained nickel to the same extent, proportionally speaking, as in the Canyon Diablo meteoric iron. It is also stated that within the larger pieces may be seen green hydroxide of nickel, while in the very minute pieces of shale the nickel has leached out to a greater or lesser extent. Occurring with the shale and believed by these authors to be related to it, are so-called "shale balls," which are described as roughly globular to oval in shape, the outside having been converted into hydrated oxide of iron, while the interior is usually magnetic oxide of iron. These are said, when broken open, to show in nearly every instance the green hydroxide of nickel. In some cases these shale balls are said to contain a solid iron center. As the magnetic oxide which surrounds this center usually presents a more or less laminated appearance, it is assumed that the so-called iron shale found on the surface, as seen on a slightly curved piece, has resulted from the alteration of the shale balls. It is also stated that the pieces of laminated oxide are often grouped, as if a shale ball or piece of meteoric iron which was once covered by a magnetic oxide of iron had fallen on the spot and the magnetic oxide of iron had been disintegrated by the fall, or afterward by atmospheric agencies. These authors apparently consider their mention of this material the first which has been published, but in Foote's account of the Canyon Diablo meteorites† mention is made of material which is probably of the

* Proc. Phila. Acad. Nat. Sci., vol. lvii, pp. 861–914, 1905 ; this Journal, June, 1906, p. 402.
† This Journal (3), vol. xlii, pp. 413–417.

same nature. Foote states that accompanying the pieces found at the base of the crater were oxidized and sulphureted fragments which were shown by a preliminary examination to be undoubtedly of meteoric origin. Foote secured about 200 pounds of this material, varying from minute particles up to pieces weighing 3 pounds 14 ounces. These fragments are described as mostly quite angular in character, and a few as showing a greenish constituent "resulting probably from oxidation of the nickel." The oxidized material Foote states to be identical in appearance to an incrustation which covers some of the iron masses and partially fills some of the pits. In Koenig's chemical examination published in the same paper he states that "the iron is associated with a black hydroxide containing Fe, Ni, Co and P in the ratio of the metallic part and therefore presumably derived by a process of oxidation and hydration of the latter." Foote evidently regarded the oxidation of this material as having taken place during the fall of the meteorite, as he states that "the remarkable quantity of oxidized black fragmental material that was found at those points where the greatest number of small fragments of meteoric iron were found, would seem to indicate that an extraordinarily large mass of probably 500 or 600 pounds had become oxidized while passing through the air and so weakened in its internal structure that it burst into pieces not long before reaching the earth." Barringer's view of the magnetic oxide seems to accord with this.[*]

In Derby's account of the constituents of the Canyon Diablo meteorite[†] reference is also made to what is undoubtedly this same material. Derby's statement is as follows:

"I was also shown in Washington schistose masses of iron oxide found in the same region, whose connection with the meteorite was considered doubtful. These closely resemble the thicker masses of rust crust formed on the Bendego meteorite and like it, as is well seen in sections prepared by Mr. Diller, show minute particles with a metallic luster which were almost certainly grains of schreibersite, as that mineral has been separated from the rust crust of both Bendego and São Francisco do Sul. In view of its occurrence it can hardly be doubted that these Canyon Diablo specimens are due to secondary alteration of the meteorite. As the iron masses in general have a thin rust crust, indicating considerable resistance to oxidation, it may be suggested that these thicker masses of oxide may perhaps come from original pyrite as in the case of São Francisco do Sul."

It is thus seen that this material has been observed by previous investigators, but no detailed examination of it seems as

[*] Op. cit. p. 882.
[†] This Journal (3), vol. xlix, pp. 102–110.

yet to have been published. As it seems desirable to throw as much light as possible on the remarkable character of the formation of Coon Mountain, the writer deemed it advisable to determine what information might be gained from a quantitative analysis. Specimens of what seemed to be the same material as that described by Messrs. Barringer and Tilghman were already in the Field Museum collections, but in order to be certain to obtain the material described by them, a request was made of Mr. Barringer for specimens. These Mr. Barringer very kindly furnished, in the shape of several pieces of "shale" weighing in all about half a pound, as well as one of the small "shale balls." The pieces of shale received were of flattened or elongated form, angular, and weighing a few ounces each. All showed a quite uniform blackish-brown color. On fresh fracture the color appears more nearly black, and the surface has a glossy appearance. A laminated structure characterized all the pieces. The laminae of which the shale is made up are more or less intercalated but average about one millimeter in thickness. The divisions between them are made in part by thin layers of a brownish-white substance which effervesces with acid and is undoubtedly the aragonite coating frequently observed on the Canyon Diablo siderites and described by Foote. These layers do not affect the appearance of the shale to the naked eye, however, for without a lens only a uniform color and structure is apparent. The shale is sufficiently coherent also to take a fair polish. The "shale ball" received from Mr. Barringer is in color and texture similar to the shale. Its lamination is however concentric rather than horizontal. Its form is ellipsoidal and diameter about one inch. Its surface is broken by broad, irregular cracks extending nearly to the center. Both the shale ball and a piece of the shale showed the same specific gravity, viz: 3·73. The large pieces of shale show sufficient magnetism to affect a compass needle, and small pieces are readily attracted by a common horseshoe magnet. The shale crushes rather easily in a mortar to a dark brown powder. This powder is also quite magnetic. Heating in a closed tube causes considerable water to be given off, showing that a hydrous oxide is present. The material appeared, therefore, to be referable neither to magnetite nor to limonite, since it was too magnetic for limonite and contained too much water for magnetite. None of the specimens showed the green hydroxide of nickel referred to by Foote and Barringer. Only the powder which was attracted by the magnet was used for analysis, but this included practically all of it. The analysis by Mr. H. W. Nichols gave the following results:

Fe_2O_3	74·63	Al_2O_3	0·05
FeO	3·91	SO_3	0·00
NiO	9·79	S	tr.
CoO	0·49	P_2O_5	0·00
CuO	0·00	P	0·10
CaO	1·27	C	0·15
MgO	0·00	Cl	0·08
			———
H_2O	8·02		99·93
SiO_2	1·09	$O = Cl =$	0·01
CO_2	0·35	$O = P =$	0·15
			———
			99·77

The results of this analysis confirm the statements of Koenig and Barringer that nickel and cobalt are to be found in the shale in the same proportion as in the meteoric iron, and leave little doubt that the " shale " is derived by oxidation from the meteoric iron. It is obvious that the analysis may be interpreted in several ways, since much uncertainty exists as to what changes iron undergoes in the process of " rusting." By some it is thought that a ferrous carbonate is first formed which later alters to ferric hydroxide. Others doubt the influence of carbonic acid and believe that the oxygen and water of the air produce ferrous oxide and hydrogen peroxide. By the first process it would be expected that limonite alone would be produced, while the second might form some magnetite. Examination under the microscope of the finely powdered shale showed differences of color and texture not observable to the naked eye. In the small grains appeared alternations of black and yellow colorings and compact and earthy textures which suggested associated magnetite and limonite. The analysis calculated on this basis gives fairly satisfactory results. By assuming that all the protoxide of iron and nickel is present as a constituent of magnetite, and that the remaining sesquioxide and water are present as limonite, the different constituents can be fully accounted for. Such a constitution also explains the magnetic character and color of the powder. Calculated in this manner and grouping the minor constituents according to their apparent origin, the following constitution of the shale is indicated :

Limonite	52·99
Magnetite	42·39
Schreibersite	0·64
Graphite	0·15
Lawrencite	0·14
Aragonite	0·80
Andradite	2·45
Quartz	0·21
	———
	99·77

The andradite here reported was not observed, but its presence was indicated by the percentages of lime, iron and silica remaining after the deduction of the other constituents. That it could readily become mixed with the shale from the surrounding sands seems probable. The other constituents indicated are readily referable to the accessory constituents of the meteorite and the results of the analysis are of interest as showing what changes take place in them. The Canyon Diablo meteorites, as is well known, contain as accessory constituents, troilite, graphite, cohenite and schreibersite. Of sulphur, representing troilite, only a trace was found. It appears, therefore, that sulphates were formed and leached out. No phosphorus was found to be present as phosphates and only 0·64 per cent as phosphides. It thus appears that while some schreibersite remained, all which had oxidized to phosphate had been removed. The percentage of carbon found, 0·15 per cent, indicated some cohenite or graphite yet remaining. The percentage of chlorine found indicates the presence of lawrencite, to which, as shown later, may be ascribed probably to some extent the oxidation of the meteorite. The percentage of nickel oxide found is somewhat higher than usually reported for the Canyon Diablo meteorites and suggests that a concentration of nickel oxide has taken place through a greater solubility of the iron. It is well known that taenite, which is the more highly nickeliferous constituent of nickel-iron, resists oxidation longer than kamacite, and this might tend to increase the nickel content of the oxidized product. Whether the nickel oxide when formed would be removed more or less rapidly than the iron oxide does not seem to be known as yet however. Test was made for metallic iron and nickel in the shale by treating the powder with iodine, but practically no indications of the presence of these constituents were thus obtained. The shale also when immersed in a solution of copper sulphate showed no deposition of copper such as would occur if the above metals were present. Undoubtedly pieces of the shale in which oxidation had been less complete would show such a content.

Comparison of the analysis of the shale with those of rust crusts of other meteorites made by other authors shows differences chiefly in the percentage of water found. Thus Pugh, in the crust of Toluca,[*] Haushofer in that of Cranbourne[†] and Cohen in that of Beaconsfield[‡] found an amount of water approximating closely to 13 per cent. This indicates

[*] Inaug. Diss. Göttingen 1856, pp. 5–14.
[†] Jour. pr. Chem. cvii, pp. 330–331 ,1869.
[‡] Meteoritenkunde, Heft ii, p. 263.

an alteration of the iron to limonite. It is not stated whether these crusts were magnetic or not. The amount of NiO and CoO found by Cohen in the Beaconsfield crust was only 1·68 per cent, and by Haushofer in Cranbourne 3·1 per cent. In these cases a leaching of the nickel-cobalt oxides has apparently occurred. It is probable that different climatic conditions would have considerable influence in affecting the composition of such rust crusts.

Explanation of the origin of the laminated structure of the shale is doubtless furnished, as suggested by Barringer, by the shale balls. Oxidation and hydration proceed from the surface inward. These changes cause an increase in bulk of the layers successively reached in the process, so that they separate slightly from the unchanged material beneath, and interstices are afforded through which the oxgyen and water enter to attack the metal. Thus the process is continuous and depends only on time and exposure for its completion. The cracks in the shale balls show that the present superficial layers once covered an interior which has since increased in bulk.

If it be accepted that the iron shale and shale balls are oxidation products of an ordinary Canyon Diablo siderite, it remains to be determined why certain of these siderites should have so oxidized while others have not. One reason is probably to be found in the observation of Barringer that the iron shale often occurs beneath the surface, while the meteoric irons are found only at the surface. Those meteorites which were covered more or less by soil and rock fragments would receive a larger supply of water and hence would suffer more rapid oxidation and hydration than those at the surface. It may also be true that the individuals which have decomposed to form shale balls and shale contained more lawrencite than those which have not. Barringer states[*] that " the iron centers of the shale balls nearly always show a peculiar oxidation of drops of moisture, often colored green, partly perhaps from the presence of nickel. This exudation, Dr. Mallett explains to me, is due to the presence of chloride of iron." It is well known that among the Toluca meteorites, for example, some individuals contain a considerable amount of lawrencite while others do not. The former " sweat" and rapidly decompose, even in a museum case, while the latter remain dry and unaltered. Mr. Nichols has called my attention to a continuous decomposing action probably exerted by lawrencite which has perhaps not been noted before in this connection. Ferrous chloride in contact with air and water forms ferric hydroxide and chloride:
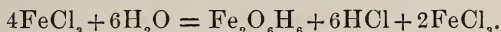
$$6FeCl_2 + 3O + 3H_2O = Fe_2O_6H_6 + 4FeCl.$$
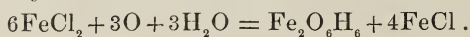
[*] Op. cit. p. 882.

The ferric chloride is, however, reduced by contact with iron to form ferrous chloride again:

$$4FeCl_3 + 2Fe = 6FeCl_2$$

so that the process is continuous. In addition there may occur a formation of free acid through hydrolysis of ferric chloride:

$$4FeCl_3 + 6H_2O = Fe_2O_6H_6 + 6HCl + 2FeCl_3.$$

This acid would obviously likewise exert a decomposing action.

In conclusion, it may be said that the view of Foote and Barringer that the oxidation which produced the "shale" took place during the fall of the meteorite, is not that of the present writer. In the present writer's view the oxidation occurred subsequent to the fall of the meteorite, and was so gradual that the production of the shale can be explained only by assuming that the fall took place many years ago.

Field Museum, Chicago, June 15, 1906.

ART. XXVIII.—*Of the Phenomena Observed in Crookes' Tubes;* by N. T. BACON.

No satisfactory explanation seems to have been made of the phenomena characterizing prolonged discharges in a Crookes tube.

Results which have been recognized are A, discharge of peculiar rays from the anode; B, discharge of different peculiar rays from the cathode; C, gradual attenuation of the discharges; D, recrudescence of the discharges on heating the walls of the tube; and E, coating of the walls with platinum black.

The attempt has been made to explain C and D by supposing the vacuum to increase, beyond the point where the discharges can pass, by absorption in the pores of the glass walls of portions of the residual gases, and redischarge of these on heating the tube. But this hardly seems rational. It is contrary to all our ideas that an intense vacuum should be intensified by absorption of gases in the walls of the containing vessel in which the vacuum was originally produced. We should expect instead a slow evolution of relics of the greater amount of the same gases absorbed in the body of the glass under the higher original pressure; and furthermore, if any such effect existed, it could hardly fail to result in a kind of osmotic transfusion from the outside, where, as in this case, the containing wall is often not over $\frac{1}{10000}$ inch thick. It seems reasonable to ascribe the gradual attenuation to increasing vacuum, as it is partly overcome by heating the walls of the tube. Glass is known to have (and particularly with aqueous vapor) the property of accumulating over its surface a film denser than the average of the surrounding atmosphere, and this is even more marked with platinum. This I lay to lack, in the solid state, of the perfect elasticity of the molecule, which is postulated by the received theories of gaseous tension. Why should we not consider molecular elasticity to be more or less imperfect in the solid state? We should then find a ready explanation of the heating of platinum sponge in an atmosphere of hydrogen, accompanied by condensation of the hydrogen even to the point of liquefaction. The molecule of hydrogen striking the imperfectly elastic platinum molecule would rebound with diminished velocity, the lost kinetic energy going to raise the temperature. In the pores of platinum sponge the hydrogen molecule will naturally strike again and again the imperfectly elastic mass, with further evolution of heat and loss of velocity, until it reaches nearly the orbital velocity of the vastly heavier platinum molecule, thus being reduced even to

the liquid condition. Subsequent molecules of hydrogen would suffer like losses (though less rapidly, owing to occasional impacts on hydrogen instead of platinum) until a film of hydrogen molecules should form a more perfectly elastic coating, and equilibrium would be established (with higher temperature in the film than in the surrounding atmosphere) when impact on the platinum of a fresh molecule of hydrogen raised the temperature of the film to the point of expelling another molecule from its surface. Evidently such a film would give off molecules when heated, and knowing platinum black to have this action on gases in higher degree than glass, we can see how the vacuum might be increased by the platinum coating, and why heating the walls of the tube should have the effect of partially restoring its activity. It is also interesting to note that by this theory the higher the vacuum the more important relatively this action becomes, as the exposed surface of imperfect elasticity remains constant, while the number of gaseous molecules diminishes, and thus the ratio increases of impacts resulting in loss of velocity.

This may sufficiently explain the recrudescence on heating the walls of the tube, but does not explain the emission of rays, and hardly seems sufficient for the continuing gradual increase of vacuum. Why should not these be accounted for on the hypothesis of a resolution of atoms into electrons or emanations under the discharge in a Crookes tube, and radiation of these (to which the glass walls might be pervious, more or less, as to the ether, though entirely impervious to molecular matter) of different polarity from the different electrodes? Of these rays we know very little, except that they differ materially from the forces with which we are accustomed to deal. The X-rays, emanating from the anode, are absorbed by mass apparently much in the way that light is absorbed by partially transparent substances, as is shown by the X-ray pictures, and they have been considered (though perhaps on insufficient grounds) to have also the velocity of light, which would tend to suggest their relation to the electric current streaming also from the anode; but no ordinary reflection or refraction of them is possible. On the other hand, about all that we know of the cathode rays is that they can be deviated by a magnetic field, thus showing some of the characteristics of mass, and, moreover, they seem to move more slowly than light.

We are not reduced here to consideration of the electron solely. Possibly we may have to do with one or both of the still more ethereal forms of matter postulated to account for the curious changes attending the transformation of radium to helium, but, from present indications, is it not probable

that, under these limiting conditions, the electric discharge can only take place by a disruption of atoms (failing chemical combinations, of which after electrolysis of the residual aqueous vapor probably none would remain) similar to the electrolysis, which alone enables the current to pass through water and other liquids?

There is, of course, the intermediate possibility of the mere disruption of molecules into nascent atoms, but this probably would not continuously intensify the vacuum by enabling the elements to escape, though it might be an intermediate stage.

The extremely tenuous condition of the residual elementary gas or gases in a Crookes tube, reducing exchanges of charges to a minimum, would apparently be a favorable condition for such disruption, and probably the high temperature would be another.

Holderness, N. H., Aug. 18, 1906.

Art XXIX.—*Northward Extension of the Atlantic Preglacial Deposits ;*[*] by Isaiah Bowman.

INTRODUCTION.

HEAVY winter storms on the New England coast following the unusually dry autumn of 1904 resulted in many changes in coastal topography, among which were the rapid cutting back of headlands of soft material and the freshening of cliffs. Good opportunities were thus presented for the study of exposed geological sections. The Third Cliff section near Scituate, Massachusetts, is of special interest because of the lithologic and stratigraphic homologies between the exposed beds and preglacial deposits farther south and their bearing on the question of the northern limit of the Atlantic Cretaceous and Tertiary. The nearest known outcrop of deposits of Cretaceous age is at Gay Head, Martha's Vineyard, 52 miles south of Third Cliff; the nearest known deposits of Tertiary are the Miocene Greensands at Marshfield, 7 miles south of Third Cliff. The latter are not commonly known to occur though they were noted by Hitchcock[†] as early as 1841 (p. 91), the latest text-book of Geology[‡] stating that "The northernmost exposure of the Miocene on the Atlantic coast is on Martha's Vineyard."

Third Cliff is one of a series of four cliffs in close succession twenty miles southeast of Boston and immediately south

[†] Final Report on the Geology of Massachusetts, vol. i, pp. xii to 831, 1841.
[‡] Geology, Chamberlain and Salisbury, vol. iii, p. 260, 1906.

of Scituate Harbor. They are represented on the Duxbury Sheet, U. S. G. S., as the eroded edges of drumlin-shaped hills, from 20 to 75 feet high and with major axes trending NNW. The accompanying sketch (fig. 1) of a part of Third Cliff depicts the chief features referred to in the following description.

Lithologic and Structural Features.

Preglacial Series. (1) *Basal clays.*—The basal member of the Third Cliff section is a layer of clay having the light yellow color of terra cotta. The top of the layer is about at the level of high tide, and an excavation of several feet failed to reach the bottom. It lies in a nearly horizontal position, with slight dip to eastward. It is extremely unctuous when wet and resists wave action to such a degree that
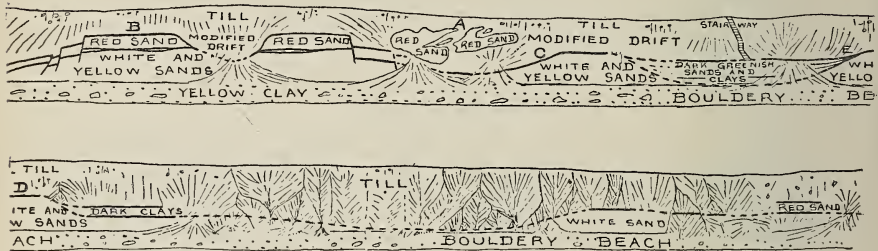
FIG. 1. Topography and structural relations of part of Third Cliff. Heavy continuous lines represent observed structures. Heavy dotted lines represent inferred structures. Horizontal scale = 175 feet to the inch. Vertical scale = 130 feet to the inch.

the height of the steeply-sloping bowlder-strewn beach (fig. 1) is determined by its upper surface. Within the body of the deposit the clay is very pure, but towards the top becomes more sandy, containing round inclusions of yellow sands up to a centimeter in diameter. Lamination appears near the upper surface, at first faintly and then more strongly marked, changing finally into cross-bedded structure, although the bulk of the material is still clay. An 18-inch deposit of alternating yellow sands and clays, of several inches thickness each, completes this lowest member of the preglacial series. The entire layer contains muscovite in considerable quantity, and under the microscope shows an occasional grain of glauconite and scattered fragments of sponge spicules, none of which have sufficient character to be identifiable, although one specimen suggested a form of *Geodia*.

(2) *Yellow and white sands.*—A deposit of yellow and white sands lies conformably upon the basal clay, the latter color gaining predominance towards the top. Like the clays

beneath them, these sands dip gently to the eastward. Their maximum thickness is 25 feet, with, however, many variations in thickness, as will be explained in a later paragraph. But slightly cross-bedded at the base, these sands become more and more irregular towards the top, where they display excellent cross-bedded structure, the upper eight feet of the layer being exclusively of this character. The sands vary in texture from fine at the bottom to coarse at the top, and show in the same direction a decreasing amount of the clayey constituent possessed throughout. Just above the clays on which they rest the sands carry sufficient clay to render them somewhat plastic when wet. At the top of the sands where cross-bedding is most marked the sands are dry and partially indurated, so that the eroded edges retreat with a nearly vertical face. The indurating process has been carried so far in a few places that the material might almost be called a sandstone. Scattered fragments of sponge spicules occur here as in the clays previously described, and an equal amount of glauconite. The sands are very silvery in general appearance, owing to the great amount of muscovite present, some of the flakes attaining a size of from 4 to 6 millimeters. There is no break in the series thus far described, every change being slow with conformable relations throughout.

(3) *Red sands.*—At the top of the white sands an unconformity occurs, the eroded edges of the white sands being overlaid by a layer of coarse and dark red sands with a maximum thickness of 10 feet. These red sands bear large quantities of muscovite, a smaller quantity of biotite, and also exhibit cross-bedding of a much greater degree of amplitude than that shown in the white sands. Occurring only in patches between the white and red sands and never present where unconformable relations between these two members are exhibited, is a thin layer (1 or 2 feet) of black, coarse sand composed of large grains of smoky quartz and with an admixture of biotite. It is cross-bedded after the manner of the red sands which overlie it.

(4) *Dark green sands and clays.*—If fig. 1 be consulted, it will be seen that below the stairway near the middle of the figure the section shows greenish black sands and clays at the level of the white sands and below the level of the red sands. The whole face was so masked by talus and landslide material near the top of the bluff that extensive excavation was necessary to determine the relations of the various beds. Both series of beds were evidently in place and the problem resolved itself into finding the line of contact between the two. This was accomplished with the results shown in fig. 2, which is an enlarged portion of fig. 1 at E.

The white sands were found to exhibit in the clearest possible manner the erosion of a considerable body of their material, the entire series above them being swept away in addition. Upon their eroded edges lies unconformably a layer of white and yellow clays and sands which are superseded above by the greenish black clays noted in the section. The overlying dark clays and the yellow sands and clays between them and the underlying white sands, thicken gradually toward the middle of their outcrop (fig. 1), where the sands attain a maximum thickness of 3 feet and the clays 8 feet. These clays exhibit
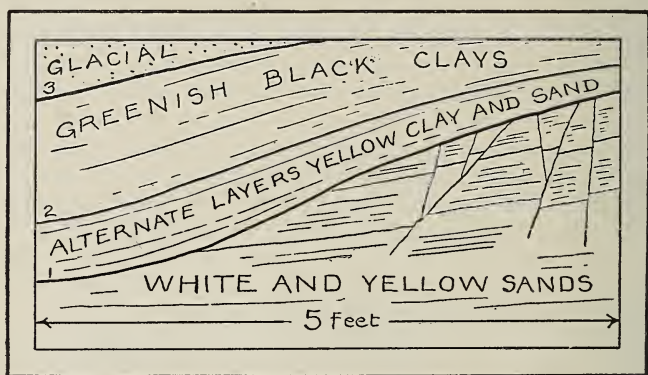
FIG. 2. Representing unconformity between dark clays and white and yellow sands at E, fig. 1. Nos. 1 and 3 in diagram represent unconformities; at 2 the deposits are conformable.

the same changes as those of the lowest clays in the series—a gradual transition into more sandy members of similar color and 12 feet thickness, which completes the upper part of the preglacial section.

As soon as this relation between the beds was discovered the entire section was re-examined with a view to interpreting the relations which proved puzzling elsewhere, and in each locality, no matter how disturbed by ice action or disguised by landslides, the greenish-black clays and sands were always found upon excavation to overlie stratigraphically the white sands of cross-bedded structure.

Glacial Series.—The glacial material which overlies all of the preceding beds may be divided into two classes. The lowest is stratified brown sand bearing a high percentage of erratic material and occupying the eroded depressions in the lower beds; the second is a confused mass of red and white sands (see A, fig. 1) intermingled with erratic sands and typical bowlder clay, the bowlders attaining a maximum diam-

eter of 6 feet. The two classes of deposits are in uncon-
formable relation to each other, and along the entire cliff face
are seen to be in strong unconformity with the beds on which
they rest (see B, C, D, fig. 1). The detailed structure of the
till is shown in fig. 3, great blocks of bowlder clay being
separated by a "filling" of horizontally stratified sand which,
being without the slightest marks of disturbance since deposi-
tion, was deposited in water either contemporaneously with the
till or later as a secondary de-
posit between the blocks of till
as fast as the ice between the
blocks was melted out. At
Fourth Cliff similar structures
are seen with a considerable
part of the material derived
from the preglacial beds eroded
by the ice sheet in its advance.
At Indian Hill, seven miles
southeast of Plymouth, a good
85-foot section shows the
further complexity of a layer
of clay entirely different than
any in the Third Cliff section,
with a thickness of 20 feet and
underlaid by erratic sand and gravel.

FIG. 3. Showing structure of till
just beyond left margin, fig. 1. Sand
between till blocks is cross-bedded
and undisturbed. Figure represents
area about 5 feet square.

This layer may represent an interglacial deposit or a deposit
formed during a temporary recession of the ice. Its homo-
logue does not exist in the Third Cliff section, nor is there
any indication whatever at the present time of deposits or
structures developed contemporaneous with those at Indian
Hill. In all three sections there exists a thin layer of iron-
stained reddish and apparently older till just above the strati-
fied material of aqueo-glacial origin.

Succession of Events in the Deposition of the Third Cliff Beds.

The points to be considered in the determination of the age
of the beds below those of glacial relationships will be better
understood after their interpretation in terms of the events
which they represent.

It appears that we have represented in the 40 or more feet
of yellow clays and sands first described, marine conditions
with a steady shallowing of the basin of deposition either
through uplift or the gradual upbuilding of the floor through
sedimentation. These conditions are marked particularly by
the sand inclusions which occur on the top of the clays and
the gradual transition of clay to sand with the upper part of

the sands strongly cross-bedded. There followed a period of erosion which may represent very shallow water conditions without actual exposure to subaërial processes. Currents and waves have already found expression in the cross-bedded structure and to their increased efficiency at this time may be attributed the unconformity in question. Then came the deposition of the black sands composed of grains of smoky quartz, followed by the deposition of the red sands. The slight thickness of the beds representing the intervals of deposition, together with their cross-bedded structure and present position and attitude with respect to other beds, and the existing shoreline favors the view that coastal changes were here of a less profound order than along the more southerly part of the Atlantic littoral, where extensive denudation followed the deposition of beds of great thickness.

Apparently the greatest erosion followed the deposition of the red sands. In many places the red, black, and white and yellow sands are entirely removed down to the basal yellow clays. In the depressions thus formed was deposited the greenish black clay of figures 1 and 2. Gradual shallowing of the deeper water in which the clays were deposited is represented by the greenish-black glauconitic sands at the top of the darker beds, figure 1.

The succeeding events of importance in the history of this part of the New England shoreline were the erosion of the whole series thus related and successive advances of the ice. The first effect of the latter process was probably the deposition of the brown erratic sands as a preliminary wash to be superseded by the deposition of the ice-borne clay and bowlders. The relations of the glacial material were not considered in detail, as the field of observation was too limited. The explanation of the manner of deposition of the stratified glacial sands may therefore be erroneous when more extensive observations are made. The retreat of the ice left the surface of the till practically as we see it today, except where it is modified by shallow gullying or by the insistent attack of the sea.

The weight and movement of the ice upon the unindurated preglacial sands and clays below resulted in the bodily removal of great masses of these deposits. They are clearly seen in the face of the cliff surrounded by erratic sands and bowldery clay (A, fig. 1). In addition, the remaining sands exhibit ice disturbance, for while they are practically in situ they are minutely fractured and faulted as shown in the upper right hand corner of fig. 2. In every case the blocks are easily restored in thought to their original positions by the help of slight variations in color and texture. The openings between

blocks are filled in some cases by a silty deposit which can in every instance be traced up to the till or sand above, from which it was derived by percolating waters. The great bowlders in the till are continually falling from the cliff face to the beach below and give added protection to the basal clays which determine the level of the beach. The clays, the partially indurated sands and the till—all alike possess sufficient tensile strength to stand in bold cliffs and thus yield under an encroaching sea a remarkably clean and perpendicular section.

Former Interpretations.

Both Third and Fourth Cliffs have been described by Upham.* As his interpretation differs widely from the one just given, the following summary of his results seems appropriate in this place. It should be said that the section is today in much better condition than when examined by Upham and probably shows the relationships of the various deposits very much more clearly than at any time heretofore.

The two cliffed hills are referred to as "two extraordinary drumlins . . . . which consist of till . . . . to a depth that varies from 15 to 25 feet . . . . but below include beds of modified drift that attain in Third Cliff a thickness of at least 40 feet, reaching to the bowlder-strewn shore . . . . ." Neither the yellow clays which, partly masked by bowlders, form the shore, nor the unconformities above and in the so-called modified drift were noted. That the material is not modified drift is shown by a wholly dissimilar structure and lithologic character ; and by the total absence of erratic material, and a remarkably pronounced and persistent unconformity between the erratic and non-erratic beds, with several smaller unconformities within the latter (see conclusion, p. 325).

Upham speaks further of the anticlinal structure of the modified drift and the approximate coincidence of the upper surface of these beds with the surface of the till at the cliff top. This is offered as evidence of the manner in which drumlins are deposited underneath the ice, but in the better section of today the cliffs show in the clearest possible manner that the apparent anticlinal structure is in reality the effect produced by successive faultings of broken blocks of white and red sands as shown near the left margin of fig. 1 ; and that the coincidence or parallelism of the structural surfaces called anticlinal is due not to similar dynamic conditions imposed by the ice, but to the control exercised on ice movement and deposition by the form of the subjacent terrane. It cannot, therefore, be argued alone from the relations exhibited here that drumlins are a subglacial deposit built up by successive accretions from the debris-laden lower part of the ice. It is

* "The Structure of Drumlins." B. S. N. H. Proc., xxiv, 228–242, 1889.

not implied that such conditions may not have occurred else where, but that such was not the case here is clearly proved.

The presence of the yellow sands was noted by Upham and also the lignitic clays, "laminated dark gray clay," the latter being attributed to deposition of material subglacially transported, the lignites being explained as the possible remnants of an interglacial forest overwhelmed by the ice, yet the absence of all bowlders and till fragments in the clays was observed. The better section of today shows also that the structure of the till is in reality like that shown in fig. 3, and not obscurely laminated. The same figure shows the presence of seams and lenses of gravel within the till, their absence having been asserted heretofore. The various anomalies, which Upham's observations led him to believe were present here, were explained by the suggestion that the modified drift of Third Cliff was deposited under very unusual sub-glacial conditions.

Occurrence of Preglacial Deposits near Third Cliff.

Deposits of pre-Pleistocene age once subaërially eroded and now submerged have been presumed by several writers to occur near shore on the floor of the sea north of Martha's Vineyard. The first to suggest this, with the possible exception of Hitchcock, who vaguely refers to this matter (p. 427), was Verrill,[*] who observed in dredged material from the north Atlantic coast compact calcareous sandstone and arenaceous limestone bearing fossil shells and fragments of lignite. About half the fossil forms were considered extinct. Verrill thinks that the fragments were probably "detached from a very extensive submerged Tertiary formation at least several hundred miles in length, extending along the outer banks, from off Newfoundland nearly to Cape Cod and perhaps constituting, in large part, the solid foundations of these remarkable submarine elevations."

Later on, Upham[†] reports finding fossils of possible Eocene or Cretaceous age in the drift materials near Highland Light, Cape Cod. Hitchcock[‡] even believed from the Miocene deposits at Marshfield (seven miles south of Third Cliff) that deposits of Tertiary age occurred "abundantly along the coast from Marshfield to Plymouth and not improbably also on Cape Cod," although their actual occurrence was not noted.

Professor Shaler, in his report on the geology of the Cape Cod District,[§] suggested the presence, at least on the sea floor,

[*] "Occurrence of Fossiliferous Tertiary Rocks on the Grand Bank and George's Bank." This Journal (3), xvi, pp. 323–324, 1878.
[†] Marine shells and fragments of shells in the till near Boston, B. S. N. H. Proc., xxiv, pp. 127–141, 1889.
[‡] See footnote, p. 9.
[§] "The Geology of the Cape Cod District," by N. S. Shaler, 18th Annual Report, U. S. G. S. Part II, p. 580, 1896–97 (see also pp. 516 and 578).

of Cretaceous and Tertiary deposits northward as far as Cape Ann, from the general likeness of the outlines of the shoals of Stellwagen Bank to Cape Cod and the relations of the now submerged valleys.* The suggestion, though a purely analogous one, is of great interest in the further exploration of the field concerned.

Correlation with Similar Deposits to the South.

The evidence upon which age determinations are attempted is gathered from a close study of the strata themselves and of adjacent areas. The paleontologic evidence secured does not have the specific quality demanded for the purposes of correlations, although none of the evidence of this nature negatives the conclusions reached by other evidence. In short, the conclusions rest upon presumptive evidence and must, therefore, be held as tentative and suggestive only.

Continuity of Deposits.—At Marshfield, seven miles south of Third Cliff, greensand beds were noted by Hitchcock as early as 1830.† Their age was later determined by Dr. Dall from fossil evidence and found to be Miocene. The deposit is highly glauconitic, occurs about up to 15 feet above mean tide level, and is in very close contact with the granitic floor, which outcrops two miles farther south. The sands do not outcrop, but are reached by excavating 6 to 8 feet beneath the surface. They were first discovered in digging for a well on the farm of Mr. Kent.

The presence of this bed suggested that coastal sections between Third Cliff and Martha's Vineyard might show similar deposits, but a search from Boston Harbor to Peaked Cliff, 15 miles southwest of Plymouth, proved fruitless except for the finding of drift material often in great abundance derived from preglacial beds undoubtedly similar to those at Third Cliff. This is particularly true of parts of the glacial deposits at East Marshfield, Kingston, Indian Hill, Lookout Point, and Peaked Hill. The unusual character of some of the glacial material in these places is very striking. There is a large amount of white and red sand rather poorly mixed with the more common brown sand noted in sections of glacial material farther inland. These suggest the wider extent of the preglacial deposits and their considerable erosion by ice.

Similarity of materials.—The fact that at least a part of these deposits were formed in relatively shallow water near shore, as shown by the cross-bedded structure of the lower sands, renders their correlation on this ground along with similar deposits on Martha's Vineyard insecure, because of

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* See map of the Cape Cod District.

† "Final Report on the Geology of Massachusetts," pp. 91–95, and 427, 1841.

the varying physical conditions under which sedimentation takes place in shallow waters. Controlled by the evidence of the unconformities it has, however, a more certain value. The relative thinness of the deposits close to this, their northern limit, and the frequent unconformities point to even greater irregularity in the physical conditions here than farther south, the deposits being more readily affected by slight oscillations of level common to the lands. The complexity of the mutual relations of coastal deposits is enhanced by the fact that continued erosion and redeposition often results in the close lithologic resemblance of beds of quite different age. In such cases there is, therefore, small value in the conclusions based on evidence of this sort. Unconformities and fossil evidence are the closest available determinants under such circumstances, and it is quite largely on the former that the conclusions of this paper are based.

The nearest known outcrop of beds lithologically similar to those at Third Cliff is at Gay Head, Martha's Vineyard. These are described by Professor Woodworth,* who mentions the following characters of the successive beds:

Lower Cretaceous: non-marine, lignitic, leaf-bearing clays.

Upper Cretaceous: locally hardened bands of sands containing molds of fossils, locally developed beds similar to those at Indian Hill (M. V.) which have a texture varying from fine to coarse with scattered larger grains of quartz and abundant muscovite scales. Inferred unconformity between Lower and Upper Cretaceous.

Miocene: thickness varies from 0 to 10 feet. Consists of two members—osseous conglomerate and foraminiferal or greensand beds, with unconformity between. The former is from 12 to 18 inches in thickness, consists of rounded bowlders or of nut-sized quartz pebbles white and well-rounded. Cetacean bones present. The foraminiferal bed is from 0 to 10 feet thick, green color below, brown above, basal part includes rolled fragments of osseous conglomerate and bears glauconite casts of *Macoma lyelli* in the attitude of growth and the crab *Archeoplox signifera* in lower part of stratum.

Probable Pliocene: yellowish green and brownish clays bearing glauconite and Pliocene fossils. Inferred unconformity between Pliocene and Miocene.

The paucity of glauconite in the Gay Head Upper Cretaceous and the variable texture of the material, the scattered quartz grains, abundant muscovite scales, correspond precisely with the conditions found in the white and yellow sands which form the basal member of the Third Cliff section. Even the occurrence of cross-bedding on a small scale in the coarse pre-

* "Unconformities of Martha's Vineyard and Block Island"; B. G. S. A., viii, 197–212, 1897.

Tertiary sands (p. 200) is noted. Were lithologic identity alone a determinant in correlation, we should be completely justified in calling these beds Upper Cretaceous. The irregularity of the New England shoreline, and the considerable distance (52 miles) between Third Cliff and Gay Head, make it probable that the physical conditions under which sedimentation took place were not persistent throughout the entire district, and it is, therefore, not surprising that at Third Cliff there should be present a layer of red sand crossbedded throughout on a large pattern which does not appear in the Gay Head section. With this exception the beds overlying the first unconformity at Third Cliff are again similar to those at Gay Head, except for the osseous conglomerate which is not present at Third Cliff, but the glauconitic sands are present bearing the white well-rounded quartz pebbles. Moreover, these beds are at precisely the same altitude as those definitely known to be Miocene (p. 321) at Marshfield, seven miles south. The Marshfield beds rest upon granite, the dark sands and clays of Third Cliff upon white sands. On the whole, the relatively close agreement of unconformities and lithologic characters seems very striking. While this resemblance, as was noted on the preceding page, may have slight value on account of marginal redeposition without the destruction of characteristic features, it is in a measure significant on account of the distinctness of the separating planes in the deposits and the strongly marked individual character of each bed. It is the more convincing to one who has seen the Atlantic Cretaceous and Tertiary farther south and has noted the persistent and distinctive character of these deposits.

It would be quite unsafe to base a correlation of the Third Cliff deposits with those of New Jersey entirely on the evidence presented here, but it is not without interest to note that with a single exception the Red Bank sands occur exclusively in the Monmouth formation, Upper Cretaceous, " except in certain marginal phases of the Rancocas formation,"[*] which latter is itself of Upper Cretaceous age. Glauconite occurs in great abundance in the Upper Cretaceous of New Jersey, and but sparingly at Gay Head, and certain yellow sands are found alike in the Miocene and Upper Cretaceous.

Paleontologic Evidence.—A fourth probability is suggested by the studies of T. C. Brown of Columbia[†] on the Chappaquiddic fauna from Martha's Vineyard. A comparison of this fauna with the Eocene faunas of the Atlantic and Gulf provinces indicates that the species closely resemble those

[*] Upper Cretaceous Formations of New Jersey, W. B. Clark ; B. G. S. A. viii, 313–358, 1896–97.

[†] A New Lower Tertiary Fauna from Chappaquiddick Island, Martha's Vineyard, Science, New Series, vol. xxi, No. 548, pp. 990–991, 1905.

found in the lower Eocene, and they are accordingly designated as lower Eocene. The fossils are found in ferruginous concretions, reassorted and deposited in their present position as glacial drift. They have apparently been moved from the north, probably from the sea bottom, and raise the question as to their relation to the Third Cliff deposits. Their relation is, of course, obscure at present, although future dredgings and soundings may throw some light on the subject.

As has been noted before (p. 321) fossil evidence is almost wanting. The sponge spicules, as already noted, were not identifiable with any degree of certainty. Their value even when identifiable is rarely great. The impression of a single bivalve was noted in the red sands, but as only the rounded and partly obliterated outline was visible it also proved of no value. Fortunately the green glauconitic sands in the upper part of the preglacial series are lignitic and a number of excellent specimens of pyrrotized lignite were obtained. These were carefully examined for me by Dr. E. C. Jeffrey, of the Harvard Botanical Laboratory, to whom I am greatly indebted for a statement of his conclusions, based on extensive comparative studies of lignites from Martha's Vineyard, Staten Island, and Germany. Dr. Jeffrey states:*

" The lignites from the cliffs at Scituate . . . . belong to an ancient type of Pityoxylon, earlier than that found in connection with the Baltic (Oligocene) amber. They closely resemble, although are not identical with, Pityoxylon from the Cretaceous beds of Staten Island and Martha's Vineyard, and are of the same general antique type. . . . . all of the material belongs to one species . . . . ."

The fact that but one species was identified makes correlation based on the above determinations quite insecure. From the paleontologic evidence the deposits might be placed anywhere between the lower Cretaceous and the Pliocene with probabilities pointing to Eocene or Oligocene. On the other hand, the lithologic and stratigraphic evidence coupled with the geographic position of the deposits with respect to the Marshfield greensands points to their Miocene age.

In general, plant remains are known to have a low value as time markers in the geological column, especially such low forms as Pityoxylon† and allied species. The presence of the former is therefore to be considered not as confirmatory but as presumptive evidence which does no violence to the conclusions based on stratigraphic grounds.

Conclusion.

The conclusions reached after an examination of the foregoing evidence may be stated as follows :

* Personal letter, March 5, 1906.
  See Palaeophytologie, Schimper and Schenck, p. 874.

(1) The lower part of the Third Cliff section is preglacial. This is based on the character of the deposits, the entire absence of erratic material, and the relation and sequence of the unconformities. The suggestion that these beds may be interglacial is opposed by a number of facts which point to the improbability of this occurrence. In the first place, two marked unconformities such as occur within the lower deposits, together with the individual character of the different beds, indicate a distinct even if small change in the conditions of deposition which one would expect should be marked elsewhere by deposits of a similar nature. No interglacial deposits of this character are known on the Atlantic coast. It would be singular, though not impossible, that an interglacial deposit of this thickness should elsewhere be swept away, a single remnant preserved in this locality only. It is more reasonable that extensive Cretaceous and Tertiary terranes should be removed leaving here and at Marshfield and Gay Head remnants of a similar nature. It would be very peculiar indeed if an interglacial deposit were to simulate so closely the stratigraphic succession and lithologic qualities of beds of known Cretaceous and Tertiary age, and at the same time be the sole representatives of their kind on the coast. To this fact we may add that the oldest known bowlder bed in New England is present here (see p. 317) and that it occurs above the unconformity represented at C, fig. 1, that is to say, above the most marked unconformity of the whole section and one which represents the most profound break in the conditions of deposition.

(2) The occurrence of Cretaceous and Tertiary deposits at Martha's Vineyard, 50 miles south of Third Cliff, and of Tertiary deposits at Marshfield, seven miles south of Third Cliff, make it seem not unlikely that deposits of the same age once extended farther north, as well as farther inland, though subsequent erosion may have all but completed the removal of such deposits.

(3) The similarity of the material and the many points of similarity of sequence in these several places indicate the strong possibility that the Third Cliff beds are to be correlated with those farther south.

(4) The identity of plant remains offers the same possibility based on an independent line of evidence.

(5) The convergence of independent possibilities renders the following more than *possibilities:* they may be accepted as *probabilities:*

(*a*) The underlying yellow clay and the yellow and white sands are considered as probably upper Cretaceous. (*b*) The overlying dark sands and clays are probably Miocene though possibly Eocene or Oligocene.

Art. XXX.—*A Delicate Color Reaction for Copper, and a Microchemical Test for Zinc ;* by Harold C. Bradley.

[From the Chemical Laboratory of the Yale Medical School.]

It has been known for a number of years that the extract of logwood-haematoxylin—would produce with copper salts a dark blue color of some intensity. One of the older and little used differential stains for tissues depended upon this reaction. The microtome section of tissue was immersed first in a copper solution, then washed and immersed again in a dilute solution of haematoxylin. Those portions of the tissue which fixed the copper would then be colored dark blue, while the rest of the tissue remained uncolored. In this way a stain is produced which will differentiate the cell nucleus from the surrounding cytoplasm. This same reaction was used by Herdman and Boyce* to demonstrate copper in the blood and tissues of the oyster, while Mendel and Bradley † made use of it in localizing the copper in the liver tissues of other marine molluscs. So far as we are aware, however, the reaction has never been used as a means of identifying small amounts of copper in solution, nor has it been realized of what extreme delicacy the reaction is susceptible.

Accordingly a number of trials were made with copper sulphate solutions of varying strengths, to determine within what limits the reaction was available for the detection of copper, and also how the reaction compared in delicacy with other well known tests for that element. Ferrocyanide, ammonium sulphide, potassium iodide and starch, are the reagents most commonly employed to detect small amounts of copper, and form some of the most delicate reactions of the laboratory. Potassium ferrocyanide gives, with dilute solutions of copper salts, a characteristic brown color, becoming indistinguishable from the color of the reagent when the copper solution contains less than 0·001 per cent of the metal. With starch paste and potassium iodide the reaction is slightly more delicate—cuprous iodide and starch iodide of characteristic deep blue being formed—but reaches its limit when the copper solution contains less than 0·001 per cent of the metal. On the other hand, the haematoxylin reaction is at its best in just such dilutions and will serve to recognize copper in solutions of much greater attenuation. The following table shows roughly the comparative delicacy of these reactions:

Reagent	0·01% Cu	0·001%	0·0001%	0·00001%	0·000001%	0·0000001%
Ferrocyanide	brown	brown	?	----	----	----
KI + starch	blue	blue	blue	----	----	----
Haematoxylin	blue	blue	blue	blue	blue	blue

* Herdman and Boyce : Report of the Thompson–Bates Laboratories, Liverpool, ii, 1899.

† Mendel and Bradley : American Journal of Physiology, xiv, 313, 1905.

That is, while under the most favorable conditions ferrocyanide of copper is formed visibly in solutions of one part copper in 100,000 parts of water, blue starch iodide in solutions of one part copper in 1,000,000 parts of water, the copper-haematoxylin compound is distinctly recognizable in solutions of one part of copper in 1,000,000,000 parts of water. This is, we believe, one of the most delicate reactions known, chemical or physical, and is comparable with the physiological effects of copper salts on certain algae, with the catalytic effect of copper in certain oxidations, and with the reactions for detecting radio-active bodies of extreme dilution. It is a thousand times more delicate than the ferrocyanide test for copper.

The possibilities for the use of such a reaction as a qualitative test for copper in drinking water from reservoirs treated with copper sulphate to destroy algae, is at once apparent. Whether the reaction can be applied directly to the proximate analyses of drinking waters, what the conditions for optimum results are, and what the intensely blue copper compound is, are problems still to be worked out.

Zinc.—In carrying out some investigations on the normal presence and distribution of zinc in certain marine gastropods,* the difficulty of recognizing definitely small amounts of that metal in tissue ash containing relatively large amounts of copper, iron, calcium, and phosphoric acid, was found to be very great. Zinc forms practically no colored compounds by which it may be identified in such a mixture, and the ordinary processes of separation are tedious and unsatisfactory. The desirability of finding some rapid and reliable test for zinc led to a thorough canvassing of the less common laboratory reagents for precipitating that metal, and the finding of a microchemical test which proved to be adequate in every way. The reaction is by no means a new one, but its possibilities as a reliable test for zinc seem to have been overlooked.

A moderately concentrated solution of a zinc salt when treated with sodium nitroprusside throws down a salmon-pink precipitate of zinc nitroprusside, fairly insoluble in cold water, much less so in hot. The characteristic feature of this precipitate is its definite and readily identified crystal form. All the other insoluble nitroprussides of the heavy metals are amorphous, slimy precipitates resembling the ferrocyanides in general physical properties. Thus even in a mixture of several metallic salts, such as copper, silver, cobalt, zinc, etc., the zinc nitroprusside can be recognized under the microscope by the presence of its characteristic crystals in the amorphous mass of the other nitroprussides. In performing the test, it is desirable to have the solution of the salts fairly concentrated—about

* Bradley : Science, 1903, xix, p. 196.

10 per cent strength is convenient—and to remove the copper by H_2S. In such solutions of tissue ash as were used in our experiments, copper was first removed and the filtrate containing iron, calcium, phosphoric acid, etc., concentrated to small bulk. A drop of this solution placed on a microscope slide and digested with a drop of the freshly prepared nitroprusside solution, deposited on cooling the rectangular plates and prisms of the zinc salt when that metal was present in such minute amounts that the ordinary methods of separation and identification failed to show it definitely, or required the ashing of large amounts of the original material. For example, by this method zinc was detected readily in the blood of certain molluscs in a few minutes, while by the ordinary methods of separation and analysis—the basic acetate method, or better, the precipitation of the metal as sulphide from a formic acid solution—many hours are required to ash sufficient material and carry through the steps of the analysis.

ART. XXXI.—*The Elimination and Alkalimetric Estimation of Silicon Fluoride in the Analysis of Fluorides;* by ALBERT HILEMAN.

THE errors of the processes for the determination of fluorine, in which that element is eliminated as silicon fluoride to be subsequently estimated volumetrically, naturally fall into two categories. First, there are those errors which are due to imperfect elimination and collection of the silicon fluoride from the decomposition flask, and, secondly, there are the errors of the titration processes. For the present purpose it will be most convenient to consider the latter class of errors first.

The Process of Titration.

As has been indicated, methods have been used for the determination, by volumetric processes, of silicon fluoride. First, the method of Penfield, which depends upon the collection of the silicon fluoride in an alcoholic solution of potassium chloride and the titration, without removal of the precipitated potassium fluosilicate, of the hydrochloric acid set free. It is assumed that in the alcoholic solution the fluosilicic acid and potassium fluosilicate are not appreciably hydrolized and that ammonia may exactly neutralize the hydrochloric acid without attacking the precipitated potassium fluosilicate. Cochineal is used as the indicator.

$$3SiF_4 + 4H_2O + 4KCl = 2K_2SiF_6 + SiO_4H_4 + 4HCl$$
$$NH_4OH + HCl = NH_4Cl + H_2O$$
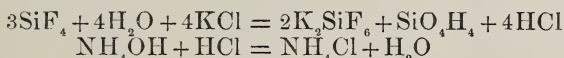
The second method of titrating the silicon fluoride, resembling that of Penfield, except that standard sodium hydroxide or potassium hydroxide is employed instead of ammonium hydroxide in titrating the free acid, which is the method of Bullnheimer[*] and used by Treadwell and Koch,[†] involves very similar reactions.

$$3SiF_4 + 4H_2O + 4KCl = K_2SiF_6 + SiO_4H_4 + 4HCl$$
$$NaOH + HCl = NaCl + H_2O$$
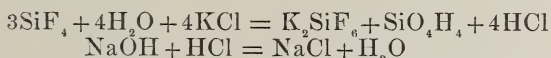
The third method, that of Offerman,[‡] differs from the preceding methods in this respect, that the silicon fluoride is allowed to act upon water and the fluosilicic acid and hydrofluoric acid thus formed are acted upon by standard potassium

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[*] Zeitschr. Angew. Chem. 101, 1901.
[†] Zeitschr. Anal. Chem. xliii, 444, 1904.
[‡] Zeitschr. Angew. Chem. 615, 1890.

hydroxide to the point of complete hydrolysis of the fluosilicate to the condition of a fluoride.

$$3SiF_4 + 4H_2O = 2H_2SiF_6 + SiO_4H_4$$
$$H_2SiF_6 + 6KOH = 6KF + SiO_4H_4 + 2H_2O.$$
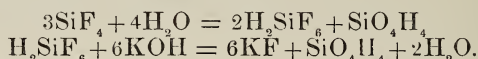
According to this process the amount of the standard alkali used is three times as great as that used to the end reaction of the preceding process. According to a fourth method advocated by Tammann[*] and useful when fluorides are to be determined in the presence of carbonates, the potassium fluosilicate is precipitated and separated with precautions and titrated by itself with standard potassium hydroxide to the point of formation of potassium fluoride and silicic acid.

$$K_2SiF_2 + 4KOH = 6KF + SiO_4H_4$$
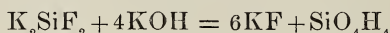
This process is essentially similar to the second process so far as concerns the reaction involved, but only two units of the alkali used for neutralization are of the standard alkali. For the present purpose therefore, it will suffice to compare the first three methods as to the degree of agreement between individual results, and between the averages and the processes. For this purpose measured portions of a solution of fluosilicic acid were treated according to the methods described and the results are recorded in the following table:

TABLE I.

Titration in Alcoholic Solution.

H_2SiF_6 cm₃.	(According to Penfield.) Standard NH₄OH cm₃.	Standard KOH cm₃.	(According to Bullnheimer.) Standard NaOH cm₃.	Fluorine Found. grm.	Average. grm.
25	7·3	- - - -	- - - -	0·1433	
25	7·3	- - - -	- - - -	0·1433	
25	7·27	- - - -	. . . .	0·1426	0·1428
25	7·23	- - - -	- - - -	0·1429	
25	7·29	- - - -	- - - -	0·1431	
25	- - - -	10·67	- - - -	0·1412	
25	- - - -	10·72	- - - -	0·1419	
25	- - - -	10·64	- - - -	0·1408	0·1411
25	- - - -	10·67	- - - -	0·1412	
25	- - - -	10·60	- - - -	0·1403	
25	- - - -	- - - -	9·11	0·1416	
25	- - - -	- - - -	9·12	0·1418	
25	- - - -	- - - -	9·07	0·1410	0·1415
25	- - - -	- - - -	9·10	0·1414	
25	- - - -	- - - -	9·12	0·1418	

[*] Zeitschr. Anal. Chem. xxiv, 328, 1885.

The differences between the amounts of fluorine indicated by the individual determinations in any one of these processes are generally slight. The averages of the determinations by potassium hydroxide and sodium hydroxide are very close together, being 0·1411 grams and 0·1415 grams of fluorine. The average of the titrations by ammonium hydroxide is a little higher, namely, 0·1428 grams. That the differences between these averages are due to gradual variations in the reading tint is shown by a comparison of three titrations as nearly simultaneous as possible, in which the greatest care was taken to bring all to the same tint at the final reading.

TABLE II.

Comparison of Simultaneous Titrations in Alcoholic Solution.

	Solution used. cm₃.	Fluorine Found. grm.
Titration by NH₄OH	7·2	0·1414
Titration by KOH	10·71	0·1418
Titration by NaOH	9·13	0·1419

So it appears that the results obtained are practically the same by the three processes of neutralization applied to a solution of fluosilicic acid. But it is to be observed that all are possibly subject to a common and constant error due to the presence of hydrofluoric as well as fluosilicic acid. If the former acid is present it tends to raise the apparent value of the latter.

With these results of titrations in alcoholic solution are to be compared the results obtained by the method of titration in the water solution (in which the fluosilicate is completely converted to fluoride), recorded in the following table:

TABLE III.

Titrations of Fluosilicic Acid in Water Solution.
(According to Offerman.)

H₂SiF₆ Taken cm₃.	Standard KOH cm₃.	Standard 1NaOH cm₃.	Fluorine Found. grm.	Average. grm.
25	30·9	- - - -	0·1358	
25	30·8	- - - -	0·1353	
25	30·9	- - - -	0·1358	0·1355
25	30·79	- - - -	0·1353	
25	- - - -	26·2	0·1357	
25	- - - -	26·15	0·1355	
25	- - - -	26·25	0·1360	
25	- - - -	26·2	0·1357	0·1358
25	- - - -	26·13	0·1354	
25	- - - -	26·14	0·1354	

It is obvious that the process of titrating fluosilicic acid in water solution yields uniform indications, both with potassium hydroxide and sodium hydroxide, but that the values for fluorine are very much below those of the titrations in alcoholic solution. And this would be the case if the solution of fluosilicic acid contains hydrofluoric acid as is natural.

In the analytical process in which silicon fluoride is passed into the alcoholic solution of potassium chloride the formation of hydrofluoric acid is likely to be at a minimum and so the titration of the hydrochloric acid set free in this metathesis should indicate closely the actual amount of fluorine present. If, however, the silicon fluoride is passed into water instead of into this alcoholic solution of potassium chloride, it is necessary to titrate together the products of action, fluosilicic acid and hydrofluoric acid, to the point of formation of the alkali fluoride, in order that the indication may be correct.

The action of ammonium hydroxide upon fluosilicic acid in water solution proves to be comparable with that of sodium hydroxide, and inferentially with that of potassium hydroxide, though the hydrolysis of the fluosilicate appears to be not quite so complete. In the table are given the results of comparative titrations.

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

H_2SiF_6 taken cm³.	NH_4OH [1cm³=0·006547] cm³.	Fluorine found by NH_4OH grm.	Fluorine found by NaOH grm.
25	31·04	0·2030	0·2057
25	31·00	0·2030	0·2057
10	12·39	0·0811	0·0823
10	12·42	0·0816	0·0823
10	12·42	0·0811	0·0823

The following expression represents the reaction :

$$6NH_4OH + H_2SiF_6 = 6NH_4F + Si(OH)_4 + 2H_2O$$
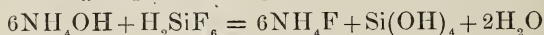
When silicon fluoride is passed into water containing ammonium hydroxide, as is suggested in Liversidge's method for the analysis of fluorides, it is obvious that nearly complete hydrolysis must take place, with formation of silicic acid precipitated or colloidal, according to the equation

$$SiF_4 + 4NH_2OH = 4NH_4F + Si(OH)_4.$$
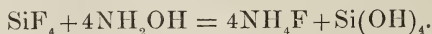
According to Liversidge, potassium fluosilicate may be thrown down by addition of potassium chloride and alcohol, after dissolving the precipitated silica by heating the ammoniacal liquid. In my experience, it has never been possible to thus dissolve all the silica, and the precipitate obtained by adding potassium chloride, with or without alcohol, appears to be

<div align="center">* Chem. News xxiv, 266.</div>

silica thrown out of its colloidal solution by addition of the electrolyte.

The Elimination of Silicon Fluoride.

As to the sources of error due to imperfect elimination, and collection, of silicon fluoride, we have the testimony of the several investigators already quoted. The importance of using the fluoride in the finest state of division, of having the sulphuric acid of highest strength, of properly absorbing the vapors of sulphuric acid evolved from the decomposition flask, and of using quartz for the silicon dioxide in the decomposition flask, have all been emphasized. Many forms of apparatus have been employed and the results have varied widely, errors of from 0·0010 grams to 0·0050 grams in the determination of fluorine by absorption and weighing of silicon fluoride being not uncommon.

At the outset of the work to be described, an investigation was made as to the limit of error likely to occur in the use of simple apparatus and sulphuric acid, prepared by heating to the fuming point, for about a half hour. The silicon fluoride evolved was estimated by absorption in an alcoholic solution of potassium chloride following the method of Penfield,[*] and the hydrochloric acid set free was estimated by standard potassium hydroxide.

The apparatus employed consisted of the following parts: First, there was an apparatus for purifying the air current by passing it through a sulphuric acid wash bottle and two large drying cylinders containing fused calcium chloride at the bottom and soda lime at the top; second, a 100$^{cm^3}$ decomposition flask provided with a doubly perforated rubber stopper, through which passed a glass tube from the drying cylinders to the bottom of the flask, while another tube, leading from this decomposition flask, was joined to a large empty U-tube intended to condense any sulphuric acid which might be carried from the decomposition flask. Third, connected with the outer limb of the U-tube for condensing sulphuric acid was an absorption system similar to that described by Burk.[†] It consisted of a test tube 34^{cm} in length and 2^{cm} in diameter, containing a few cm^3 of mercury into which extended a delivery tube with a capillary opening. The test tube was placed at an angle to diminish the pressure throughout the system.

Before making a determination, the apparatus was first carefully dried. The absorption tube was filled with a saturated solution of potassium chloride in 50 per cent alcohol, and the material to be analyzed, weighed on a watch glass, was trans-

[*] Am. Chem. Jour., i, 27.
[†] Jour. Am. Chem. Soc. xxiii, 825 (1901).

ferred to the decomposition flask through a funnel with a short neck. To the material were added fifteen times its weight of ignited quartz sand and 50^{cm^3} of sulphuric acid which had been previously heated strongly and cooled in a desiccator. To an iron plate supporting the decomposition flask, heat was applied by a burner and regulated so that a flask of sulphuric acid placed where it received the same amount of heat as the decomposition flask should have a temperature of between 150° and 160°. During the heating a slow current of air was passed through the apparatus. In the reaction in the decomposition flask hydrofluoric acid was generated which acting on the silica formed silicon fluoride. In the absorption tubes silicon fluoride acted on water according to the following equation :

$$3SiF_4 + 4H_2O = 2H_2SiF_6 + SiO_4H_4$$
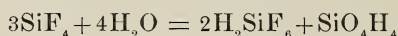
In the presence of potassium chloride and alcohol the fluosilicic acid was precipitated as potassium fluosilicate, and a corresponding amount of hydrochloric acid set free.

$$H_2SiF_6 + KCl = K_2SiF_6 + 2HCl.$$
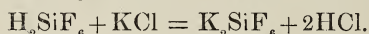
The hydrochloric acid was then titrated with a standard potassium hydroxide solution, using cochineal as an indicator.

A series of experiments, carried out in the manner described, was made with ordinary pulverized fluorite. The heating was continued in every case above the time limit of two hours. All gas bubbles had disappeared from the acid mixture, which fact, according to Fresenius[*] and Offerman,[†] shows that the decomposition is complete.

The time required to decompose fluorite is stated by Penfield to be two hours for 0·2 to 1·0 grams ; by Fresenius two hours for 0·1 gram and four hours for 1·0 gram.

TABLE V.

	CaF_2 grams.	Silica grams.	KOH cm³.	Theory Fluorine grams.	Found Fluorine grams.	Error Fluorine grams.
			$(1^{cm^3} = 0.01045 F.)$			
1.	0·5000	7·0	22·7	0·2432	0·2372	—0·0060
2.	0·5000	7·0	22·56	0·2432	0·2357	—0·0075
3.	0·5000	7·0	22·7	0·2432	0·2372	—0·0060
4.	0·5000	7·0	23·15	0·2432	0·2419	—0·0013
5.	0·5000	7·0	22·4	0·2432	0·2340	—0·0092
6.	0·5000	7·0	21·7	0·2432	0·2277	—0·0155
7.	0·5000	7·0	22·	0·2432	0·2299	—0·0133
8.	0·5000	7·0	21·7	0·2432	0·2267	—0·0165
9.	0·5000	7·0	22·5	0·2432	0·2351	—0·0081

* Zeitschr. Anal. Chem., vi, 190.   † Loc. cit.

The cause of the variation in the results, and of the occasionally very large errors in the above series of experiments, was not apparent at the time when the experiments were made, but reference will be made to this later.

Crystals of fluorite, perfectly clear and of a pale green color, were next tried. The powdered mineral on treatment with sulphuric acid yielded the theoretical amount of calcium sulphate.

TABLE VI.

	CaF_2 grams.	KOH cm^3	Fluorine Theory grams.	Fluorine Found grams.	Flourine Error grams.	Time hours.	Temperature.
			($1^{cm} = 0.01045$ Fluorine.)				
1.	0.5000	21.77	0.2432	0.2274	—0.0158	6	} 150°
2.	0.5000	22.	0.2432	0.2299	—0.0133	6	} 160°
3.	0.5000	31.77	0.2432	0.2274	—0.0158	3.25	
4.	0.5000	23.6	0.2432	0.2466	—0.0034	6	
5.	0.5000	22.15	0.2432	0.2314	—0.0118	6	} 180°
6.	0.5000	22.19	0.2432	0.2318	—0.0114	6	
7.	0.5000	19.37	0.2432	0.2014	—0.0418	6	
8.	0.5000	16.2	0.2432	0.1692	—0.0740	3	
9.	0.5000	22.2	0.2432	0.2325	—0.0107		} boil-
10.	0.5000	21.25	0.2432	0.2220	—0.0212		} ing.

In experiment (1) above, the heating was continued for six hours at 150–160°. In experiment (2) the powdered mineral was fused with sodium carbonate and the mixture transferred to the decomposition flask. In experiments 2–8 above, the temperature was raised as high as 180°, while the empty U-tube was immersed in a freezing mixture of salt and ice. Blank determinations showed that some sulphuric acid was carried over under these conditions. In experiments (9) and (10) the acid was heated to boiling and allowed to cool before the air current was passed through.

The effect of precipitated silica instead of quartz sand was next tried. In experiment (1) the silica was air dried; in (2) it was strongly ignited.

TABLE VII.

	CaF_2 grams.	Silica grams.	KOH cm^3	Theory Fluorine grams.	Found Fluorine grams.	Error Fluorine grams.
1.	0.5000	7.0	6.4	0.2432	0.0668	0.1764
2.	0.5000	7.0	21.2	0.2432	0.2215	0.0217

These experiments indicate that the small amount of water in the air dried silica may cause great deficiency in the fluorine found, and suggests the idea that even the amount of water produced in the reaction involving the sulphuric acid, the fluoride and silicon dioxide may be the occasion of trouble.

A Specially Devised Apparatus for use at High Temperatures.

Owing to the lack of success with the silicon fluoride processes in which the decomposition was effected at temperatures between 150°–160°, an attempt was made to devise a simple and convenient form of apparatus in which the acid mixture might be heated to boiling to facilitate the removal of the silicon fluoride to the absorption system.
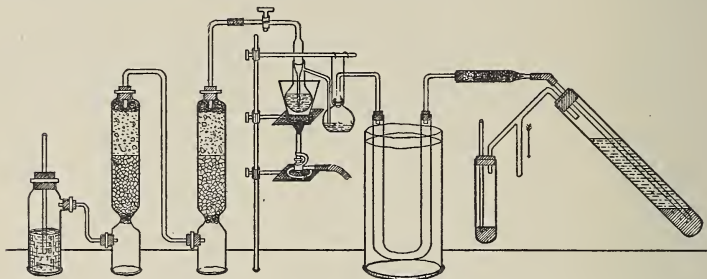
After a number of experiments with this end in view the following model of apparatus was found to be the most satisfactory: a glass stopper, made by drawing out a glass tube 1^{cm} in diameter and sealing a small glass tube on each end, is ground into a 70$^{cm^3}$ side neck flask. To one end is sealed a glass stop-cock. The other end extends to the bottom of the flask. The side neck is sealed to a Voit flask. The length of the tube between the two flasks is 17^{cm}, and it is bent at right angles, 12^{cm} from the Voit flask. The tube leading from the Voit flask enters a large empty U-tube through a rubber stopper. A tube from the other limb of the U-tube enters a trap loaded with phosphorus pentoxide. A rubber connection joins the trap with the delivery tube of the absorption apparatus described above. Connected with the absorption tube is a pressure regulator. This consists of a T-tube, one opening of which enters a test tube of mercury through a rubber stopper. Another perforation is closed with a glass tube which may be raised or lowered in the mercury. The third opening of the T leads to the aspirating pump.

Preparatory to making a determination the apparatus is carefully dried. The tip of the delivery tube is then placed beneath the surface of the mercury in the absorption tube and distilled water is added, care being taken that enough space remain for the rise in level when air bubbles are in the liquid. The pressure regulator is then connected with the absorption tube and adjusted so that a rise of pressure in the apparatus should be relieved but no appreciable vacuum created. The U-tube is then immersed in a vessel of cold water and connected with the trap. Next, the mineral, together with quartz powder

to about three times the weight of the fluorine present, is transferred to the decomposition flask. Next, enough sulphuric acid to seal the delivery tube from the side neck flask is introduced into the Voit flask. The two flasks are then tilted so that the acid should moisten the connecting tubes to the bend. About 40$^{cm^3}$ of sulphuric acid and several capillary tubes 1^{mm} in diameter sealed 1^{cm} from an open end and at the other end* to prevent bumping, are added to the decomposition flask, and the stopper quickly replaced and sealed with a drop of sulphuric acid. The acid used above had been boiled for half an hour and a current of dry air passed through on cooling. A thin strip of asbestus is wrapped about the neck of the flask, and the stop-cock having been closed, the bulb is heated in a radiator whose top is covered with a sheet of asbestus matting.

When heat is applied in the process, bubbles of gas are given off, the solid material rises to the surface, and during the course of the heating an oily film gathers on the upper part of the flask and in the delivery tube. On boiling, this film is replaced by a white deposit which recedes before the acid vapors. The success of the determination depends, as was found, on the removal of this deposit. When the acid vapors have penetrated the length of the tube leaving it clear or translucent, the decomposition is complete, and the stop-cock having been opened, the side neck flask is cooled to about 75°. A current of purified air is drawn through the apparatus, slowly at first and then more rapidly. About six liters are necessary to remove the last trace of silicon fluoride.

Daniels'† suggestion that the deposit mentioned above is a polymer of SiF$_4$ appears unwarranted. It seems more probable that this is a product of partial hydrolysis of silicon fluoride by the action of water generated in the action of sulphuric acide on the fluoride, as suggested above, the process of forming and hydrolyzing silicon fluoride being repeated until the water is finally absorbed in the cold acid of the Voit flask.

If it happens that the acid mixture bumps before the decomposition is complete, some of the deposit may become dislodged from the tube and remain undecomposed in the Voit flask. Bumping also renders it difficult to boil the acid vapors through the delivery tube. On this account the tube between the two flasks should be as short as is practicable. Unsatisfactory results were obtained when the tube was about one-half longer than the dimensions given above. If the acid tends to suck back from the Voit flask, it is arrested by opening the stop-cock for a moment to relieve the vacuum. If, at this point of the experiment, the pressure regulator should not be adjusted properly, acid vapors would be drawn through the

* Scudder, J. Am. Chem. Soc., xxv, p. 113.
† Zeitschr. Anorg. Chem. xxxviii, 257.

apparatus into the absorption tube. The decomposition is ended in fifteen to forty minutes. The delivery tube is washed and the absorption solution transferred to a flask and titrated with sodium hydroxide* from an alkali burette, with phenolphthalein as an indicator, according to the method of Offerman, the third method referred to above.

$$H_2SiF_6 + 6NaOH = 6NaF + Si(OH)_4 + 2H_2O$$
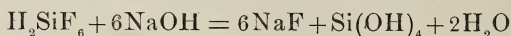
The following series of results was obtained according to the method outlined above.

TABLE VIII.

	CaF$_2$ grams.	Quartz grams.	Na$_3$OH cm.	Theory Fluorine grms.	Found Fluorine grms.	Error Fluorine grms.
			($1^{cm}_3 = 0·005123F.$)			
1.	0·3000	0·4	28·2	0·1459	0·1444	—0·0015
2.	0·3000	0·4	28·35	0·1459	0·1452	—0·0007
3.	0·3000	0·4	28·34	0·1459	0·1451	—0·0008
4.	0·3000	0·4	23·5	0·1215	0·1203	—0·0012
5.	0·3000	0·4	28 3	0·1459	0·1419	—0·0010
6.	0·3000	0·4	28·37	0·1459	0·1453	— ·0006
	NaF.					
7.	0·3000	0·4	26·2	0·1356	0·1342	—0·0012
8.	0·3000	0·4	26·44	0·1356	0·1355	—0·0001
9.	0·3000	0·4	26·46	0·1356	0·1356	— ·0000
10.	0·3000	0·4	26·3	0·1356	0·1347	—0·0009
11.	0·3000	0·4	26·34	0·1356	0·1349	—0·0007
12.	0·3000	0·4	26·3	0·1356	0·1347	—0·0009
		Ignited Silicic acid				
13.	0·3000	0·4	26·29	0·1356	0·1346	—0·0010
		Quartz				
14.	0·3000	0·4	26·3	0·1356	0·1347	—0·0009
	Ca = 40·1 Na = 23·04 F—19 (error—0·0008)					

With the apparatus described above, in which the sulphuric acid in the decomposition flask may be boiled, the silicon fluoride formed passes rapidly to the absorption system, other products of partial hydrolysis of silicon fluoride formed in the flask or tube are ultimately reconverted to silicon fluoride, and regular results of a fair degree of accuracy are obtained. In all the experiments above except (6) and (14) phosphorus pentoxide, about 2·0 grams was introduced into the decomposition flask, the purpose being to retain water formed in the reaction. The results of the experiments specifically mentioned show, however, that phosphorus pentoxide in the flask is not essential.

In three blank experiments, where the acid in the decomposition flask was heated to boiling, amounts of acid in each case equivalent to 0·0002 grams of fluorine were found in the absorption solution; the above results therefore are subject to this trifling error.

* Kuster, Zeitschr. Anorg. Chem. xli, 475.

ART. XXXII.—*Note on the Actual Drop of Pressure in the Fog Chamber;* by C. BARUS.

1. THE apparatus for condensation, as I have endeavored to use it, consists of a fog chamber in communication with a vacuum chamber through a wide stop-cock. The former may be put in connection with the filter; the latter with the air pump. It is necessary to wait between operations, all observing being done at the same temperature. In this case the isothermal value of the drop of pressure cannot be read off at the fog chamber (as I supposed it could, nearly), however rapidly the cock is closed after exhaustion; but it may be computed from the initial pressures of the isolated fog and vacuum chambers before exhaustion, and the final pressure when the vessels are in communication after exhaustion, if the ratio of volumes of the vessels is known.

2. Let v be the volume of the fog chamber, V the volume of the vacuum chamber, k/c the ratio of specific heats of the gas (moist or dry as required); let p, v, τ, ρ, denote its pressure, volume, absolute temperature and density under conditions given by the subscripts. It will be convenient to refer to the vacuum chamber by the same symbols with *accents*. Hence the thermal states will be for dry air.

	For the Fog chamber.			For the Vacuum chamber.		
Initially	p	τ	ρ	p'	$\tau'=\tau$	ρ'
Adiabatically (alone)	p_1	τ_1	ρ_1	$p_1'=p_1$	τ_1'	ρ_1'
Isothermally (alone)	p_2	$\tau_2=\tau$	$\rho_2=\rho_1$	p_2'	$\tau_2'=\tau$	$\rho_2'=\rho_1'$
Isothermally (together)	p_3	$\tau_3=\tau$	ρ_3	$p_3'=p_3$	$\tau_3'=\tau_3$	$\rho_3'=\rho_3$

The equations describing the transformations are (for dry air)

$$(\tau/\tau_1) = (p/p_1)^{(k-c)/k} \quad (\tau/\tau_1') = (p'/p_1)^{(k-c)/k} \qquad (1)$$

$$
\begin{aligned}
p &= R\rho\tau & p' &= R\rho'\tau \\
p_1 &= R\rho_1\tau_1 & p_1' &= R\rho_1'\tau_1' \\
p_2 &= R\rho_1\tau & p_2 &= R\rho_1'\tau \text{ or} \\
p_3 &= R\rho_3\tau & p_2/p_2' &= \rho_2/\rho_2'
\end{aligned}
\qquad (2)
$$

$$\rho v + \rho' V = \rho_1 v + \rho_1' V = \rho_2 v + \rho_2' V = \rho_3(v + V) \qquad (3)$$

From these one may deduce relative to the value of p_1

$$p_1^{c/k} = \frac{p_3(1 + v/V)}{p'^{(k-c)/k)} + (v/V)\, p^{(k-c)/k}} \qquad (4)$$

$$p_2' + p_2 \cdot v/V = p_3(1 + v/V) \qquad (5)$$

where p, p', p_3, are observable with certainty. While equation (5) is variously useful in checking the results, it does not admit of the individual determination of p_2 and p'_2. For this purpose, however, the equations (1) and the second and third of group (2) are available, with the results (for dry air)

$$p_2 = p^{(k-c)/k} p_1{}^{c/k} \qquad p'_2 = p'^{(k-c)/k} p_1{}^{c/k} \qquad (6)$$

as $p_1{}^{c/k}$ is given in equation (4).

Using these equations the data of the following table were computed in connection with incidental results tested for the purpose.

TABLE.—Pressures p (cm) and temperatures t (°C.) at the fog and vacuum chambers, the latter marked with an accent.

p	p'	p_3	$p'_1{}^*$	p_1	p_2	p'_2	p''_1†	t_1	t'_1
76	43·5	45·5	47·9	45·7	52·9	45·0	45·6	−20·2	24·3
76	51·5	52·5	54·3	52·4	58·3	52·1	_ _ _	− 9·9	21·5
76	59·5	59·7	62·2	59·4	63·8	59·4	_ _ _	− ·2	20·

3. The pressures of the table are computed for dry air throughout and if charted in terms of p', graphically, are found to lie very nearly on straight lines. The results of the table are very important. In the first place it will be seen not only that isothermal pressures or nearly isothermal pressures are not observed, but that the effect of the vacuum chamber is preponderating. Thus the pressure at the latter p_1'', read off as soon as possible and nominally adiabatic, is within one millimeter of p_3. Similarly the computed adiabatic pressure p_1 is within a few millimeters of p_1'' and p_3. It follows, therefore, that even an approach to isothermal pressure, to say nothing of adiabatic pressure, cannot be observed at the fog chamber at all; or that before the exhaust cock can be closed again the vacuum chamber has practically regained its isothermal pressure by cooling and that the fog chamber is further exhausted by a corresponding amount.

The pressure $p_1' = p''_2$ observed under isothermal conditions‡ at the fog chamber, exceeds p_1 (computed) by about $1\cdot9^{cm}$ on the average, which might be regarded as the average vapor pressure of water at the temperature at which the observation was made. Leaving this for further consideration, the final result of importance is the following : p_2 the computed isothermal pressure in the closed fog chamber is from 2 to 5^{cm} above the (nominally) isothermal pressure $p_1' = p_2$ observed : and correspondingly more than this above the common isothermal

* Observed as soon as possible after exhaustion at the closed fog chamber.
† Observed as soon as possible after exhaustion at the vacuum chamber, stop cock-closed at once after exhaustion.
‡ This pressure varies but slightly.

value p_3 usually taken. For the region in which colloidal nuclei lie the correction will be 6 to 8^{cm}. Now this is in excess of the difference between the pressure regions in which Wilson's data for colloidal nuclei, as reduced elsewhere,[*] and the region in which my own data as summarised heretofore, would lie.

In other words, the data in my large coronal apparatus lie in regions of exhaustion at least as moderate as those observed in Wilson's small apparatus; or the two types of apparatus comparing efficiency if the drop of pressure taken is in my case not the (apparent) experimental value, but that deduced for the computed isothermal pressure p_2 of the fog chamber as above explained.

4. For the case of air saturated with water vapor in both chambers, all pressures must be reduced by the corresponding vapor pressure, π of water, except p'_1, when the vapor is slightly superheated. Apart from this, the equations take the above form, though special computation is needed, since a different initial pressure $(p - \pi)$ enters. So computed, the relation between the observed drop of pressure $p - p_3$ and the computed drop $p - p_2$ was found to be

$$(p - p_2) / (p - p_3) = \cdot 775$$

and very nearly constant with the pressure interval involved. The conclusions as to efficiency are like the above.

The fact that a limit has been reached for condensations, within the given type of fog chamber, may be considered as proved, apart from comparison with Wilson's results, since for a successively increasing drop of pressure $(p - p_3)$, no matter whether the nuclei are relatively large like the ions or relatively small like the colloidal nuclei, the same terminal corona is eventually reached in both instances. Higher exhaustions are thereafter powerless. Finally, since the colloidal nuclei in case of dust-free air saturated with alcohol vapor[†] are larger than in case of water vapor (caet. par.), these nuclei must probably be associated with the saturated vapor, the gas being but secondarily in question.

Brown University, Providence, R. I.

[*] Presidential address; Physical Review, xxii, 1606, p. 107.
[†] This Journal, August.

Art. XXXIII.—*On a New Method for Standardizing the Coronas of Cloudy Condensation;* by C. Barus.

Assuming that for ions produced within the fog chamber the rate of decay in the lapse of time t is as the square of the number, or that $1/n - 1/n' = b(t-t')$ where b is constant, a few incidental attempts were made to compute b, when the number, n, of nuclei (ions) is expressed in thousands per cubic centimeter. The table gives an example of such results, obtained by exhausting the fog chamber at a stated time t, after the removal of radium. If the drop in pressure is *below* the coronal fog limit of air, precipitation takes place on ions, only.

TABLE.—Decay curve. Nucleation observed and computed. $b = \cdot 0024$ relative to $n \times 10^{-3}$. Radium suddenly removed from top of fog chamber (glass) and exhaustion made t sec. thereafter. $\delta p = 23^{cm}$ (below the coronal fog limit of dust free air). $s/30$ (nearly) angular diameter of coronas.

t sec.	s cm.	(observed) $n \times 10^{-3}$.	(Computed for $b = \cdot 0024$) $n \times 10^{-3}$.
0	5·9	67	67
5	5·0	41	37
10	4·6	32	26
15	4·0	21	20
20	3·5	15	16
30	3·3	12	12
50	2·9	7	7
120	1·7	2	3
∞	1·0	1	--

For the first five seconds $b = \cdot 0019$; for the first fifteen seconds $b = \cdot 0022$; etc., values obtained ranging from $\cdot 002$ to $\cdot 003$. This is larger than the corresponding electrical datum, say $\cdot 0014$, when n is given in thousands. Decay is more rapid than the equation warrants. Initial coronas are too large, final coronas too small, in spite of the presence of air nuclei, the number of which should be deducted, at least in part. Other experiments show similar coefficients. Naturally the present method for b is much inferior to the electrical method, even if the two coefficients are identical; and the b here is obtained under possible complications with the larger gradations of the colloidal nuclei of dust free air, though these are probably inefficient.

If the values of $1/n$ be inserted the curves should be linear since $1/n = 1/n_0 + bt$ where t is the time dated since the occurrence of n_0. The line passing through the observations at 5, 30, 50 seconds is best adapted to represent the results, and

from it $b = \cdot0024$ (n in thousands of nuclei per cubic centimeter) may be roughly assumed. These computed values of n are given in the table. Shown in a chart, they are too low initially and too high finally, even if the air value is quite ignored; but the constant probably reproduces the true conditions better than the observation, remembering that the initial corona ($t = 0$) is not quite invariable.

A very important consequence may be deduced from these results. The equations specified may be written $n_0 = (n_0/n -1)bt$. Hence if the ratio of nucleations or of ions is known (for instance by my method of geometric sequences), n_0/n is given, and the absolute value of n_0 may be computed if b is known. Now if b for the case of ions may be taken as identical with the value found in electrical experiments, where $b = \cdot0014$ roughly and relative to ionization in thousands,

$$bn_0 = \cdot0014n_0{}'$$

where $n_0{}'$ is the true nucleation. Thus in the table $b = \cdot0024$, $n_0 = 67 \cdot 5$; therefore $n_0{}' = (\cdot0024/\cdot0014)\,n_0$ or 115,000 nuclei per cubic centimeter, instead of 67,500 for the initial corona. Quite generally if n_0/n and b are determined from purely coronal measurements

$$b\,/\,\cdot0014$$

is the reduction factor for all the relative nucleations to absolute value.

Another important consequence may be drawn: If the coefficient is known from direct experiments, it will then be possible to standardize the residual curve (depressed asymptote) leading to the terminal corona, corresponding to groups of nuclei of different sizes occurring together.

Moreover, in any such curve, let the ordinates denote the computed number of ions, the abscissas denote the observed number of *efficient* nuclei, being the colloidal nuclei and ions occurring together in the course of a stated time. Then the curve gives an indication of the distribution of the precipitated water on the two groups of nuclei different in size and present in different proportions, for the given supersaturation. Experiments of this kind are of the highest importance and the present cursory treatment is admitted provisionally in view of a restandardization of the coronas of cloudy condensation which the variety of results since obtained has made necessary.

Brown University, Providence, R. I.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *Barium Sub-oxide and the Preparation of Metallic Barium.* —According to Winkler, magnesium reduces the alkaline earth oxides, but he was unable to isolate the metals from the resulting mixtures. GUNTZ has now repeated Winkler's experiment with barium oxide and magnesium in a vacuum at a high temperature with the expectation of collecting the metallic barium by distillation. It was found, however, that when the calculated quantities of the substances were thus treated at about 1100°, approximately one-half of the magnesium distilled off together with traces of barium. Upon examination of the residue it appeared that a sub-oxide of barium, Ba_2O, had been produced. This forms a black fritted mass, the properties of which are similar to those of metallic barium, since it decomposes water, gives Ba_3N_2 with nitrogen at a red heat and at the same temperature yields BaH_2.

When aluminium, a non-volatile metal, was used in place of magnesium in the experiment mentioned above, it was found that crystallized barium of 98·8 per cent purity was obtained at once at near 1200°, and by a second distillation in a vacuum it was obtained absolutely pure. This new method applies equally well to strontium and furnishes an easy means of obtaining these metals, which, up to the present time, have been so difficult to prepare.— *Comptes Rendus,* cxliii, 339.   H. L. W.

2. *The Thermal Formation of Nitric Oxide and Ozone in Moving Gases.*—FRANZ FISCHER and HANS MARX have made the interesting observation that ozone, as well as hydrogen peroxide and nitric oxide, may be obtained by burning hydrogen in air or oxygen by the use of a rapid current of the oxidizing gas, as a jet blown through the hydrogen flame. It has been previously known that suddenly cooling the hydrogen flame in other ways gives nitric oxide and hydrogen peroxide, but the formation of ozone from this source is new. They have found also the previously unknown fact that a rapid current of air blown over the glowing Nernst pencil gives ozone in addition to nitric oxide, and it appears that the proportion of ozone increases, in its relation to the nitric oxide, as the rapidity of the current of air increases. Quantitative results have not yet been obtained, but it seems possible to produce in this way enough ozone so that the nitrogen peroxide produced at the same time, when led into water or sulphuric acid, will yield no nitrous acid, but nitric acid exclusively.— *Berichte,* xlix, 2557.   H. L. W.

3. *The Action upon Carbon of Oxygen, Carbon Dioxide and Steam.*—It has been found by P. FARUP that, under the same conditions of experiment, water vapor and carbon dioxide act upon solid carbon at 850° C. with the same speed, while oxygen acts at this speed at about 450°. According to the temperature-coefficient

of the oxygen reaction between 450 and 500°, it is calculated that the speed of this reaction at 850° is 3×10^6 times as great as that of the carbon dioxide and water vapor reactions. From results obtained by Nernst and v. Wartenberg in regard to the dissociation of water vapor and carbon dioxide, it appears that oxygen at atmospheric pressure and 850° has a concentration about 0.7×10^6 times as great as in water vapor and carbon dioxide at the same pressure and temperature; hence it appears that there is a connection between their dissociation and rate of action upon carbon. —*Zeitschr. anorgan. Chem.*, 1, 276.   H. L. W.

4. *The Combustion of Halogen Compounds.*—In determining carbon and hydrogen in substances containing halogens, CHARLES J. ROBINSON uses a cylinder of copper gauze filled with lead chromate in the combustion-tube. The cylinder is 6 or 7 cm. long and its copper parts are oxidized before use. The lead chromate is thus kept from contact with the glass. Some analyses are given showing satisfactory results by the use of this device with chlorine and bromine compounds, but no results are given for compounds containing iodine. Strange to say, the author recommends the use of the same device for nitrogen combustions, and gives a satisfactory result here also. It would be expected that oxygen would escape from the hot lead chromate and contaminate the nitrogen produced.   H. L. W.

5. *Introduction to General Inorganic Chemistry*, by ALEXANDER SMITH. 8vo, pp. 780. New York, 1906 (The Century Co.).—This text-book contains many excellent features and it is a very interesting work for a teacher of chemistry to read. The author has wisely made the elucidation of theory the main feature of the book, but an ample amount of facts is included for the purpose in view. The clear and able treatment of the theories by basing them upon facts is noteworthy. The book is intended for the use of beginners in college courses. It is a more thorough and difficult book than those generally used, but this feature may be considered a favorable one. It may be added that the subject is treated from the most modern point of view, but without giving undue prominence to the newer theories.   H. L. W.

6. *A First Course in Physics;* by ROBERT ANDREWS MILLIKAN and HENRY GORDON GALE. Pp. v, 488, with 494 figures. New York, 1906 (Ginn & Co.).—This appears to be an excellent text-book for high schools. The aim of the authors as stated in their preface has been to give " a simple and immediate presentation, in language which the student already understands, of the hows and whys of the physical world in which he lives." This idea has been consistently carried out; the explanations are lucid and free from technicalities; at the same time they are not generally open to the criticism which applies to many "simple" explanations, viz: that they are not true. In some cases the traditional order of subjects has been abandoned and the changes appear to be advantageous from the pedagogical point of· view.

The illustrations are well-chosen and attractive, and the diagrams clear. H. A. B.

7. *A Laboratory Course in Physics for Secondary Schools;* by R. A. MILLIKAN and H. G. GALE. Pp. x + 134. New York 1906 (Ginn & Co.).—This is a collection of fifty-one experiments designed to accompany the text-book noticed above. The experiments are well chosen and clearly described; the necessary apparatus is simple in character and well designed for its purpose.

H. A. B.

8. *Outlines of the Evolution of Weights and Measures and the Metric System;* by WILLIAM HALLOCK and HERBERT T. WADE. Pp. xi + 304. New York, 1906 (The Macmillan Co.).— The first chapter of this work gives an interesting outline of the historical development of metrology, so far as it is known, from the earliest times. The succeeding eight chapters have to do mainly with the metric system: its origin, development and extension throughout Europe; its advantages for commerce, manufacturing, engineering, medicine and pharmacy; and the international electrical units which have been derived from the fundamental metric units.

A final chapter deals with standards and methods of comparison and an appendix contains tables of equivalents and useful constants. H. A. B.

II. GEOLOGY.

1. *United States Geological Survey,* CHARLES D. WALCOTT, Director. — Titles of publications recently received are contained in the following list:

FOLIOS.—No. 138. Redding Folio, California. Description of the Redding quadrangle by J. S. DILLER. Pp. 14, with maps of topography and areal geology, structure and columnar sections.

No. 139. Snoqualmie Folio, Washington. Description of the Snoqualmie quadrangle by GEORGE OTIS SMITH and FRANK CATHCART CALKINS. Pp. 14, with maps of topography, areal geology, structure and columnar sections.

PROFESSIONAL PAPERS.—No. 50. The Montana Lobe of the Keewatin Ice Sheet; by FRED. H. H. CALHOUN. Pp. 62, with 7 plates and 31 figures.

BULLETINS.—No. 275. Slate Deposits and Slate Industry of the United States; by T. NELSON DALE, with sections by E. C. ECKEL, W. F. HILLEBRAND, and A. T. COONS. Pp. 154, with 25 plates and 15 figures.

No. 277. Mineral Resources of Kenai Peninsula, Alaska. Gold Fields of the Turnagain Arm Region; by FRED. H. MOFFIT. Coal Fields of the Kachemak Bay Region; by RALPH W. STONE. Pp. 80, with 18 plates and 5 figures.

No. 278. Geology and Coal Resources of the Cape Lisburne Region, Alaska; by ARTHUR J. COLLIER. Pp. 54, with 9 plates and 8 figures.

No. 284. Report on Progress of Investigations of Mineral Resources of Alaska in 1905; by ALFRED H. BROOKS and others. Pp. 169, with 14 plates and 10 figures.

No. 285. Contributions to Economic Geology, 1905; S. F. EMMONS, E. C. ECKEL, Geologists in charge. Pp. 506, with 13 plates and 16 figures.

No. 290. Preliminary Report on the Operations of the Fuel-testing Plant of the United States Geological Survey at St. Louis, Mo., 1905; JOSEPH A. HOLMES in charge. Pp. 240.

No. 291. A Gazetteer of Colorado; by HENRY GANNETT. Pp. 185.

WATER SUPPLY AND IRRIGATION PAPERS.—No. 155. Fluctuations of the Water Level in Wells, with Special Reference to Long Island, New York; by A. C. VEATCH. Pp. 83, with 9 plates and 17 figures.

No. 156. Water Powers of Northern Wisconsin; by LEONARD S. SMITH. Pp. 145, with 5 plates and 5 figures.

No. 158. Preliminary Report on the Geology and Underground Waters of the Roswell Artesian Area, New Mexico; by CASSIUS A. FISHER. Pp. 29, with 9 plates.

No. 160. Underground-Water Papers; MYRON L. FULLER, Geologist in charge. Pp. 104, with a map and 4 figures.

No. 162. Destructive Floods in the United States in 1905; by E. C. MURPHY and others. Pp. 105, with 4 plates and 11 figures.

No. 163. Bibliographic Review and Index of Underground-Water Literature published in the United States in 1905; by MYRON L. FULLER, FREDERICK G. CLAPP, and BERTRAND L. JOHNSON. Pp. 130.

Nos. 170, 172, 173, 174, 176, 178. Report of Progress of Stream Measurements for the Calendar year 1905. Prepared under the direction of F. H. NEWELL. Parts VI, VIII, IX, X, XII, XIV. Part. VI.—Great Lakes and St. Lawrence River Drainages; by R. E. HORTON, F. W. HANNA, and J. C. HOYT. Pp. 116, II, with one plate and two figures. Part VIII.—Missouri River Drainage; by C. C. BABB, M. C. HINDERLIDER and J. C. HOYT. Pp. 283, with one plate and 2 figures. Part IX.—Meramec, Arkansas and Lower Western Mississippi River Drainages; by M. C. HINDERLIDER, J. M. GILES and J. C. HOYT. Pp 103, with one plate and 2 figures. Part X.—Western Gulf of Mexico and Rio Grande Drainages; by T. W. TAYLOR and J. C. HOYT. Pp. 133, with one plate and 2 figures. Part XII.—The Great Basin Drainage; by M. C. HINDERLIDER, G. L. SWENDSEN, and HENRY THURTELL. Pp. 142, 11, with one plate and 2 figures. Part XIV.—Columbia River and Puget Sound Drainages; by D. W. ROSS, J. T. WHISTLER, and T. A. NOBLE. Pp. 250, II, with one plate and 2 figures.

List of the Publications of the United States Geological Survey. (Except Topographic Maps.) Pp. 58.

2. *Geologic Map of the Buffalo Quadrangle;* by D. D. LUTHER. Bull. 99, N. Y. State Mus., 1906, 29 pp. and map.—A general description is here given of the seventeen formations

outcropping in this quadrangle from the uppermost beds of the Silurian to the top of the Devonian. Diagnostic fossils for each formation are also listed. The map gives the areal distribution of the formations described. c. s.

3. *Second Report of the Director of the Science Division, 1905.* N. Y. State Mus., 1906, 99 pp.—This is the 59th report of the New York State Museum and the 2nd report of the Director of the Science Division, John M. Clarke. It deals with the work done and in preparation throughout the various divisions of the State Museum during the year 1905. Of particular interest to stratigraphers is the announcement,—"It is quite probable however that the Oswego sandstone [heretofore always accepted as Silurian] represents a near-shore condition, which was unfavorable for life, but farther west the Richmond fauna flourished under more suitable conditions." In other words, it is probable that the Oswego and Medina formations are the closing formations of the Ordovician. This is the view maintained by Ulrich of the U. S. Geological Survey, during the past three years, based on the Medina stratigraphy of the southern Appalachian.

Another striking correlation is that the Shawangunk conglomerate is not of Medina (Oneida) age, but " represents the invading basal member of the Salina formation in the eastern part of the State." c. s.

4. *The Upper Ordovician Rocks of Kentucky and their Bryozoa;* by John M. Nickles. Bull. 5, Kentucky Geol. Survey, 1905 (not received until July, 1906), 64 pp. and 3 pls.— This report describes the rocks of the Cincinnatian series and lists the Bryozoa of the various formations as found in Kentucky along the Cincinnati arch. Twenty-eight species are described, of which five are new. The illustrations show the macroscopic characters of the species. c. s.

5. *The Chazy Formation and its Fauna;* by P. E. Raymond. Ann. Carnegie Mus., iii, July, 1906, pp. 498–598.—This is the first article of a series of papers in which the author proposes to describe the stratigraphy and faunas of the Chazy as found in northeastern North America. The part now at hand deals with the stratigraphy of the various areas and lists of the fossils occurring in the various beds. The author's main conclusions are as follows:—

" This fauna shows a decidedly closer affinity with the fauna of the Black River and Trenton formations of New York and Canada than with the Beekmantown of the same regions. The strong Mohawkian facies of the Chazy fauna suggests that the Chazy formation should be taken out of the Canadian, the Beekmantown and Chazy having very little in common." There is but one species common to the two formations. " While the Black River and Trenton formations have only a few species in common with the Chazy, yet when the fossils are compared with one another it is found that almost every one in the Chazy is

represented in the Trenton by a very closely allied species " (p. 562). Thirteen new species are described.   c. s.

6. *A New American Cybele;* by J. E. NARRAWAY and P. E. RAYMOND. Ann. Carnegie Mus., iii, July, 1906, pp. 599–604.— In America, this genus of trilobites is always rare and entire examples are almost unknown. The writers describe a nearly complete specimen preserving all the essential characters. It is named *Cybele ella*, and occurs in the Black River limestone of the Ordovician, near Ottawa, Canada.   c. s.

7. *Uber Phylogenie der Arthropoden;* by A. HANDLIRSCH. Verh. k. k. zool.-bot. Gesellsch. Wien, 1906, pp. 88–103.—For several years, Handlirsch has had in preparation an octavo work entitled " Die Fossilen Insekten und die Phylogenie der Rezenten Formen,"* now being printed by Wilhelm Engelmann in Leipzig. From this work has resulted the paper under review.

The writer holds that the Arthropoda are monophyletic ; that *Peripatus* stands much closer to the worms than to the true Arthropoda, and can not be regarded as the link uniting branchiate and tracheate Arthropoda. The stem group for all Arthropoda, he holds, must be sought among the trilobites. From these the Crustacea were first differentiated. The Arachnida are united with the trilobites through the limuloids, and with these the eurypteroids are closely related. The myriopods are seemingly difficult to derive from trilobites, but in the Carboniferous are many myriopod-like forms, the majority of which had a relatively broad and large head, with well-developed, large compound eyes like those of trilobites. Many of these forms were broad and had short segments in moderate numbers; some even had distinctly marked pleural parts quite similar to those in trilobites.

" From all these facts it seems clear that the primitive forms of myriopods were also relatively broad animals with homonomous segments, compound eyes, and cloven feet, living at least part of the time in water, and gradually adapted their breathing organs to a land existence. If we assume that the trilobites possessed nephridia on all segments, it is easily explained how in the very beginning two diverging myriopod-like stems originated, one of which had adapted the segmental organs situated far to the front, the other those far to the rear, to the service of sexual parts. In this event, the Progoneates and the Opisthogoneates are to be regarded as independent phyla " (p. 97).

This paper is of great interest to all students of the Arthropoda.   c. s.

8. *Die Entwickelung von Indoceras baluchistanenense Noetling. Ein Beitrag zur Ontogenie der Ammoniten;* von F. NOETLING. Geol. u. Pal. Abh., Jena, viii, n. ser., 1906, pp. 1–96,

* Die Fossilen Insekten und die Phylogenie der Rezenten Formen. Ein Handbuch für Paläontologen und Zoologen ; von Anton Handlirsch. I. Lieferung (mit 9 Tafeln). Pp. 160, Leipzig, 1906 (Wilhelm Engelmann).

7 plates.—This elaborate work describes in great detail the development of the highest Cretaceous ammonite mentioned in the title, and having a ceratite suture line. The development is as follows : (1) Protoconch stage ; (2) Embryonic or Sphæro-ceras stage ; (3) Metaconch or Oxynoticeras stage (has always five volutions irrespective of size of shell) ; (4) Paraconch or Indoceras stage.

The author concludes that on the basis of the developmental characters of the suture line alone it is at present not safe to decide as to the age of the strata in which the form occurs, for the reason that as yet we know the complete development of but few ammonites, and further that a primitive form may occur in young beds and a highly specialized species in old deposits.

In regard to the ancestry of *Indoceras*, the author concludes that "it had a different descent than *Sphenodiscus* or *Placenti-ceras* and that it can hardly be arranged with these in the family Pulchelliidæ, or with the Upper Cretaceous Oxynotus forms : *Garnieria, Lenticeras* and others are to be united in a family of indoceratids " (p. 92).

9. *Untersuchungen uber die Familie Lyttoniidae Waag. emend. Noetling;* von F. NOETLING. Palæontographica, li, 1906, pp. 129-153, pls. xv-xviii.—Some years ago, the author, while in India, collected in the Upper Permian of Chideru in the Salt Range an abundance of the genera *Oldhamina* and *Lyttonia*. As some of his specimens are preserved as silicious pseudo-morphs, he was able through careful etching with hydrochloric acid to free them from the limestone and thus to reveal the entire structure of these remarkable and highly degenerate brachiopods. So strikingly aberrant are these forms that at first they were described as gasteropods (*Bellerophon*) and later as the teeth of fishes (*Leptodus*). The latter generic name Waagen displaced by his *Oldhamina* when he discovered these remains to be brachiopods. This proceeding is irregular, and it is to be regretted that Noetling does not return to *Leptodus*, especially after he remarks that according to the law of priority Waagen had no right to make this change (p. 133). On the other hand, *Oldhamina* can not be confused with *Oldhamia* even though the names sound 'nearly alike ; and it is therefore further to be regretted that Noetling in a half-hearted way tries to dispossess the former by suggesting *Oldhamella*. The author prints the name in a foot-note (p. 129), and though it is only suggested, not seriously proposed, it can not be overlooked. Thus another synonym is added to the terminology of these shells. Some years ago he considered these fossils to be Bryozoa, and at that time proposed the name *Waagenopora*. Thus is literature burdened by giving way to printing all the unassimilated thoughts passing through an author's mind.

These shells are cemented to foreign bodies by the umbo of the ventral valve, and the scar of attachment is plainly preserved in young and apparently in adult specimens also (see pl.

xv, figs. 2a, 3). Because of the abnormal and very irregular lamellar thickenings of the posterior region of the shell margin (no two shells are alike in this character) covering over the scar of attachment, Noetling thinks these animals finally lost fixation and lay with the dorsal shell on the sea bottom.

He arrives at this conclusion because the majority of the specimens by far are ventral shells; some show the inner side of the dorsal valve and but a few preserve both valves in place. One might suppose that if the animal finally came to live as suggested by the author, all the specimens would preserve both valves, because after death, as the animal matter decayed, its place would be occupied by the "very soft calcareous mud" in which it lay. The reviewer thinks that during the weathering process the very thin dorsal shell is either dissolved away, or because of its deeply cleft nature and exterior papillose condition it adheres firmly to the outer rock, only to be dissolved away by weathering from this side. The fact that the mantle is constantly depositing shell on the outer posterior cardinal area is evidence that in some way it embraced foreign objects by which it held the shell in place. In old age such deposition may cease, but as these animals apparently lived in large communities they are nevertheless firmly held in place by their neighbors. On the other hand, if lying with the dorsal valve down in the soft mud, as suggested by the writer, it would seem that death must soon ensue through suffocation, because of the mud squeezing in through all of the many lateral clefts of the dorsal valve, but especially in preventing free water circulation with a fresh supply of food and oxygen.

Of the many cemented brachiopods, it is very rare to find one preserving the object of attachment, and on this account it should not be expected to occur here more than elsewhere. The reviewer believes that these animals lived with the deeply cleft dorsal valve uppermost, or that the posterior region of both valves lay somewhat embedded in the mud, with the greater portion of the anterior region protruding above the sea floor.

The author correctly removes these shells from the Thecidiidæ and regards them as more closely related to the Productidæ. He adds, "it may be that this aberrant group can even be included in this family so rich in forms" (p. 147). It seems now more probable that the Leptodidæ (new name) arose in some cemented form of the Productidæ, in which case it would be best looked for among *Strophalosia.*   c. s.

III. Miscellaneous Scientific Intelligence.

1. *Les Prix Nobel en 1903.* Stockholm, 1906 (P. A. Norstedt & Söner).—The recipients of the Nobel prizes in 1903 were as follows : Henri Antoine Becquerel for his discovery of spontaneous radio-activity ; Pierre and Marie Sklodovska Curie for their researches in the phenomena of radiation discovered by H. Becquerel ; Svante August Arrhenius for the theory of electro-

lytic dissociation ; Niels Ryberg Finsen for the treatment of diseases by light rays ; Björnstjerne Björnsen for his poetical works. This interesting volume contains, in addition to an account of the ceremonies accompanying the prize distribution, biographical notices of the recipients with portraits and also reproductions of the Nobel medals and diplomas. The addresses at the *Conférences Nobel* by H. Becquerel, P. Curie, S. Arrhenius and W. Randal Cremer close the volume.

2. *British Association.*—The annual meeting of the British Association for the Advancement of Science was held at York from August 1 to 8 ; at which place the Association met both for the first time in 1831 and again in 1881. Prof. E. Ray Lankester in his presidential address reviewed the scientific advance of the past quarter century. The next meeting, for 1907, will be held in Leicester, that for 1908 in Dublin, and for 1909 at Winnipeg.

3. *Carnegie Institution of Washington.*—The following are titles of publications recently received :

No. 34. American Fossil Cycads ; by G. R. Wieland. 4to. Pp. vii + 296, 51 plates, 141 figures. A notice will follow.

No. 46. An Investigation into the Elastic Constants of Rocks, especially with reference to their Cubic Compressibility ; by F. D. Adams and E. G. Coker. 8vo. Pp. 69, 16 plates. An abstract was published in the August number, pp. 95–123.

No. 50. The Relation of Desert Plants to Soil Moisture and to Evaporation ; by Burton E. Livingston. Pp. 78, 16 cuts.

No. 52. Inheritance in Poultry (Paper No. 7, Station for Experimental Evolution) ; by C. B. Davenport. Pp. 136, 17 pl.

No. 53. Egyptological Researches ; W. Max Müller. 4to. In press.

Obituary.

William Buck Dwight, Professor of Geology at Vassar College for nearly thirty years, died at Cottage City, Mass., on August 29, at the age of seventy-three years. He was born in Constantinople, the son of an American missionary, and came to this country in 1849. He was graduated at Yale College in 1854, at the Union Theological Seminary in 1857 and received the degree of B.S. from the Sheffield Scientific School in 1859. He carried on extensive field work in geology, chiefly in Dutchess County, N. Y., between 1879 and 1890 ; a number of papers giving his results are contained in this Journal. He invented a rock-slicing machine in 1891 and had charge of the department of geology in the Standard Dictionary. He was one of the original fellows of the Geological Society of America.

Dr. Paul Drude, Professor of Physics and Director of the Physical Laboratory at Berlin, died on July 5, at the age of forty-three years. He was the author of important theoretical and experimental researches on the electro-magnetic theory of light and since 1890 had been editor of the *Annalen der Physik*, during that period often known as Drude's Annalen.

Sir Walter Lawry Buller, well known for his work on the ornithology of New Zealand, died on July 19, at the age of sixty-eight years.

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SCIENTIFIC INTELLIGENCE.

S. L. Penfield

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

SAMUEL LEWIS PENFIELD.

In the recent death of Samuel Lewis Penfield, the mineralogist, science in America has lost one of its best representatives, his chosen field of work its ablest exponent and investigator and the community in which he lived a man of the highest type of character. His loss is a heavy blow to his profession, to his University and to his friends. Men of his attainments come but rarely, and when they pass, the place they have made can never be exactly filled.

Attacked some three years since by a very serious malady which occasioned great anxiety, his unwearying and patient fidelity to the regimen prescribed for him and the devotion and care of his family enabled him to resist the disease, and it was hoped that his life might be prolonged for years to come. His trouble took, however, a sudden and unfavorable turn, and after a very brief illness he passed peacefully away on Aug. 12th, at the little village of South Woodstock, among the hills of eastern Connecticut, where he was spending the summer.

Penfield was born Jan. 16th, 1856, in the town of Catskill on the Hudson River, where his father, George H. Penfield, who was engaged for many years in a mercantile and shipping business, was a prominent, useful and highly esteemed citizen. His mother, whose maiden name was Ann A. Cheeseman, was of Connecticut stock; she was a notable woman in her community and family, and from both his parents Penfield had a

fine inheritance and thorough training in high principles and ideals. He was one of several children; his father's roof sheltered other members of the family, all united by strong ties of affection, and he thus grew up in an atmosphere which made him feel keenly all his life the ties of kindred and gave him a humanitarianism which strongly marked him.

His early education was received in his home and in the school at Catskill. Ideals of learning and culture were traditional in his family; some of his ancestors had been college-bred men, and it was early determined he should have a college education. To fit himself to enter Yale he attended the academy at Wilbraham, Mass., and in the autumn of 1874 he became a member of the freshman class of the Sheffield Scientific School. Like many other graduates of that institution, who have become well-known in natural science, he took the course laid out in chemistry. Languages he learned with difficulty though he retained them well, but in mathematics and natural science, and especially analytical chemistry, he excelled. He was graduated with honors in 1877, receiving the customary degree of Bachelor of Philosophy. While devoted to his studies, the social side of university life had not been neglected and he was loved and respected in his class, and made many enduring friendships.

After his graduation he became one of the assistants in the laboratory of analytical chemistry, a position held for two years and which, outside of the benefits of the training which its duties conferred, gave him excellent opportunities for continuing his chemical education. At this time Professors Brush and Edward Dana were engaged in their researches on the remarkable mineral locality at Branchville, Conn., which has become classic in the history of mineralogical science for the great number of new mineral species, chiefly phosphates, which it afforded.

The task of ascertaining the chemical composition of these minerals was confided to Penfield and his classmate and fellow assistant, now Professor H. L. Wells. The importance of the work, its great scientific interest, the new problems in analytical chemistry involved, all combined to excite the enthusiasm of the young investigators and to stimulate their powers

to the highest degree, while giving them a training of the
greatest value. Penfield, who took to analytical chemistry
with the keenest eagerness, no doubt in great part had his
future career determined by his work during these two years
and the one following, when he was transferred from the chem-
ical to the mineralogical laboratory as assistant.

During this period he analyzed the new minerals eosphorite,
triploidite, dickinsonite, fairfieldite and fillowite, and made
analyses also of triphylite, childrenite, amblygonite, cymato-
lite, spodumene, etc. Up to this time his work, though deal-
ing largely with minerals, had been entirely of a chemical
nature and it is certain that he expected to make chemistry the
subject of his life work, for in the years 1880–1881 he went
to Germany to obtain advanced instruction in the organic side
of this science. He spent two semesters in the laboratory of
Prof. Rudolph Fittig at Strassburg and a part of the work
resulted in the publication with him of a joint paper on organic
compounds prepared and studied. He heard some lectures
under Prof. P. Groth, at that time located at Strassburg, but
there can be no doubt that, had he known the work he was to
do in the future, his studies would have been almost wholly
under the direction of this eminent teacher and crystallog-
rapher. He never regretted, however, the time he had thus
spent, for it added greatly to his general knowledge of chem-
istry and to his training in the solution of chemical problems.

It was at the close of this stay in Germany that the oppor-
tunity opened which finally determined Penfield's career in
science. The constant growth of the Sheffield Scientific
School had laid such an increasing burden of executive duties
upon its director, Professor Brush, that he was no longer able
to give more instruction in mineralogy in the institution than
was involved in the course of lectures on the descriptive side of
the subject and suggestions and advice in advanced work.
The practical work in the subject in the laboratory, the deter-
minative mineralogy, was given by his assistant, who, at that
time, was the late Dr. G. W. Hawes. The authorities of the
National Museum offered the latter an opportunity to develop
a department of Geology, which he accepted, and Penfield
was called to fill his place. He entered on his duties with

the beginning of the fall term in 1881, having the title of Instructor in Mineralogy, and from that time until his death he was actively engaged in teaching and in extended researches in this subject. Feeling the need of more advanced training in certain ways, especially in methods of optical and microscopical research, in 1884 he again went to Germany and spent the summer semester at Heidelberg under Professor Rosenbusch and with great benefit to his future work. In 1886 he assumed entire charge of the instruction in mineralogy, he was appointed an assistant professor in 1888 and in 1893 was promoted to a full professorship and became a member of the Governing Board of the Sheffield Scientific School.

That which Penfield accomplished during his life divides naturally into two parts, the results of his investigations and his work as a teacher of mineralogy. In regard to the first the bibliography appended to this notice speaks far more eloquently to those acquainted with the history of mineralogical science during the last quarter of a century than could the efforts of any pen. Yet out of this great volume of important results of work which issued from his laboratory during the twenty-five active years of his life—results which have been equalled in scope and value by but few men during a much longer working period—certain salient facts may well be mentioned to indicate his achievements. He published over 80 papers relating to Mineralogy and Crystallography, either under his own name or in collaboration with others, besides the large number which came from the assistants and students in his laboratory and which were directly due to his inspiration and oversight. Moreover this does not include a great number of notes, representing crystallographic and chemical work, scattered through the literature as published in the papers of other workers, for Penfield was ever most generous of his time and skill in helping others and he had long come to be regarded in America as an ever present aid and final source of appeal in problems relating to mineralogy by workers in the geological sciences.

The mere statement of the volume of his work would, however, mean little unless it were taken in connection with its

quality. Both in the importance of the problems treated and in the ability and technical skill with which they are handled his work is of the very highest scientific character, and the greater part of it, together with his methods and ideas, has already become classic in the history of his science. In regard to this the following facts are of interest and may be mentioned. Fourteen new mineral species were established and described by him,—sometimes in combination with others. These are: *Bixbyite, Canfieldite, Clinohedrite, Gerhardtite, Glaucochroite, Graftonite, Hamlinite, Hancockite, Leucophoenicite, Nasonite, Nesquehonite, Pearceite, Roeblingite, Spangolite.*

What in reality was of even greater importance was the large number of already described minerals, many of them well known and prominent species, which he studied and whose true chemical composition and mineralogical affinities he established. These include *Alurgite, Amblygonite, Argyrodite, Aurichalcite, Childrenite, Chondrodite, Clinohumite, Connellite, Cookeite, Ganomalite, Hanksite, Herderite, Howlite, Humite, Monazite, Ralstonite, Staurolite, Sulphohalite, Topaz, Tourmaline* and *Turquois.*

Among the more important facts which he brought out as the result of his chemical work was the discovery of germanium in silver ores from Bolivia and the determination of the correct formula and crystallization of argyrodite, the Freiberg mineral in which germanium was originally discovered. Another contribution of the highest value was his recognition that fluorine and hydroxyl are isomorphous in chemical structures, and that they play a significant function in the composition of many minerals whose correct formulas may be derived by the application of this principle. He showed also that the variations in the physical properties of certain prominent minerals were dependent upon the variations in the relative amounts of these radicals. This was shown very strikingly to be the case with topaz, and applying these ideas to the chondrodite group of minerals, whose relations until then had proved an unsolved problem, he derived their correct compositions and showed that they formed a definite series with related physical properties. He was, moreover, able to indi-

cate the probable existence of another member of the series and to predict its composition and properties, a forecast whose correctness has since been established by Sjögren in the discovery of prolectite.

The idea of the isomorphism between hydroxyl and fluorine was suggested in the first Branchville paper by Brush and Dana from Penfield's analysis of triploidite. At first it was not accepted by prominent chemists and mineralogists, but Penfield by steady work in his laboratory again and again demonstrated its validity and importance, until now it has gained general acceptance and it has become recognized that the existence of these isomorphous radicals not only explains the structure of many minerals, but that their presence is of the greatest importance in understanding the mode of formation, especially in magmatic processes.

Another contribution of the first order, in the field of chemical crystallography, was his announcement of the mass action of complicated inorganic acids in determining crystal form. Thus while the bases in combination with such acids may be of the most diverse kinds, the system of crystallization is not affected. This was brought out in his important paper with Foote on the chemical composition of tourmaline, but has since been shown to be of wide application.

As an analytical chemist Penfield must be ranked as one of the great masters of this art. He had a broad and comprehensive grasp of its principles, was very fertile in their application, suggestive in combinations and in details and joined to this a technical skill and dexterity in manipulation that was really marvelous. In consequence of this the ease and speed with which he turned out complicated analyses of remarkable accuracy have always been a source of admiration among his friends and fellow-workers. His analysis of the rare mineral connellite and derivation of its formula was performed upon less than a tenth of a gram of material. Many similar feats of his skill might be cited. He rarely took up any new analytical method that he did not suggest excellent improvements in it, and he devised new methods, many of which are now in general use ; his mineralogical papers in fact are full of contributions to analytical chemistry and he published several useful papers directly upon analytical methods.

Penfield's work as a crystallographer is scarcely of less importance than that which he performed on the chemical side of mineralogy. He handled mathematical relations with ease and clearness and his work was both rapid and accurate. His perception of crystal forms and symmetry seemed almost intuitive and in practical operations he was greatly aided by the same manual dexterity that he showed in chemical manipulation; thus he made measurements on the goniometer of crystals of such a degree of minuteness, as in the case of sperrylite, that it seemed almost impossible that they could be handled.

Besides establishing the crystallization of the new minerals already mentioned, Penfield determined that of the following species: *Amarantite, Argyrodite, Bertrandite, Herderite, Lansfordite, Metacinnabarite, Penfieldite, Polybasite, Sperrylite, Tiemannite, Willemite.*

In addition to his contributions to the crystallography of minerals we also owe to Penfield the determination of the other physical properties of many species, especially the optical; a work which he first took up in Rosenbush's laboratory and afterwards accurately and skillfully carried out whenever possible upon all of the species which he investigated.

His labors as a crystallographer were not, however, confined to minerals. For a number of years he spent much time in the determination of the crystallization and optical properties of compounds prepared in the chemical laboratory of the Sheffield Scientific School. As may be seen by reference to the appended bibliography, this work was done either directly by himself or under his care and supervision by the assistants and advanced students in the laboratory whom he had trained. Among these compounds studied there may be mentioned as of special importance the large series of new double salts, particularly the double halides, prepared by his colleague Professor Wells or under his direction. During the later years of his life Penfield gave much time and thought to the perfecting of practical methods for the solution of problems in crystallography. He was led to a study of the stereographic projection as a means of expression and in 1901 published an important paper on this subject, showing how it could be used for solving problems, not only in crystallog-

raphy, but also in astronomy, geodesy, navigation, etc. He prepared also an ingenious set of instruments for use in connection with this method of projection by means of which laborious calculations could be avoided and the problems quickly and accurately solved by graphic methods. He extended these practical methods and applied them to the drawing of crystals, devising special plates of axes to be used in connection with his instruments by which the solving of the form of a crystal and the drawing of its figure could be easily and rapidly carried out. These methods have since come into very general use.

In reviewing Penfield's work in mineralogical science one is struck, not more by its quantity than by its quality and varied aspects. He was a thoroughly trained man and had a firm grasp on every phase of his subject. He had a wide and accurate knowledge of minerals and the correctness with which he often identified them at sight seemed almost like intuition. While he clearly apprehended principles and, as has been shown, produced generalizations of wide importance, the great majority of his contributions to science are not of a theoretical nature but consist of direct and positive additions to knowledge. He had a highly analytical mind, and this combined with his inventive faculty and the great manual skill with which he was gifted made him a born investigator, one of the greatest who has yet appeared in his field of science. It is safe to say that with his gifts he would have had a successful career in whichever of the physical sciences he might have entered. The thoroughness of Penfield's work, its high quality and the completeness with which he covered every side of his subject, is well illustrated in his last paper on stibiotantalite, published in the current July number of this Journal, in conjunction with his junior associate and former pupil Professor Ford.

His services to science have been worthily recognized at home and abroad : in 1893 he was made an associate Fellow of the American Academy of Arts and Sciences in Boston : in 1896 he became a Foreign Correspondent of the Geological Society of London and his university conferred on him the degree of Master of Arts : in 1900 he was elected a member of the National Academy of Sciences : in 1902 he was chosen as a Fellow of the American Association for the Advancement of Sci-

ence, a Corresponding Member of the Royal Society of Sciences at Göttingen, Germany, and member of the Scientific Society of Christiania, Norway : in 1903 he was elected Corresponding Member of the Geological Society of Stockholm and Foreign Member of the Mineralogical Society of Great Britain : in 1904 the University of Wisconsin conferred upon him the degree of Doctor of Laws. He was also a member of the Connecticut Academy of Arts and Sciences and a Fellow of the Geological Society of America.

As a teacher Penfield was a striking example of what may be accomplished by an intelligent and painstaking devotion of one's effort toward a given end. He was not naturally gifted as a teacher—as a lecturer and speaker—as some men are. Of an extremely modest, quiet and retiring disposition and somewhat reserved except among his intimate friends, he always found it difficult, and naturally disliked, to express himself in public. Thus at the outset the management and instruction of students in numbers was for him not an easy matter. But he so entirely overcame this and perfected to so great a degree his methods of teaching, that the many students who came under his instruction regarded him as one of the best teachers in the University. In laboratory work, where the contact with the student is personal, he always had great success from the beginning of his career, because, in his kindliness of disposition, great patience and persistency, and in his interest in the student and his work, he had natural aptitudes which specially fitted him for this kind of instruction, and he took morever distinct pleasure in it. He always insisted upon great thoroughness and completeness in allotted work, and the mental discipline and training in method which students received under him were not less valuable than the knowledge of mineralogy which they acquired.

With those who came under him for advanced instruction he was particularly fortunate. The untiring care and oversight which he gave to their work and the thoroughness and accuracy upon which he insisted gave almost invariably successful results, and thus, especially in research, he communicated his own energy and enthusiasm to his pupils and stimulated their interest. This is clearly shown in the large number of important pieces

of work executed by him in conjunction with his students or by them under his direction. The writer, who was greatly aided by Penfield's instruction at the beginning of his own scientific work in mineralogy, can abundantly testify to his generous helpfulness and sympathetic interest in others and their work.

Penfield gave unlimited pains and thought to perfecting his material equipment for teaching and to this much of his success was due. In his laboratory he had many carefully chosen collections of models, of crystals and of minerals, each designed for particular purposes, and the arrangement of these and of the apparatus was carried out with a system and a completeness for uses of instruction that always excited the admiration of those qualified to judge of their character. In the same way with great skill and ingenuity he constructed models and apparatus for use in teaching crystallography and the optical properties of minerals to his classes and advanced students. Nor should there be forgotten in this connection the care and labor he expended in preparing the new edition of Brush's Manual of Determinative Mineralogy, the additions to which, dictated by his experience in teaching, are of the greatest value to students.

It was in fact a question which Penfield ever had upon his mind—how he could improve his methods and equipment for instruction, and as a result they attained to so high a degree of completeness and practice that many teachers of mineralogy who were not his pupils found a visit to his laboratories a source of help and inspiration.

It is a matter of satisfaction to his friends that, after the first attack of illness, his life was spared long enough for him to realize his cherished ambition in the completing of the new laboratories he had planned in Kirtland Hall and in the arrangement and perfecting of their equipment. In his new quarters he passed, in spite of illness, two very happy years of busy work, with his students and in investigations.

Penfield's activities were not confined to his laboratory. In the middle eighties he spent two summers as assistant in geological work to Professor Iddings in the survey of the Yellowstone Park, and later a number of summers were spent by him in northern New York, in North Carolina and Colo-

rado, collecting minerals and studying their modes of occurrence and field relations. The inspiration to a number of important pieces of work was given by these experiences. He also spent two summers in Europe, in 1894 and again in 1897, visiting other workers in his science and seeing collections and well known mineral localities. In these travels he was everywhere cordially received and made a large number of friends.

For many years Penfield, with several of his colleagues, one of whom was the late Prof. C. E. Beecher, lived in apartments in the top of one of the buildings of the Sheffield School. In this little coterie of young scientists were knitted enduring bonds of intimacy and friendship which had the most happy effect upon his life and work and in it he both gave and received.

As previously remarked, Penfield was distinguished by a broad humanitarianism, by a warm heart and ready sympathy which responded quickly to every call. He was always interested in charitable work and for many years was a weekly visitor to the children's ward in the City Hospital, where he cheered and helped the little patients.

In January 1897 he married Miss Grace Chapman of Albany, N. Y., who survives him. His great happiness in his married life and in the home circle he drew around him and in its generous hospitality was evident and a matter of sincere pleasure to all his friends.

The dominant notes of Penfield's character as a man were his benevolence, his simplicity, earnestness and downright honesty and sincerity in word and deed. These traits, together with a certain sweetness of disposition and a wonderful patience, never more strikingly shown than during his illness, greatly endeared him to his friends. To know him well was to love him.

Great as is the loss, that a man of Penfield's type should be cut off in the midst of his active career, and sincere and deep as our sorrow must be thereat, there is a satisfaction, which helps somewhat to console, in the thought that all there is to such a man can never die. The work that he achieved still remains, and better yet, the influence and memory of the high

principles he inculcated, not only in science but in daily life, as a man and a citizen, still mould the thoughts and feelings of his friends and students. His science is better today, not only by what he did, but still more by the influence he exerted and the high ideal of character he left behind him. This is a precious heritage which can never be lost.

The portrait accompanying this notice has been reproduced from a photograph taken some four years ago.

L. V. Pirsson.

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Art. XXXIV.—*The Conductivity of Air in an Intense Electric Field and the Siemens Ozone Generator;* by Arthur W. Ewell.

In connection with a study of the electrical production of ozone, the writer desired information regarding the electrical conductivity of air, self-ionized in a strong electric field. Since little qualitative and no quantitative data could be found, the writer investigated the subject and obtained the results here presented.

For quantitative measurements the ionization should be uniform over a considerable cross section. Parallel electrodes of relatively large area give the most uniform field, yet at unavoidable minute projections on the electrodes the electric force will be excessive and the air will be considerably ionized before it is elsewhere. Owing to the increased conductivity of this air, the electric force increases in the remainder of the distance to the other electrode and a narrow discharge or *spark* occurs before the potential is sufficient to uniformly ionize the air.

If an alternating electromotive force is employed a plate of dielectric such as glass may be interposed in the air and any current in the air will be transmitted through the glass as a displacement current. There will still be excessive ionization in the immediate vicinity of any minute projections on the electrodes, but the dielectric prevents the appreciable extension of this ionization as a spark, and when the electric force is sufficient, the entire body of air is very uniformly ionized.

The ionization current, when large, is accompanied by a loud noise and the air between the electrodes is of a very uniform purple color.

The apparatus used is illustrated in fig. 1. The electrodes *A* and *B*, of tinned copper, and the glass plate *C*, constitute essentially the simplest type of Siemens ozone generator.* *F* and *F'* are equal, non-inductive resistances. *E* is a Thomson electrostatic voltmeter. *H* is one of Prof. Harold B. Smith's high potential transformers with a maximum ratio of transformation of 1000 : 1 and a capacity of 100 kw. One side of the transformer was grounded and the potential of the other side was obtained from the primary voltage, read at *G*. From readings of the actual secondary voltage with a Braun electrometer, *K*, for secondary currents of various magnitudes and phases, the ratio of transformation was found to be accurately 500 : 1, the ratio for which the primary was connected.

The discharge heated air, glass, and electrodes. Since the dielectric constant of the glass increases with rise of temperature and since it was essential that the temperature of the air

* See article by the writer in Phys. Rev., p. 244, April, 1906.

should be definite, the air under investigation, between electrodes and glass, was frequently renewed, the glass was cooled whenever it became appreciably warmer than the electrodes and the electrodes were maintained at a constant temperature by ten liter water baths directly behind them. For the small polar distances employed, such electrodes were able to keep air and glass approximately at their own temperature.

Electrode B was $30^{cm} \times 30^{cm}$. Electrode A consisted of an inner portion $20^{cm} \times 20^{cm}$, soldered directly to the water tank,
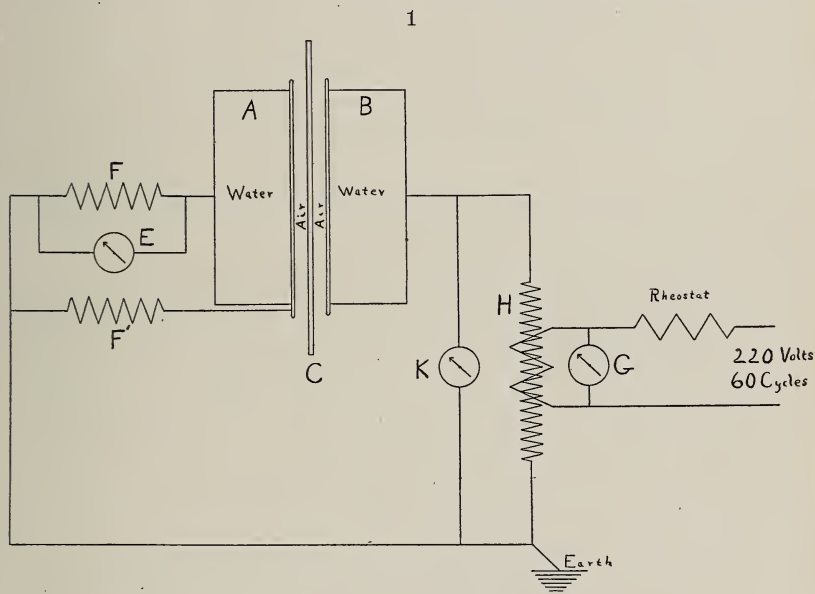
and an outer guard ring insulated from the tank, the separation from the central portion being 1^{mm} and the outer edge $30^{cm} \times 30^{cm}$. The central portion and the guard ring were accurately in the same plane. Without the guard ring there was considerable spreading of the discharge at the edges, which became particularly serious when the difference of potential was so high that the electric intensity was sufficient to ionize the air along paths bending far out from the direct line of the edges. The current through the air opposite the central portion was determined from the fall of potential across the non-inductive resistance F. The insulation of the guard ring was assured by testing with a telephone, and by measuring the current through F when F' was varied. If the insulation was perfect the current through F was practically independent of F'.

Under the alternating difference of potential between the electrodes, displacement currents traversed air and glass, and when a certain difference of potential was exceeded, depending upon the distance between the electrodes, the air was ionized and a conduction current was established in the air. The displacement currents follow well known laws and it is the current transported by the ions in the air and the electromotive force applied to the air which is of interest. The displacement current in the air is a quarter period in advance of the electromotive force and the ionization current is in phase with the electromotive force. The current in the glass will be a displacement current equal to the vectorial sum of the two currents in the air, but it is most convenient to resolve it into two parts, each in phase with the corresponding current in the air, and to resolve similarly the electromotive force applied to the glass.

In fig. 2, let A represent the total e.m.f. applied to air and glass, B the total e.m.f. applied to the glass, C that applied to the air. B is the vectorial sum of D, the e.m.f. required to maintain in the glass the equivalent of the displacement current in the air, and E the e.m.f. required for the equivalent of the ionization current in the air. A, the total applied e.m.f., is observed directly, B, the e.m.f. required to maintain the total current in the glass, can be determined with electrodes directly against the glass. Since D maintains a displacement current in the glass which requires an e.m.f. C in the air, their ratio must be the inverse ratio of the capacities of two plate condensers of equal area, one having the given thickness of air as its dielectric and the other the glass. If k is the dielectric constant of the glass, d_1 the thickness of the glass and d_2 that of the air,

$$\frac{D}{C} = \frac{d_1}{kd_2} \text{ or } D = rC \text{ where } r \text{ is a constant.} \quad (1)$$

Moreover by geometry $C^2 + 2CD = A^2 - B^2$

$$\therefore C = \frac{\sqrt{A^2 - B^2}}{\sqrt{1 + 2r}} = \sqrt{A^2 - B^2}\left(1 - r + \tfrac{3}{2}r^2\right) \quad (2)$$

to a sufficiently close approximation, for the e.m.f. applied to the air. The magnitude of the ionization current equals the
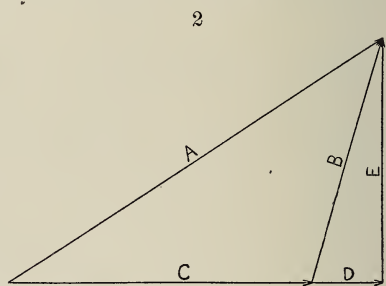
total current less the air displacement current, and it is the geometrical difference or the square root of the difference of the squares, since the ionizations and displacement currents differ in phase a quarter period. The displacement current obviously equals,

$$\frac{2\pi n A}{4\pi d . 9 \cdot 10^{11}} \, C \qquad (3)$$

where n is the frequency ($= 60$), A the area of the electrodes, d the thickness of air, and C, as before, the e.m.f. applied to the air.

The following observations of a typical experiment will illustrate the preceding paragraphs:

July 5. Fair, Dry. Bar. $= 75 \cdot 2$, Temp. of water $= 22° \cdot 5$.
Thickness of glass $= \cdot 59^{cm}$, of air $= \cdot 43^{cm}$.*
Primary e.m.f. $= 58 \cdot 6$† ∴ e.m.f. applied to electrodes($=A$) $= 29300$.†
Non-inductive resistance $= 40000$. Electrostatic voltmeter $= 187$† ∴ Total current $= 4 \cdot 67$ milliamperes†.

From the curve of the observations of May 1 (see below) an e.m.f. of 23300 ($= B$) was required to maintain a current of $4 \cdot 67$ milliamperes in the glass. The effective area of the central portion was 404^{cm^2},‡ and using the above values of the thickness and the frequency, k comes out $8 \cdot 4$, in electrostatic units, and $r = \cdot 16$. By formula (2) the e.m.f. applied to the air $= 15900$ and correcting as described above for the displacement current, the ionization current in the air $4 \cdot 15$ milliamperes.

Observations.—Glass = Plate glass, $70^{cm} \times 80^{cm}$, $\cdot 59^{cm}$ thick.
May 1. Sultry. Bar. $= 74 \cdot 3$, Temp. $= 20°$.

Electrodes of tin foil pasted on glass, areas and guard ring same as for copper electrodes described above.

E.m.f. in volts, current in milliamperes.

E.m.f.	30700	28500	26500	24200	22200	20000	18000
Current.	6·20	5·70	5·30	4·90	4·45	3·97	3·50
E.m.f.	12200	10000	7000	5000	15300		
Current.	3·00	2·45	1·90	1·38	1·00		

July 5. Dry. Bar. $= 75 \cdot 2$, Temp. $= 22° \cdot 5$.
Tinned copper electrodes as described above. Thickness of air $= \cdot 43$.

E.m.f.	37000	34700	32000	29300	26500	24300	21500
Current.	6·60	6·00	5·40	4·67	4·20	3·45	2·90
E.m.f.	19000	17500	16000	14000	13000	11300	40200
Current.	2·30	2·20	1·73	1·08	·77	·48	7·40

* Total thickness of air on both sides of glass. The current was not appreciably affected if the glass was not exactly midway between the electrodes.
† Effective, throughout.
‡ Maxwell, Elect. and Mag., § 228.

Conditions identical except air thickness = 1·31.

E.m.f.	36500	39300	34200	31700	29300	27000	24600
Current.	6·20	6·60	5·70	5·00	3·80	2·64	1·48

E m.f.	22200	23000	37800	39300
Current.	·54	·71	6·50	6·90

July 6. Dry. Bar. = 75·9, Temp. = 20°. Air thickness = ·20^{cm}

E.m.f.	40200	38000	36200	34200	31800	29000	26300
Current.	7·80	7·30	6·70	6·30	5·60	5·00	4·35

E.m.f.	42300	39500	37500	41500	23200	21500	19300
Current.	8·20	7·60	7·00	7·90	3·70	3·30	2·75

E.m.f.	15300	12500	10500	13800	17000	8500	39500
Current.	1·88	1·26	·95	1·61	2·30	·60	7·40

Identical conditions except air thickness = 2·41.

E.m.f.	40700	40000	38200	39000	36800	35200	35700
Current.	6·90	7·00	5·70	6·40	5·00	2·75	3·55

E.m.f.	37000	38500	40500	40000	32800	31300
Current.	5·00	5·80	6·60	6·50	1·44	·48

These results are plotted in fig. 3 and full lines are drawn through the observations. The dotted curves show the relation between the e.m.f. applied to the air and the ionization current and are calculated, as described above, from the full curves.

As a check upon these observations, similar experiments were made with a different glass.

Glass = Window glass 70^{cm} × 90^{cm}, average thickness = ·24.
July 7. Dry. Bar. = 75·5, Temp. = 17°.
Tinfoil electrodes, pasted on glass, similar to those used with plate glass.

E.m.f.	26000	24000	22300	21200	19700	18400	15700
Current.	10·10	9·40	8 80	8·20	7·70	7·00	6·20

E.m.f.	13700	11300	9500	6300	5000	4300
Current.	5·40	4·40	3 65	2·57	1·95	2·63

$$k = 6·7.$$

July 9. Damp. Bar. 75·3, Temp. = 21°.
Tinned copper electrodes described above. Thickness of air = 1·66.

E.m.f.	32000	31000	29300	27500	26500	25500
Current.	10·00	8·50	6·90	5·70	3·95	2·55

E.m.f.	24800	23500	31700
Current.	9·50	4·40	9·40

Conditions identical except air thickness = ·30.

E.m.f.	32700	30500	29000	27000	24300	22300	19700
Current.	11·5	10·10	9·30	8·40	7·00	6·10	5·20

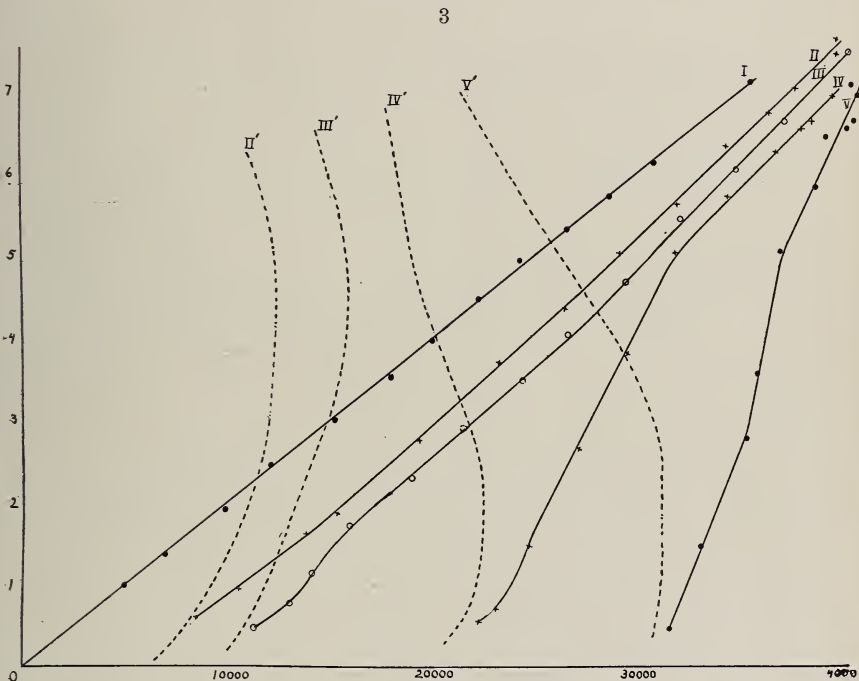| E.m.f.	48000	15300	12500	10500	8500
Current.	4·07	3·10	1·96	1·19	·63

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FIG. 3. Abscissæ = volts. Ordinates = milliamperes. I, Electrodes against ·59cm of plate glass. II, 59cm of glass + ·20cm of air. III, ·59cm of glass + ·43cm of air. IV, ·59cm of glass + 1·31cm of air. V, ·59cm of glass + 2·41cm of air. II′, III′, IV′, and V′ are corrected curves of II, III, IV, and V respectively and give the relation between the e.m.f. applied to the air and the ionization current.

These observations are plotted in fig. 4. The corrected curves fit in well with the curves of fig. 3 for the different distances.

The lower portions of the corrected curves show the well known rapid increase of current with slight increase of potential, while in the upper portions two facts are conspicuous, first, that, *as the ionization current in the air increases the electromotive force necessary to maintain the current decreases*, and, second, that, *as the current increases, the curves for the dif-*

ferent distances approach each other. The latter result may be explained by the compensation of the reduction in electric force when the electrodes are separated, by the increased volume in which ionization occurs. The first result shows that when the current is increased beyond the values repre-
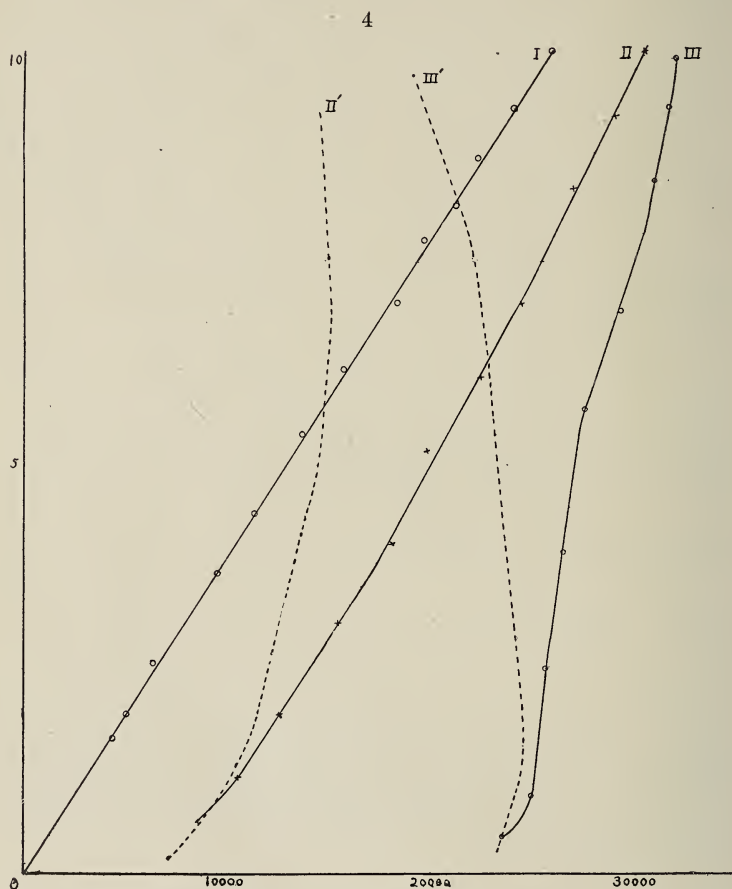

Fig. 4. Abscissæ = volts.   Ordinates = milliamperes.   I, Electrodes against ·24cm of window glass.   II, ·24cm of glass + ·30cm of air.   III, 24cm of glass and 1·66cm of air.   II′ and III′ are corrected curves of II and III respectively and give the relation between the e.m.f. applied to the air and the ionization current.

ented by the familiar lower portions of the curves, the air *under normal conditions* exhibits so called "*negative resistance*," which has hitherto been demonstrated only under the

special conditions of high temperature (the arc discharge[*]), and low pressure.[†]

The following empirical formula agrees approximately with the upper portion of the corrected curves (i. e., where the current density exceeds 15 microamperes per square centimeter):

$$i = 50 - V \frac{\cdot 018}{\sqrt[3]{d}} \tag{4}$$

where i is the current per square centimeter in microamperes and V is the electromotive force applied to the thickness, d, of air.

The effective values of the potentials at which appreciable ionization commences and the maximum electric intensity at the different distances are as follows:

Air thickness	---	·20	·43	1·31	2·41	·30	1·66
Ionization potential	---	6000	9000	19000	30000	6000	22000
Ionization intensity (max.)	---	423000	29600	21200	17000	28200	18400

The latter is given approximately by the formula:

$$F_{\max} = 22,500 \frac{1}{\sqrt[3]{d}} \tag{5}$$

The decrease in requisite intensity for ionization with increase in distance is probably due to partial ionization.[‡]

In fig. 5 are plotted the *power factor* and *power absorbed* for the different distances. [From fig. 2 it is readily seen that the power factor is the sine of the angle between A, the applied e.m.f., and B, which is a quarter period in advance of the total current: $= \dfrac{E\,C}{A\,B}$; and the power absorbed is the product of the current, the potential applied to the electrodes, and the power factor.]

The current heats the glass but little and therefore before appreciable ionization begins the current and e.m.f. differ in phase by nearly a quarter period and the power factor is low. When ionization commences this part of the current in the air is in phase with the e.m.f. and hence the power factor increases. As the ionization current increases, however, the fraction of the total e.m.f. which is applied to the glass must greatly increase, and since in the glass, e.m.f. and current differ in phase by a quarter period, the power factor reaches a maximum and then decreases with increasing current.

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[*] Thomson, Conduction of Elec. through Gases, § 214.

[†] Winkelmann, IV, 2d ed., p. 519; Townshend, Phil. Mag., March, 1905, p. 289; Toepler. Ann. der Phys., xiv, p. 757, 1905.

[‡] Thomson, Conduction of Elec. through Gases, § 197.

The curves for the power absorbed show that the power absorbed does not increase proportionally with increasing distance or current and is independent of the thickness of the glass.
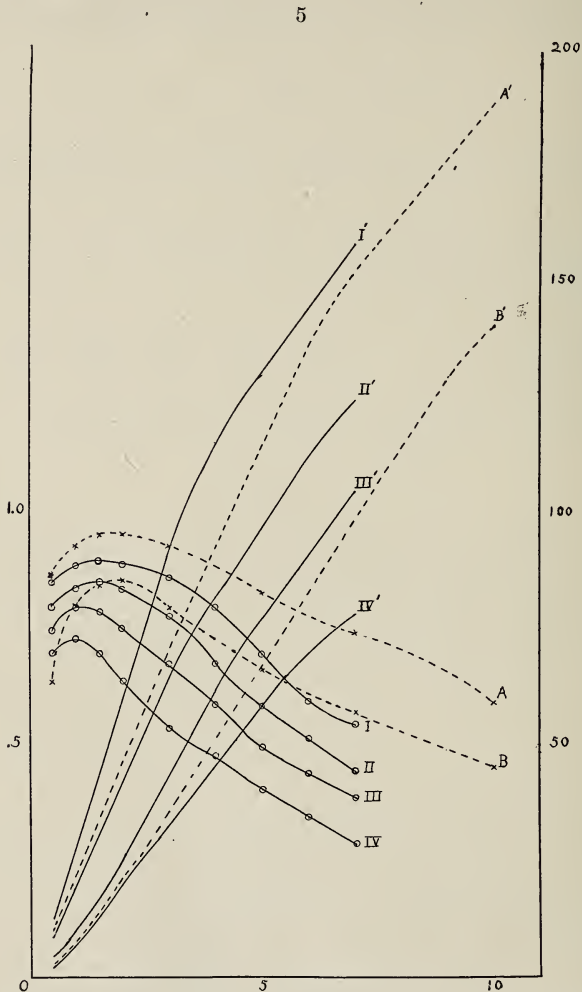

FIG. 5.   Power factor and power absorbed in a Siemens ozonizer. Abscissæ = ionization current in milliamperes.   Ordinates : left = power factor ; right = watts.   Effective area of discharge = 404$^{cm^2}$.   Temp. = (approx.) 20°. I, II, III and IV give the power factors for ·59^{cm} of plate glass + ·20^{cm}, 43^{cm}, 1·31^{cm}, and 2·41^{cm} of air, respectively ; A and B for ·24^{cm} of window glass + ·30^{cm} and 1·66^{cm} of air, respectively.   I', II', III', IV', A', and B' are the corresponding curves for the power absorbed.

The complete electrical characteristics of any type of *Siemens ozonizer* may be approximately calculated from the relations given above, if the dimensions, and the dielectric constant of the dielectric for the particular frequency employed, are known. The minimum potential is obtained from equation (5). *B*, fig. 2, may be calculated from equation (3), adding *k* to the numerator, and *C* from equations (1) and (2) and then the ionization current per square centimeter, when large, is given by equation (4), on substituting for *V*
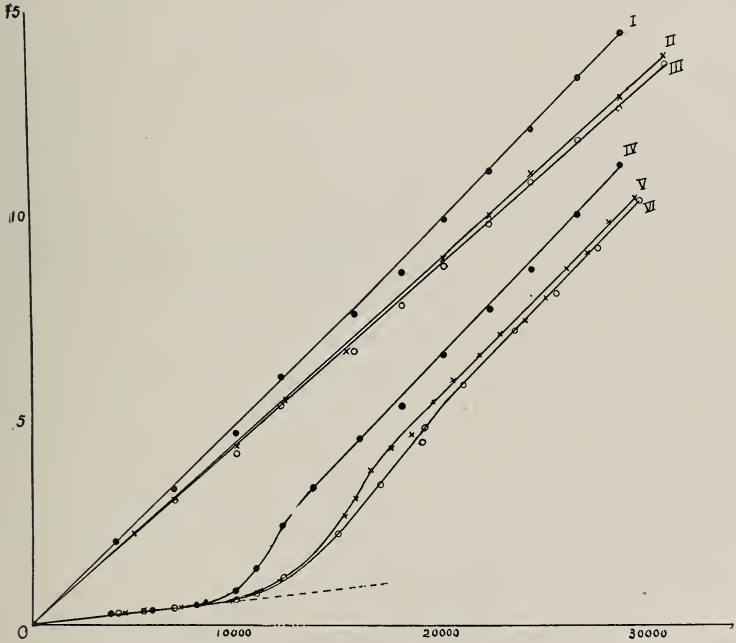

FIG. 6. Influence of Temperature. Abscissæ = volts. Ordinates = milliamperes. I, II, III, Electrodes against ·59^{cm} of plate glass. IV, V, VI, ·59^{cm} of glass + ·43^{cm} of air. Temperatures. I, 63°; II, 20°; III, 7°; IV, 54°; V, 18°; VI, 5°. (These observations are uncorrected; see text.)

the value found for *C*, and the power factor may then be calculated.

The ratio of current to electric intensity is greatest in curve *V*[1] of fig. 3, where 7 milliamperes are maintained by an electric intensity, *F*, of $\dfrac{21,000}{2\cdot41}$. Substituting in the equation

$$i = n\,e\,v\,F$$

10^{-19} for e; 1.55 for v, which is Chattock's value for the mean velocity of the ions in the point discharge at atmospheric pressure, under unit intensity;[*] and $\frac{7}{404}.10^{-3}$ for i, the current per square centimeter; n, the number of ions per cubic centimeter comes out $1.3 \cdot 10^{10}$. Taking the number of molecules per cubic centimeter as $2.4 \cdot 10^{19}$, the proportional ionization of the molecules is $2.7 \cdot 10^{-10}$.[†]

The effect of temperature and the displacement current before ionization begins are illustrated in fig. 6. Both electrodes were $30^{cm} \times 30^{cm}$. No guard ring was used because the insulated guard ring made it difficult to maintain a uniform temperature different from that of the room, and the area of the inner portion was too small to enable the displacement current to be measured with the apparatus at my disposal. The curves are therefore uncorrected. The temperature within this range has evidently little influence except upon the dielectric constant. The dotted line gives the calculated displacement current (equation (3)).

An alternating e.m.f. has been employed throughout for reasons explained at the beginning. The character of the e.m.f. could not, however, qualitatively affect the main results, and therefore, *for air at ordinary temperature and pressure, as the current carried through the air by ions increases, the required electromotive force slowly increases to a maximum and then decreases, and tends to become independent of the thickness of air.* Moreover, for alternating electromotive forces of approximately sine form, quantitative results have been obtained which make possible the calculation of Siemens ozonizers.

I wish to express my thanks to Prof. Harold B. Smith for the use of the high potential apparatus of the Department of Electrical Engineering.

[*] Thomson, Conductivity of Elec. through Gases, p. 56.
[†] Compare the data given in Winkelmann, vol. IV, 2d ed., p. 561.

Art. XXXV.—*The Hydrolysis of Salts of Ammonium in the Presence of Iodides and Iodates ;* by Seth E. Moody.

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

Bruck[*] has shown that when salts of ammonium are subjected to heat they are hydrolyzed and that as the acid is increased, either as a direct product of this hydrolysis, or by addition, further dissociation is inhibited. The decrease in dissociation is dependent upon the increase of the acid, and when sufficient acid is present, further hydrolysis is entirely prevented. The amount of hydrolysis is, however, small under the most favorable conditions.

It is interesting to discover how rapidly hydrolysis will proceed if the free acid is constantly removed by the presence of a mixture of potassium iodide and potassium iodate, and with this end in view a solution of ammonium sulphate, containing 5 grms. to a liter, was prepared with which to carry out subsequent experiments. The value of the solution was determined by precipitating barium sulphate, and by calculation its equivalent in iodine according to the equation

$$3H_2SO_4 + 5KI + KIO_3 = 3K_2SO_4 + 3H_2O + 6I$$
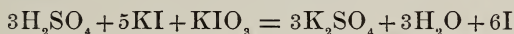
was found to be 0·4773 grm. of iodine to 25^{cm^3} of the ammonium sulphate, upon the supposition that all the sulphate of ammonia can be broken up and that the full amount of sulphuric acid may be made available for reaction with the iodide-iodate mixture.

To the solution of ammonium sulphate were added potassium iodide and potassium iodate and the mixture was allowed to stand. At the ordinary temperature of the room little effect was noticed, as shown by the following results :

Table I.

$(NH_4)_2SO_4$. cm^3.	KI. grm.	KIO_3. cm^3.	Time in hours.	Approx. N/10 $Na_2S_2O_3$. cm^3.	I. grm.
25	1·0	20	3	0·25	0·0031
25	1·0	20	3	0·25	0·0031
25	1·0	10	19	0·35	0·0044
25	1·0	10	19	0·35	0·0044

In another series of experiments in which the solution of ammonium sulphate was boiled for three hours in an Erlenmeyer beaker before adding the iodide-iodate mixture, results were obtained which vary with the vigor of the boiling, but which show that small amounts of ammonia are volatilized, as

[*] Dissertation, Giessen, 1903.

shown by the subsequent slight liberation of iodine upon the
addition of the iodide-iodate mixture to react with the sulphuric
acid left behind. Yet the amount of hydrolysis which takes
place when the ammonium sulphate is boiled with water is
greater than when the ammonium sulphate and the iodide-
iodate mixture are allowed to stand at the ordinary room tem-
perature.

The following table shows the results of these experiments:

Table II.

$(NH_4)_2SO_4$. cm³.	Time in hours.	KI. grm.	KIO_3. cm³.	Approx. N/10 $Na_2S_2O_3$. cm³.	I. grm.
25	3	1·0	10	1·25	0·0156
25	3	1·0	10	1·55	0·0193
25	3	1·0	10	1·30	0·0162
25	3	1·0	10	1·47	0·0183

If the acid produced is eliminated as fast as it is formed, the
hydrolysis of the salt should proceed more rapidly. The
action of the iodide-iodate mixture, which reacts with the sul-
phuric acid to form potassium sulphate and iodine, should
bring this about; and the iodine may be removed by boiling,
in the presence of a current of hydrogen, and collected for
estimation. In experiments made under these conditions it
was found, curiously enough, to be impossible to collect the
iodine in the Drexel flask used as a receiver when charged
with potassium iodide only, although it was evident that much
iodine came over. It appeared, upon investigation, that ammo-
nium iodide and ammonium iodate were formed by reaction in
the receiver between the liberated iodine and the ammonia
also volatilized, and to obviate the difficulty sulphuric acid was
added to the contents of the receiver into which the distillate
was passed. Under these conditions iodine is obtained in
amount corresponding to that which should be eliminated
when the ammonium sulphate is entirely hydrolyzed.

This is shown in the subjoined table:

Table III.

$(NH_4)_2SO_4$. cm³.	KI. grm.	KIO_3. cm³.	Time in hours.	H_2SO_4 (1:1) in the receiver. cm³.	Approx. N/10 $Na_2S_2O_3$. cm³.	I. grm.	Diff. grm.
25	1·0	10	3	40	38·25	0·4769	− 0·0004
25	1·0	10	3	40	38·25	0·4769	− 0·0004
25	1·0	10	3	40	38·30	0·4775	+ 0·0002
25	1·0	10	3	40	38·25	0·4769	− 0·0004
25	1·0	10	3	40	38·23	0·4766	− 0·0007

In another series of experiments, the apparatus was changed, so that the distillate passed from the first Voit flask, V^1, through a second Voit flask, V^2, containing an excess of standard acid to take up the ammonia and then into the receiver containing potassium iodide without acid.

Table IV gives results of experiments thus modified.

TABLE IV.

Ammonium sulphate. cm³.	KI. grm.	KIO₃. cm³.	Approx. N/10. H₂SO₄. cm³.	Time in hours.	Iodine equivalent of ammonia absorbed in Voit flask.			Iodine estimated in Drexel flask.		
					Approx. N/10 Na₂S₂O₃. cm³.	I. grm.	Diff. grm.	Approx. N/10 Na₂S₂O₃. cm³.	I. grm.	Diff. grm.
25	1·0	20	50	3	38·15	0·4757	−0·0016	38·23	0·4767	−0·0006
25	1·0	20	50	3	38·20	0·4763	−0·0010	38·25	0·4769	−0·0004
25	1·0	20	50	3½	38·15	0·4757	−0·0016	38·20	0·4763	−0·0010
25	1·0	20	50	3	38·20	0·4763	−0·0010	38·27	0·4771	−0·0002
25	1·0	20	50	3½	38·17	0·4759	−0·0014	38·20	0·4763	−0·0010
25	1·0	20	50	3½	38·15	0·4757	−0·0016	38·20	0·4763	−0·0010
25	1·0	20	50	3	38·20	0·4763	−0·0010	38·25	0·4769	−0·0004

These experiments show that the sulphuric acid neutralized in the Voit flask is a measure of the ammonia while the iodine in the Drexel flask corresponds to the sulphuric acid of the ammonium sulphate.

Similar results were obtained with ammonium chloride. The e x a c t value of a solution of 5 grms. of this salt made up to 500^{cm3} was obtained by precipitating and weighing the silver chloride produced by silver nitrate, 25^{cm3} of the solution containing of the salt the equivalent of 0·5922 grm. of iodine.

Portions of this solution were measured from a burette into a flask, to which was added, in each experiment, the iodide-iodate mixture and in the presence of a current of hydrogen boiled until no further color, due to iodine, remained. The distillate was passed through a trap of standard sulphuric acid, to absorb the ammonia, into the Drexel flask charged with an aqueous solution of potassium iodide to dissolve the iodine, which became known upon titration with standard sodium thiosulphate. The difference in amount of iodine which equivalent volumes of the sulphuric acid used in the trap liberated from
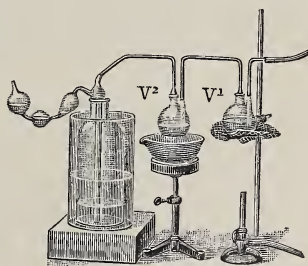
the iodide-iodate mixture before and after the passage of the distillate indicates the amount of ammonia volatilized in the boiling.

A table showing results of such experiments follows :

TABLE V.

Ammo-nium chloride. cm³.	KI. grm.	KIO₃. cm³.	Approx. N/10. H₂SO₄. cm³.	Time in hours.	Iodine equivalent of ammonia absorbed in Voit flask.			Iodine estimated in Drexel flask.		
					Approx. N/10 Na₂S₂O₃. cm³.	I. grm.	Diff. grm.	Approx. N/10 Na₂S₂O₃. cm³.	I. grm.	Diff. grm.
25	1·0	20	50	$2\frac{3}{4}$	47·47	0·5918	—0·0004	47·45	0·5916	—0·0006
25	1·0	20	50	$2\frac{3}{4}$	47·40	0·5909	—0·0013	47·44	0·5915	—0·0007
25	1·0	20	50	$2\frac{1}{2}$	47·50	0·5922	±0·0000	47·48	0·5920	—0·0002
25	1·0	20	50	$2\frac{1}{2}$	47·45	0·5916	—0·0006	47·47	0·5918	—0·0004
25	1·0	20	50	$2\frac{1}{2}$	47·47	0·5918	—0·0004	47·48	0·5920	—0·0002

It is to be noticed that the time necessary for the hydrolysis of ammonium chloride is less than that for the sulphate.

On account of the time required, this procedure cannot be considered as having claims to be called an analytical method for determining ammonia, or the acid-ion of either of these ammonium salts, except under circumstances most extraordinary. It is here presented because the hydrolysis of ammonium salts must not be ignored in work wherein such salts are heated in solution with the iodide-iodate mixture.

Art. XXXVI.—*The Estimation of Fluorine Iodometrically;* by Albert Hileman.

It is obvious that the reaction by which fluosilicic acid liberates iodine from a mixture of potassium iodide and potassium iodate may be turned to account in the analysis of fluorides as well as in the determination of fluosilicic acid provided the course of action is regular.

Upon testing the action of hydrofluosilicic acid upon the iodide-iodate mixture, it was found that, while iodine is liberated freely in the cold, a complete reaction was not obtained in the course of several hours—the amount of iodine liberated indicating that an acid other than fluosilicic acid, as a unit, was acting. It appeared, however, that on boiling the mixture nearly one equivalent of iodine is liberated for every equivalent of fluorine present as fluosilicic of hydrofluoric acid. The reaction may be written

$$5KI + KIO_3 + H_2SiF_6 = 6KF + 6I + SiO_2 - H_2O$$
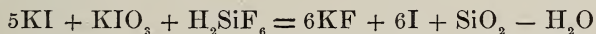
To the fluosilicic acid in a flask was added a neutral solution of potassium iodide and iodate in excess and the flask closed with a glass stopper fitted with a trap containing a solution of potassium iodide to retain volatilized iodine. The solution in the flask was heated to boiling, then cooled, and, together with the contents of the trap, titrated with a standard solution of thiosulphate.

In section A of Table I are given the results obtained with a solution of commercial fluosilicic acid. Titrations with sodium hydroxide and comparative iodometric determinations are given. In section B of Table I the results of similar experiments with fluosilicic acid made by the action of hydrofluoric acid on an excess of silica are given.

The indications by the iodometric method are lower than those of the alkalimetric method of titration by about 0·0008 grams, on the average. This fact would indicate that the iodine liberated does not quite correspond to the complete hydrolysis of fluosilicic acid indicated by the theoretical equation.

Likewise Table II shows the results obtained by applying the iodometric method to the silicon fluoride eliminated from calcium fluoride according to the method proposed in a previous paper.[*]

* This Journal, xxii, 329.

TABLE I.

H$_2$SiF$_6$	Standard NaOH$_3$	Standard Na$_2$S$_2$O$_3$	Fluorine found
		A	
	(1cm^3= 0·005137 of Fluorine)	(1cm^3= 0·002335 of Fluorine)	
cm^3.	cm.	cm^3.	Grams
25	10·82	----	0·0556
25	10·87	----	0·0559
25	10·83	----	0·0557
25	----	23·54	0·0549
25	----	23·52	0·0549
25	----	23·48	0·0548
25	----	23·50	0·0548
25	----	23·45	0·0548
25	----	23·48	0·0548
		B	
	(1cm^3= 0·005137F of Fluorine)	(1cm^3= 0·002441 of Fluorine)	
25	9·08	----	0·0466
25	9·05	----	0·0464
25	9·05	----	0·0464
25	----	18·78	0·0458
25	----	18·80	0·0459

Calcium fluoride was treated in the apparatus figured by the method described, the silicon fluoride was absorbed in water and after separating the mercury used in the apparatus by means of a separating funnel, the iodide-iodate mixture was added to the solution and the iodine liberated was titrated by sodium thiosulphate.

TABLE II.

CaF$_2$ Gram	Na$_2$S$_2$O$_3$	1(cm^3= 002335) Theory Fluorine	Found Fluorine	Error Fluorine
0·2500	51·35	0·1216	0·1199	0·0017
0·2300	46·75	0·1119	0·1091	0·0028
0·2300	47·15	0·1119	0·1100	0·0019
·NaF				
0·2000	38·50	0·0903	0·0899	0·0014

The average error of — 0·0019 grams is considerable greater than that of the alkalimetric method, 0·0008 grams. It appears, therefore, that, while the iodometric method of determining fluorine in fluorides may in special cases present some advantages, it does not equal in accuracy the alkalimetric method when it is properly conducted.

Art. XXXVII.—*Minerals of the Composition MgSiO₃; A Case of Tetramorphism;* by E. T. Allen, Fred Eugene Wright and J. K. Clement.

Part I.—Formation and Properties of the Four Crystal Forms.

The study of magnesium silicate, to which the following pages are devoted, is part of a general investigation of the pyroxene and amphibole groups, and had for its immediate object the preparation of its several crystal forms, the determination of the conditions under which these may be produced, their relative stability, and the measurement of their accessible constants. A combination of accurate data of this kind with the geologic study of the occurrence of minerals in nature constitutes the only reliable basis for the science of mineral genesis.

The materials for this synthetic work consisted of the purest quartz and magnesia which could be obtained. The quartz contained about 0·1 per cent of non-volatile impurities and the magnesia only a few hundredths of one per cent of ferric and calcium oxides. Some slight additional contamination, however, usually resulted from repeated fusion of the same material. In one of the preparations, which had been remelted many times, we found by direct analysis 0·3 per cent of ferric and aluminic oxides and practically no other impurities.

	Found.	Calculated for $MgSiO_3$.
SiO_2	59·85%	60·00%
MgO	39·77	40·00
Al_2O_3 and Fe_2O_3	·30	
	99·92	100·00

Four distinct crystal forms of magnesium metasilicate were found to exist and to be reproducible at will in the laboratory. These forms agree in their optical and other physical properties closely with the following minerals: (1) the monoclinic magnesian pyroxene* ; (2) enstatite ; (3) kupfferite† ; (4) a monoclinic amphibole corresponding to kupfferite; our products form in fact the end members of certain solution series toward which the natural minerals approach, and sometimes almost

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* Discovered by Fouqué and Lévy in certain meteorites (Bull. Soc. Min., p. 279, 1881) and by the authors in the Bishopville meteorite. We shall show later that this form differs considerably in its axial ratio $c : a$ from other pyroxenes.

† See Hintze, Mineralogie, Bd. II, p. 1196.

reach, when practically free from impurities. The conditions of formation and the properties of these four minerals will first be described; their relations to one another will then be considered in a subsequent portion of the paper.

1. *Monoclinic Pyroxene.*—This form of magnesium silicate is the product usually obtained from fusion, though small but variable quantities of enstatite and kupfferite commonly crystallize with it. Ebelmen,[*] who was the first to synthesize the monoclinic magnesium silicate, accomplished it by melting magnesia and silica with boric anhydride. The latter substance served as a flux and was evaporated later by long-continued heating at a high temperature. Hautefeuille[†] reached the same result by dissolving amorphous silica in molten magnesium chloride with partial exclusion of moisture; Stanislas Meunier[‡] effected its synthesis through the action of silicon chloride and water vapor on metallic magnesium. Hautefeuille, Daubrée and other earlier observers mistook this form for enstatite. Their work was done at a time before modern microscopic methods had been developed, and their conclusions were therefore based chiefly on chemical and morphological evidence, which misled them, as was proved later by Fouqué and Lévy[§] and by Vogt,[‖] who examined the original preparations of Ebelmen and Hautefeuille preserved in the museum of the Collège de France.

In our own experiments we have observed the formation of the monoclinic pyroxene in several different ways: (1) from a melt of the same composition; (2) by heating the glass to a temperature above 1300°; (3) by heating any of the other crystalline forms; (4) from the action of molten magnesium chloride or tellurite on amorphous silica; (5) by recrystallizing magnesium silicate from a flux of magnesium chloride, magnesium vanadate, calcium vanadate, or tellurium dioxide.

(1.) The first method, except under conditions of slow cooling, yields crystalline aggregates, usually in radial spherulites, consisting chiefly of the monoclinic form, generally intermixed with more or less enstatite and kupfferite; but if the molten silicate crystallizes at a temperature only slightly below the melting point, an operation which can readily be carried out in the electric resistance furnace, the product is homogeneous, and consists entirely of the monoclinic form. This is the best method for preparing this substance in quantity, though the crystals are not individually well developed.

(2.) The product obtained by heating the glass to 1300° or

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[*] Ann. Chim. Phys. (3), xxxiii, 58, 1851.   [†] Ibid. (4), iv, 174, 1865.
[‡] Comptes Rendus, xc, 349, 1880.
[§] Synthèse des Minéraux et des Roches, p. 107.
[‖] Mineralbildung in Schmelzmassen, p. 71. These observers also studied preparations of their own, and Vogt has described the occurrence of the same mineral in blast furnace slags.

more was similar to that from the melt, with the difference that the spherulites and their component fibers were smaller.

(3.) All other forms of magnesium silicate change to the monoclinic pyroxene by heating to temperatures from 1150° upwards, the temperature depending on the original form and the time allowed.

(4.) A repetition of Hautefeuille's work proved the correctness of his observations except as to the crystal form of his product. Magnesium chloride dissolves amorphous silica in the presence of small quantities of moisture

$$\mathrm{MgCl_2 + H_2O + SiO_2 = MgSiO_3 + 2HCl)}$$
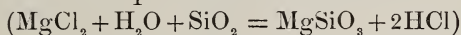
but exerts little action on quartz. Instead of the chloride one may use the tellurite, an easily fusible salt which acts as readily on the silica as the chloride, has the advantage of being less susceptible to the action of water, and the disadvantage of being readily reducible to the metal and attacking the platinum crucible in which the fusion is made. The following equation represents the reaction :

$$\mathrm{MgTeO_3 + SiO_2 = MgSiO_3 + TeO_2.}$$
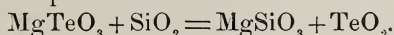
The tellurous oxide is volatilized at the temperature of the experiment (700°–800°). The crystals obtained by both magnesium chloride and magnesium tellurite were generally small and not so well developed as those crystallized by method (5).

(5.) A considerable number of fluxes were found to dissolve magnesium silicate at temperatures of 800°–1000° and to precipitate it again in crystals of the monoclinic variety, a fact which has an important bearing on the question of the relative stability of the different crystal forms. It soon became evident, moreover, that certain fundamental questions connected with the pyroxene series could only be settled by the crystallographic study of the monoclinic form, so that we made a rather extensive investigation of the conditions necessary to obtain from these fluxes crystals sufficiently well developed for measurement. Among these solvents which did not prove satisfactory, we may mention calcium chloride, sodium sulphate, sodium chloride and potassium chloride. The last two gave small yields of an unpromising crystalline product which was not fully investigated. The fusible silicates of lead, sodium and potassium* all gave glasses. In point of time, we first tried fusible magnesium salts as probably best suited to dissolve the silicate without decomposing it. Of these there are the tellurite, the vanadate and the chloride.

With Magnesium Tellurite.—As stated above, the tellurite is a readily fusible salt, and though not soluble in water, it

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* It was found later that a solution of magnesium silicate in a small quantity of sodium and potassium silicates yields good crystals of enstatite.

may be decomposed with hydrochloric acid, so that we expected to be able to remove the excess of reagent from the silicate without difficulty. The silicate and tellurite were therefore mixed in about equal quantities (about 5 grams of each) and heated in a covered platinum crucible by means of a resistance furnace to prevent reduction of the tellurite. At 1000°–1100° some monoclinic pyroxene was obtained, but the greater part of the product proved to be fosterite, formed by the decomposition of the tellurite and the volatilization of tellurous acid, which partly condensed on the cooler parts of the furnace. The equations:

$$MgTeO_3 + SiO_2 = TeO_2 + MgSiO_3.$$
$$2MgTeO_3 + SiO_2 = 2TeO_2 + Mg_2SiO_4.$$
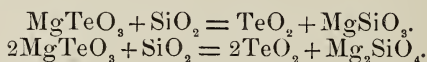
represent these reactions. The crystals obtained by this method are not well formed and it is difficult to remove the tellurium completely.

The above reaction led us to believe that magnesium silicate might perhaps crystallize from molten tellurous oxide, but, though well developed monoclinic prismatic crystals were occasionally obtained, most of the silicate was apparently decomposed by this method.

With Magnesium Vanadate.—In some earlier experiments on wollastonite carried out in this laboratory,* it was found that calcium silicate could be readily dissolved and recrystallized from molten calcium vanadate, the excess of which could be easily removed by alternate treatment with very dilute hydrochloric acid and ammonia ; we therefore expected to be more successful with magnesium vanadate than with tellurite. The conditions followed in the beginning were similar to those which had worked so well with calcium silicate, but as the first results were not satisfactory, we eventually tried various proportions of silicate and vanadate at temperatures ranging from 800° to 1050°. At the lower temperature monoclinic crystals of rather poor development were obtained, but at the higher temperature a good deal of fosterite always accompanied it, and vanadic anhyride was evidently set free, as the product was colored a dark brown. Most of the vanadate and vanadic acid can be removed by cold dilute hydrochloric acid and hot concentrated ammonia, but several per cent are generally retained by the silicate.

With Calcium Vanadate.—In spite of our apprehension of double decomposition with salts containing no common ion, we found that calcium vanadate dissolved and crystallized magnesium silicate unchanged in composition and sufficiently

* Allen, White and Wright, this Journal (4), xxi, 97, 1906.

well developed for goniometric measurement. The best
results were obtained by following the conditions just referred
to for the formation of wollastonite.*
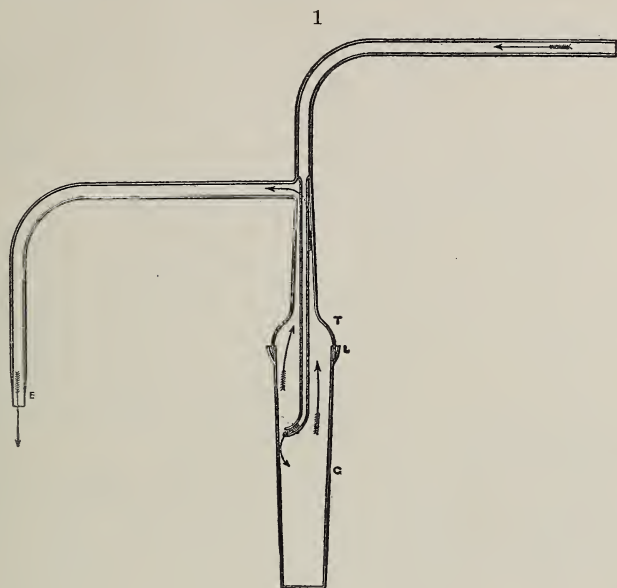
*With Magnesium Chloride in a stream of Hydrochloric
Acid Gas.*—These experiments were carried out in the plat-
inum crucible fig. 1, invented by Professor Gooch for the
determination of water in difficultly decomposable silicates.†
It consists essentially of a long crucible slightly conical in
form, with a collar around the top so constructed as to leave a
narrow groove between it and the cap which covers the cruci-
ble.   Into this groove sodium tungstate can be melted to form an
air-tight seal.   The cap is so constructed as to permit the pas-
sage of a current of gas through the crucible.

Two or three grams of magnesium silicate were first put
into the dry uncovered crucible.   A quantity of anhydrous
magnesium chloride, prepared by the decomposition of mag-
nesium-ammonium chloride‡, was heated just before the experi-
ment in a current of dry hydrochloric acid gas, cooled and
dropped immediately into the crucible.   The cover was then

* Loc. cit.
† Bull. U. S. Geol. Survey, No. 176, p. 42.
‡ It is not easy to prepare magnesium chloride in quantity free from oxide ;
the product of the decomposition of magnesium-ammonium chloride, as this
is ordinarily carried out, requires a thorough treatment with dry hydro-
chloric acid gas.

sealed on without delay and the crucible connected with a
generator furnishing a slow stream of well-dried hydrochloric
acid gas.* In our experiments the crucible was heated over a
burner to about 1000°. It was not possible to measure the
temperature inside the crucible during the progress of the
work, but in the empty crucible a bare thermoelement, touch-
ing the bottom, read 1050° just before the charge was inserted.
This was therefore the approximate temperature in the hottest
part of the crucible. In the first experiment the outlet was
left unprotected against moisture. After four days the silicate
was found to be converted entirely into fosterite.

In all the later experiments with magnesium chloride, the
outlet tube of the crucible was well guarded by a U-tube con-
taining sulphuric acid and a straight tube containing calcium
chloride to prevent the passage of moisture into the crucible.
At temperatures between 1000°–1100° (in the hottest part of
the crucible) we invariably obtained some fosterite and peri-
clase as by-products, but in the main the substance crystal-
lized as the monoclinic pyroxene. This method gives by far
the best results of any we have discovered.

Optical Constants of Fosterite.—Inasmuch as crystals which
appeared to be fosterite were often obtained in the course
of our work,—crystals which by optical tests alone it was
found difficult to distinguish from minute crystals of ensta-
tite, it seemed advisable to determine the crystallographic
constants of these from magnesium chloride. The crystals were
colorless, transparent, and about $0.2 \times 0.1 \times 0.1^{mm}$ in size, short
prismatic in habit, doubly terminated, and similar to natural
fosterite in appearance. The cleavage, perfect after 001 and
010, was obtained by actual fracture of a crystal under the

TABLE I.

| No. | Letter. | Symbol. | Miller. | Measured. | | Goldschmidt.† | |
				ϕ	ρ	ϕ	ρ
1	b	0	001	- - - -	0° 00′	- - - -	0° 00′
2	a	0∞	010	0° 00′	90 00	0° 00′	90 00
3	n	∞	110	64 26	90 00	65 01	90 00
4	d	10	101	90 00	51 37	90 00	51 32
5	k	02	021	0 00	49 44	0 00	49 39
6	e	11	111	65 51	54 19	65 01	54 15

* The platinum is often slightly attacked during the fusion. Whether
this comes from the decomposition of the chloride by oxygen :

$$MgCl_2 + O + MgSiO_3 = Mg_2SiO_4 + 2Cl \,(?)$$
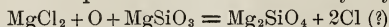
has not been worked out. When the magnesium coloride is mixed with
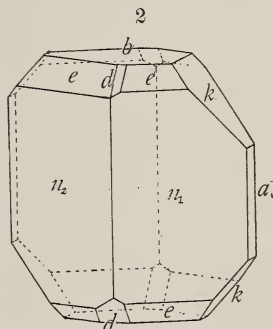sodium chloride, the platinum is very strongly attacked.
† V. Goldschmidt, Winkeltabellen, Berlin, p. 251–252, 1897.

microscope. The crystal faces were well defined, giving fair
reflection signals on the goniometer. The measurements were
made on a two-circle goniometer with reducing attachment,
and the results were found to agree fairly well with the same
constants for natural fosterite. The crystals measured were
too small to permit a very accurate measurement of the angles
(Table I).

The crystal represented in fig. 2
measured ·15^{mm} in length and 0·12^{mm}
in thickness, was transparent, colorless,
and well developed on all sides. The
development was noticeably unsym-
metrical and the quality of the dif-
ferent faces varied considerably. The
indices of refraction were determined
by Schroeder van der Kolk's method
of refractive liquids in which the pos-
sible error does not exceed ± ·003 ; $a =$
1·645 ± ·003, $\beta = 1·656$ ± ·003, $\gamma =$
1·668 ± ·003. Birefringence = 0·023
± ·006. The interference colors are
bright, usually of the first and second

2

Olivine crystal from melt
of MgSiO₃ in MgCl₂.

orders. The crystals extinguish parallel to the cleavage direc-
tions. The plane of the optic axes is perpendicular to the most
perfect cleavage lines after 010 and to the prismatic develop-
ment of the crystal and lies in the plane 001. The optic axial
angle is very large with c the acute bisectrix. The crystals
were decomposed by hydrochloric acid with the separation of
gelatinous silica. In one preparation fosterite crystals were
observed enclosing original fragments of the pyroxene which
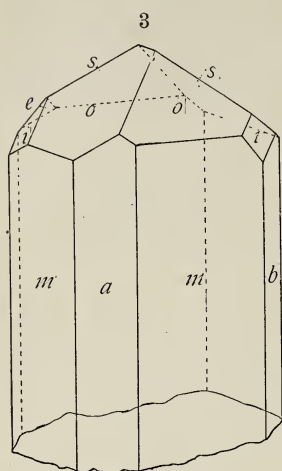had not been fully dissolved by the solvent.

In a number of experiments with magnesium chloride we also
observed the formation of periclase (MgO) in well-formed
octahedra (1^{mm} in length), isotropic and of characteristic cleav-
age and refractive index 1·73.

Properties of the Monoclinic Pyroxene.—Though crystals
of monoclinic pyroxene were obtained from many fluxes and
under different conditions, as a general rule they were ex-
tremely small and could be used only in a few favorable
instances for crystallographic measurement. Crystalline aggre-
gates of this form were also readily obtained direct from
the molten silicate and then usually as large radiating spheru-
lites, the individual fibers of which were frequently 1 to 2^{cm}
long. The crystals were measured on the two-circled goniome-
ter with reducing attachment, were colorless, transparent, of
glassy luster and varied in length from ·1 to 1^{mm}, and in width
from ·05 to ·5^{mm}. An extremely small crystal of this substance

0.1^{mm} long and 0.04^{mm} wide, from a solution in calcium vanadate, was first measured. A single fine twinning lamella after the orthopinacoid was observed under the microscope, but could not be detected on the goniometer. The reflection signals were very faint and the recorded angles fluctuated somewhat in consequence. The largest and best developed crystals (fig. 3) were produced by heating magnesium metasilicate with magnesium chloride in a stream of dry hydrochloric acid gas. Six different crystals obtained by this method were measured and the forms: c (001) (?), a (100), b (010), m (110), n (120), l (250) (?), k (310), r (210) (?), o (111), i (121), p ($\bar{1}$01), s ($\bar{1}$11), e ($\bar{1}$21), (103) (?), and ($\bar{1}$03) (?) observed. Several of these forms, c (001) (?), r (210) (?), l (250) (?), (103), ($\bar{1}$03), were noted only once, gave poor reflection signals, and are therefore uncertain. The faces in the prism zone were much better developed than the terminal forms and, although small, usually gave sharp reflection signals and concordant angles. The prismatic cleavage angle (110 : $\bar{1}$10 = 88° 08′) thus obtained has a probable error of only ± 3′. The terminal faces, on the other hand, were much smaller, less clearly defined and seriously interrupted by intergrown twinning lamellae, so that the axial ratio obtained for the vertical axis is of a lower order of certitude.

In order to show graphically the variations in the angles observed in the different crystals, a gnomonic projection of the results from the six crystals measured is presented in figure 4. The irregularity in the position of many of the projection points is due in large measure to the indistinct reflection signals obtained. Transitional faces were observed in several zones and have been indicated in the figure by the shaded portions of the zone lines. They furnish an excellent criterion for the primary zones and nodes which dominate the development of the forms bounding the crystal.

On comparing these crystallographic measurements with the angles given for enstatite and diopside, it was found that the prism angles, and therefore the axial ratio $a : b$ for the three minerals, were very similar, while the angles for the terminal faces differ so noticeably that they cannot be ascribed to experimental error alone. The axial ratio $a : b : c$ for
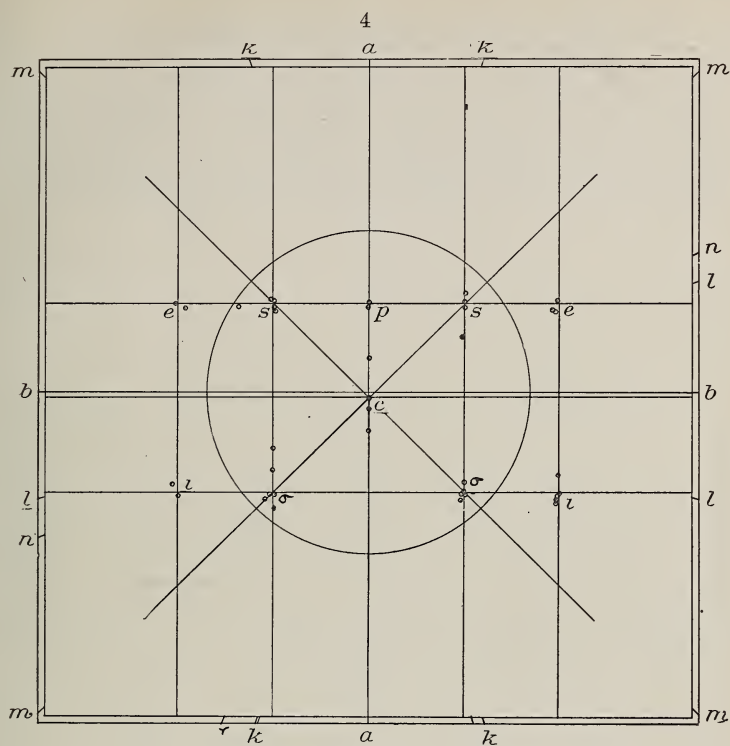

3

Mg-pyroxene.

TABLE II.*

No.	Letter.	Symbol.	Miller.	ϕ	ρ
1	c (?)	0	001	———	2° 00′
2	a	$\infty\,0$	100	90 00	90 00
3	b	$0\,\infty$	010	0 00	"
4	m	∞	110	44 04	"
5	n	$\infty\,2$	120	23 07	"
6	l (?)	$\infty\,\frac{5}{2}$	250	17 56	"
7	k (?)	$3\,\infty$	310	70 44	"
8	r	$2\,\infty$	210	66 54	"
9	o	1	111	43 29	39 58
10	i	12	121	24 58	52 11
11	p	$\bar{1}0$	$\bar{1}01$	$\bar{9}0$ 00	29 09
12	s	$\bar{1}1$	$\bar{1}11$	$\bar{4}6$ 52	40 21
13	e	$\bar{1}2$	$\bar{1}21$	$\bar{2}8$ 30	53 10
14	(?)	$\frac{1}{3}0$	103	90 00	11 55
15	(?)	$\frac{1}{3}0$	$\bar{1}03$	90 00	12 55

* The angles given in this table are the weighted averages of the angles measured.

$$\text{Mg-Pyroxene} = 1\cdot033 \quad : 1 : 0\cdot77 \quad \pm\cdot01$$
$$\text{Enstatite} \quad = 1\cdot0308 : 1 : 0\cdot5885$$
$$\text{Diopside} \quad = 1\cdot0934 : 1 : 0\cdot5894$$

These relations appear even more clearly in a gnomonic projection of the most prominent forms of the three minerals (fig. 5). The character of the projection of the principal forms of the Mg-pyroxene, although distinctly monoclinic in aspect,

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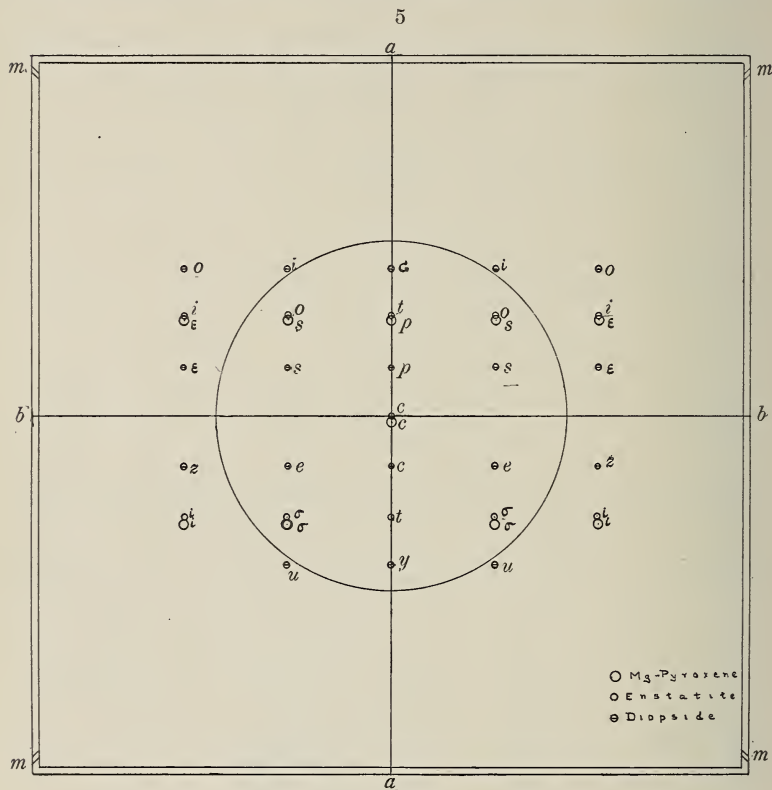
is closely related to that of the enstatite projection, and only vaguely to that of diopside. It is clear from the figure that the principal zones for diopside do not coincide with those of the Mg-pyroxene, but are located in an intermediate position. Though the symbols of the latter might be expressed very roughly in terms of diopside by choosing for the basal pinacoid of the Mg-pyroxene the possible form (102) in place of the present basal plane, thus complicating the entire set of symbols, the differences in distances between corresponding forms are even then too great to justify this change, and cast, there-

fore, grave doubt on a possible isomorphic relation between the two substances, especially when the different zonal development of the two is also taken into consideration. The investigation of this important question is still in progress.

Polysynthetic twinning after the orthopinacoid occurs almost invariably and is apparently as characteristic of this particular pyroxene as twinning according to the albite law is characteristic of the plagioclase feldspars : between crossed nicols the sections frequently bear a striking resemblance to those of plagioclase.

A peculiar type of these monoclinic crystals was observed in several of the preparations ; they were developed in flat tabular form after the orthopinacoid, and in consequence of this lay invariably on this face when immersed in one of the refractive liquids. Thus the extinction was of course always parallel and might have led to erroneous conclusions in regard to the crystal system and confusion with enstatite, if special pains had not been taken to test their behavior in other positions. The crystals were accordingly imbedded in thickened Canada balsam, in which medium they could be slowly turned by moving the cover glass. The thin upturned edges then showed the polysynthetic twinning after 100, and the extinction angles characteristic of this form. In the examination of later preparations, a device for turning the crystals in any direction and in liquids of equal refractive index was constructed and proved satisfactory. The immersion method in Canada balsam, however, is less complex and usually answers equally well.

The hardness of the monoclinic pyroxene is about 6 ; the crystals are only slightly attacked by acids.

The refractive indices were determined by the immersion method of Schroeder van der Kolk :

$$\alpha = 1\cdot647 \pm \cdot003, \ \beta = 1\cdot652 \pm \cdot003, \ \gamma = 1\cdot658 \pm \cdot003 \ ;$$

the birefringence is not strong—about ·01. The extinction angle on the clinopinacoid—remarkably low for a pyroxene—was carefully measured on well-developed crystals obtained from a fusion of the metasilicate in magnesium chloride. These crystals were twinned polysynthetically and the extinction angle was obtained, as in the feldspars, by using the symmetrical extinction angles of adjacent lamellae. An average of 25 readings gave $c:\mathfrak{c} = 21°\cdot8$ (with extreme values of $19°\cdot5$ and $24°\cdot5$). Measurements in sodium light were also made with practically the same result. The dispersion of the bisectrices was found to be very slight. The plane of the optic axes lies in the clinopinacoid ; the optical axial angle is very large. The optical character is positive and was ascer-

tained by observing in convergent polarized light on a section after 010 the direction in which the dark hyperbolae of the interference figure emerge from the field on revolving the stage, this direction being that of the acute bisectrix.* The result was, furthermore, confirmed on a section normal to an optic axis. An attempt was made to measure the optic axial angle on such a section by the graphic method recently described by F. Becke,† but the fine intercalated twinning lamellae affected the sharpness of the figure to such an extent that valid numerical results were out of the question. The black axial bar of the figure, however, is only slightly curved in the diagonal position and indicates a large axial angle.

The disturbing influence of the twinning lamellae was furthermore felt in some unsuccessful attempts to etch the prism faces with hydrochloric acid. The fine lamellae apparently destroyed the continuity of any larger etch figures which might otherwise have formed.

The specific gravity at 25° was determined on preparations from the melt by the method of Day and Allen :‡

Specific gravity of the Monoclinic Pyroxene, H_2O at 25° = 1.

Preparation I.	Preparation II.
3·191	3·194
3·192	3·191
Average,	3·192

Melting Point of Magnesium Metasilicate.—The melting point was determined by the Frankenheim method, using a control element, as described by Allen, White and Wright.§

The results are contained in Table III.

TABLE III.

Element E.	Element K.	
1521·3°	1521·3°	Both elements in same porcelain tube
1519·7	1522·2	Both elements in same porcelain tube
	1521·	
Mean,	1521°.	

After every experiment, elements E and K were compared with the standard element, H, which was protected from contamination and deterioration due to absorption of iridium vapor, by a tube of pure platinum. The heating coils of the furnace, which we have used heretofore, have been wound with platinum wire containing 10 per cent of iridium. It has been found that at temperatures of 1200° or more, the iridium

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* Wright, F. E., this Journal (4), xvii, p. 385, 1904.
† Becke. F., Tscherm. Min. petr. Mitth., xxiv, 32–49, 1905.
‡ This Journal (4), xix, 93, 1905.   § Loc. cit.

volatilizes and is absorbed by the thermoelements.* This contamination produces a drop in the electromotive force of the element which with continuous usage may result in a large aggregate error. An unglazed porcelain tube is quite permeable to the vapor. For exact measurements above $1000°$, therefore, the thermoelement must be protected by an enclosing tube of pure platinum in the hot portion of the furnace, whenever a furnace coil containing iridium is used.

The maximum difference of any two determinations is $2.5°$. The absolute value of the melting temperature is based on extrapolation from the copper melting point.

II. *Orthorhombic Pyroxene. Enstatite.*—So far as our knowledge goes, pure enstatite, free from other polymorphic forms, has never been prepared. Ebelmen and Hautefeuille obtained some true enstatite which was afterwards proved to be mixed with the monoclinic variety. The crystals of Meunier,† who believed that he had synthetized enstatite, were shown by Fouqué and Lévy to be monoclinic. Daubrée's product,‡ which was obtained by melting portions of meteorites, was, according to his own statement, too opaque for optical examination, so that he could not say whether his crystals were orthorhombic or monoclinic.

The same experimenter also melted olivine with 15 per cent silica, and obtained a crystalline cake, the interior of which consisted of a fibrous mass which was unattacked by acids, and "which had the properties of enstatite."§ Not only is no proof of the orthorhombic nature of these fibers offered, but we know from our own experiments that Daubrée's conditions must have yielded a product which consisted in the main of the monoclinic form. Fouqué and Lévy, in the effort to reproduce meteorites by artificial means, succeeded in crystallizing enstatite intermixed with a small amount of monoclinic pyroxene in the following way: 12 grams silica, 3 grams magnesia, and 5 to 5.5 grams ferric oxide, were melted and rapidly cooled. The cake showed arborescent crystals which by prolonged reheating at a temperature a little above the melting point of copper, developed into larger needles showing parallel extinction.

As previously stated, we also obtained enstatite in small but variable quantities from melts of magnesium silicate, except when it was slowly cooled. The crystals of enstatite thus formed were intercalated between the fibers of monoclinic pyroxene and could only be distinguished from the latter

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* W. P. White, "The Constancy of Platinum Thermoelements and Other Thermoelement Problems," Phys. Rev., vol. xxii, p. 372, 1906.

† Synthèse des Minéraux et des Roches, pp. 109, 111.

‡ Compt. Rendus, lxii, 202, 1866.   § Ibid., lxii, 374, 1866.

by the aid of the microscope. The two forms resemble each other so closely in habit and optical properties that one must rely chiefly on the extinction angle to distinguish between them. In the prism zone enstatite shows parallel extinction on all planes, while the monoclinic variety extinguishes parallel only on the orthopinacoid. Inasmuch as crystals of the latter frequently show pronounced development after the orthopinacoid, their monoclinic nature can only be recognized by immersing the crystals in a viscous liquid such as Canada balsam and rolling them, log-like, and observing the extinction in the different positions.

We have succeeded in preparing enstatite which contains only slight traces of impurities by a method similar to that used in this laboratory for the preparation of pure wollastonite,[*] and which, as may be noted, bears considerable resemblance to the method of Fouqué and Lévy. It consists simply in crystallizing a glass of the same composition by heating it to a temperature below 1100°. The practical details of preparing this glass, however, involve considerable difficulty owing to the readiness and rapidity with which crystallization proceeds in this silicate. Not more than 10 grams of it should be used for a single charge, the temperature of the platinum containing vessel should be raised well above the melting point of the silicate, and the fusion should be instantly chilled by plunging it into cold water. Care should also be taken that the temperature is sufficiently high to melt the silicate (m. p. 1521°) and yet not high enough to melt the platinum crucible (1720°). In our earlier experiments, crucibles were ruined so frequently by partial melting that we were compelled to make some rough temperature measurements by inserting a thermoelement under the hood of the Fletcher furnace. Though the temperatures thus observed were not those of the crucible, they indicated the latter approximately, and when the readings ranged from 1500° to 1550°, the results were fairly satisfactory.

Even under these conditions, the most favorable we have found, the glass is rarely obtained entirely free from crystalline material. After the glass had been mechanically separated from the latter, small samples were crystallized at various known temperatures and the products examined microscopically.

To insure the crystallization of a glass as nearly as possible at a given temperature, the following method was used. An empty platinum crucible was placed in an electric resistance furnace, through the cover of which passed a thermoelement, reaching nearly to the bottom of the crucible, together with

* This Journal (4), xxi, 89, 1906.

an unglazed porcelain tube of about 1^{cm} inside diameter, the lower end of which was directly over the uncovered platinum crucible. The upper end of this tube was covered by a porcelain lid. (An arrangement similar to fig. 10.) The temperature of the furnace having been raised to the desired temperature, the glass, in small fragments, is then dropped through the porcelain tube into the crucible. Only small fragments can be used, for the initial temperature of the crucible is materially lowered by the introduction of any considerable mass of the cold substance, after which the heat of crystallization of a large mass of the glass will raise the temperature of the portion last to crystallize above that of the furnace. At 1150°–1200°, when small particles, each of a few milligrams weight, were used, no perceptible change in the temperature of the crucible was noted. Under such conditions about 20 seconds elapsed, and we estimated that the temperature of the crucible was reached, before crystallization began. The temperature of the glass particles, however, does no doubt rise above the temperature of the crucible, for they become more luminous during the process. It is interesting to watch the crystallization; it begins at the surface and proceeds inward with rise in temperature, which is especially noticeable when the particles are large; the outer portion contracts and squeezes out the still liquid interior in the form of hollow, rounded projections, which crystallize last, and at a higher temperature, for they are always of coarser grain. These grains bear a strong resemblance to a kernel of ordinary popped corn.

Table IV contains the results of the experiments on the crystallization of magnesium silicate glass at different temperatures by the process above described.

<div align="center">

Table IV.

Crystallization of Magnesium Silicate Glass.

</div>

750°	No crystallization in 45 minutes.
900	Too fine-grained for identification.
990	" " " " "
1075	Nearly all enstatite ; presence of monoclinic form doubtful.
1125	Enstatite, with some monoclinic form.
1175	Enstatite and monoclinic form.
1225	" " " "
1275	" " " "
1300	Monoclinic form and probably some enstatite.
1325	" " " " " "

It is plain from these figures that below 1100° the product is enstatite; while not far above that point the monoclinic form begins to appear. To prepare a nearly homogeneous aggre-

gate of enstatite crystals in quantity, therefore, it suffices to crystallize the glass somewhat below 1100°, but not below 1000°, if the preparation requires microscopic identification, for the product then formed is cryptocrystalline. The enstatite was distinguished from the monoclinic form solely by its parallel extinction in the prism zone, the refractive indices of the two forms not differing sufficiently to permit the use of that method. By cooling mixtures of magnesium silicate with 10 per cent of its weight of albite, or the same amount of sodium and potassium silicates, enstatite may be obtained in long, well-developed prisms, the index of refraction of which indicates only a small quantity of dissolved albite or other foreign matter. Some experiments in this direction are described in detail farther on p. 433.

Properties of Chemically Pure Enstatite.—Thus far, we have obtained pure enstatite only in fibrous aggregates and radial spherulites which do not admit of a precise determination of its morphologic constants. It is a remarkable fact that the direction of elongation of the fibers in the small radial spherulites is not the prism axis, but another, such that the greater ellipsoidal axis a is parallel to it instead of c.

Cleavage after 110 is well marked; its angle approximates 90° and was observed under the microscope by tilting on end the individual fibers embedded in thick Canada balsam. The extinction is parallel in the prism zone and the least ellipsoidal axis c coincides with the prism axis.

The optical properties are similar to those of the monoclinic magnesium pyroxene, differing chiefly in the parallel instead of inclined extinction, lower average refractive index and smaller optic axial angle. The refractive indices were determined by the immersion method in liquids:

$$a = 1\cdot640 \pm \cdot004, \ \beta = 1\cdot646 \pm \cdot004, \ \gamma = 1\cdot652 \pm .004 ;$$

birefringence not strong, about ·01. The plane of optic axes contains the prism axis (c = c); optical character, positive. The optic axial angle was measured on a section nearly perpendicular to an optic axis by the graphical method recently described by F. Becke.[*] This method is based on the difference in curvature of the black hyperbola bar which passes through the optic axis, for different optic axial angles in the diagonal position. In place of the type of revolving drawing stage described by Becke, a somewhat simpler form was devised which can be clamped directly to the microscope and can be readily adjusted to suit the conditions. This method of Becke is only an approximate one and should only be used when

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[*] Becke, F., Die Messung der optischen Axen der Hyperbola-Krümmung. Tscherm. Min. petr. Mitth. xxiv, pp. 32–49, 1905.

better methods cannot be applied—a point which was realized and emphasized by Becke in the original paper. The values for the optic axial angle in air thus obtained were much lower than those given for natural enstatite, ranging between 44° and 70°,—a fact for which no explanation has yet been found. Similar low angles were also measured on the pure enstatite from the Bishopville, S. C., meteorite, which will be discussed in a later paragraph.

The specific gravity at 25° is lower than that for the monoclinic variety:

Preparation I (not entirely free from monoclinic).	Preparation II (free from monoclinic).
3·176	3·176
3·174	3·174
Average	3·175

Intergrowth of enstatite and monoclinic pyroxene.—Both from the molten silicate and from solutions of it, though only rarely from the latter, enstatite and the monoclinic form were obtained together, sometimes in parallel intergrowth. In a product of magnesium metasilicate in molten magnesium chloride and also in a preparation of amorphous silica heated with magnesium chloride, the intergrowth of the two phases was clearly marked on a section after the clinopinacoid (fig. 6). In the figure the arrows represent the positions at which the different lamellae extinguish between crossed nicols. Lamellae 1 and 3, monoclinic, are in twinning position and extinguish at an angle $c : c = 22°$; 2 extinguishes parallel and is enstatite.

Fig. 6. Intergrowths observed on (010), Enstatite—Mg-pyroxene.

On such sections the difference in refractive indices between the two forms was very slight; the birefringence of the monoclinic lamellae appeared somewhat stronger.

Parallel intergrowths of enstatite and a monoclinic pyroxene are not uncommon in nature, and although they have been frequently described, no one, apparently, has suspected that the two forms may have the same composition.

In scanning the literature on this subject, it soon became evident that natural enstatite is rarely pure magnesium silicate, but nearly always contains some ferrous silicate. The purest enstatite is probably that of the well-known Bishopville, S. C., meteorite, specimens of which are preserved in the National
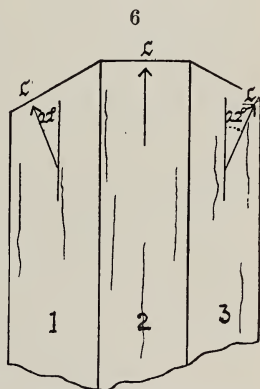
Museum. Through the kindness of Prof. C. U. Shepard, the owner of these specimens, and the courtesy of Dr. G. P. Merrill, the writers obtained ·75 gr. of this material, which, on microscopic examination, proved to contain not only enstatite but also occasional intercalated lamellae of monoclinic pyroxene identical in its optical properties with our artificial monoclinic variety. The Bishopville enstatite was analyzed by J. Lawrence Smith[*] and shown to be almost pure magnesium metasilicate. On this enstatite the following properties were determined: cleavage 110 good; $\gamma = 1·658 \pm ·003$, $\beta = 1·653 \pm ·003$, $a = 1·650 \pm ·003$ (by Schroeder van der Kolk's method of refractive liquids); $c = \mathfrak{c}$; optic axial angle 2-V $= 31°$, average of six determinations on different sections nearly normal to an optic axis by the graphical method of Becke; optical character, positive. The refractive indices of the interbanded monoclinic lamellae were very close to those of the enstatite and extinguished at an angle $c : \mathfrak{c} = 21°·6$, an average of 10 measurements on two different sections.

Dr. G. P. Merrill has called the attention of the writers to the fact that in his experience the pyroxenes of meteorites often show extinction angles much too low for augite or diopside, and are, moreover, very frequently twinned polysynthetically after the orthopinacoid. Time has not permitted an extensive microscopic examination of natural intergrowths of enstatite and monoclinic pyroxene to test the above inference, but the conclusion seems reasonable that not only those of meteorites but those of rocks also, which are not uncommon, are likewise aggregates of two polymorphs, and do not, as generally believed, contain diopside or augite.

The Transformation of Enstatite into Monoclinic Pyroxene.—When heated to high temperatures, enstatite passes over very slowly into monoclinic pyroxene, the time required depending mainly upon the temperature, as will be readily seen from the table below.

TABLE V.

Change of Enstatite into Monoclinic Pyroxene at Different Temperatures.

Time.	Temperature.	Change.
1 day	1200°	None detected.
2 days	1250	" "
22 hours	1260 −1280°	Slight if any.
3 days	1260 −1290	Probably some change.
18 hours	1335 −1350	None detected.
17 hours	1365 −1415	Evident change.
5 hours	1440 −1460	Much change.
20 minutes	1500 max.	Apparently complete.

[*] This Journal (2), xxxviii, p. 225, 1864.

The above data show that in a few days time the change is first apparent between 1260° and 1290°, and that it is here extremely slow. Comparing this table with the one on p. 399, it is clear that the glass crystallizes directly to monoclinic pyroxene about 100° lower. By the use of a solvent, the same change proceeds as low as 800° and probably even lower. Calcium vanadate, or still better, magnesium chloride, under the conditions described on p. 389, yields well-shaped crystals of the monoclinic variety at 800°.

The natural enstatite of the Bishopville meteorite showed. an identical behavior when heated to 1450°; the enstatite with its parallel extinction disappeared completely and was replaced by the twinned monoclinic lamellae, the latter still preserving the original prismatic direction of the enstatite and also apparently the cleavage, the size of grain of the two phases being about the same and the original outline of the enstatite fragments being still preserved after the paramorphic change. A specimen of enstatite from Webster County, North Carolina,* containing ferrous silicate also passed into the more stable monoclinic form when it was heated. Here magnetite was observed as a by-product.

III. *Monoclinic Amphibole.*—In several of our preparations of magnesium silicate which had been crystallized by more or less rapid cooling, small quantities of a twinned monoclinic form were observed, whose properties, with the exception of the extinction angle, were similar to those of the orthorhombic amphibole (the fourth form which is described under IV). Later, in studying the action of water on the latter substance at 375°–475°, we observed the constant recurrence of this monoclinic amphibole in larger amounts than in the original preparations; when, however, the amphibole was heated alone to considerably higher temperatures (above 900°) no such transformation took place. The change with water was always quite incomplete, but further experiments, it is hoped, may point the way to satisfactory conditions of formation.

Properties of Monoclinic Amphibole.—The crystallites of the monoclinic magnesian amphibole were invariably microscopic in size and too small to admit of a satisfactory study of their optical constants. Their direction of elongation is the prism axis, with which they extinguish at a small angle. In polysynthetically twinned fragments, a maximum extinction angle $c : c = 11°$ was observed, though smaller angles, 4°–8°, were noticed more frequently. The average refractive index

* The writers are indebted to Dr. G. P. Merrill of the National Museum for these specimens.

is very nearly equal to that of the orthorhombic amphibole ($\beta = 1\cdot585$), while the birefringence is not strong and is of the same order of magnitude as that of the orthorhombic form. The crystals, like those of the orthorhombic amphibole, are not so clear and transparent as the higher refracting pyroxenes, often showing distinct lines of growth; the twinning lamellae are usually fine and less sharply defined than in the monoclinic pyroxene. Intergrowths of the orthorhombic and monoclinic amphiboles were also observed occasionally, though they were distinguished with less certainty than in the pyroxenes.

The change of the orthorhombic to the monoclinic amphibole with water at temperatures of 375°–475° did not yield any well-formed crystals; the product appeared to be rather the result of a paramorphic change in the solid state. In the hope of getting individually developed crystals, we attempted the synthesis of this form from magnesium salts and soluble silicates or silica, and succeeded in getting a product with optical properties similar to those of the magnesian amphiboles, but in fibers so small that it was impossible to say whether they were orthorhombic or monoclinic. In view, however, of the partial change of the former into the latter, it seems probable that they were monoclinic.

Experiments in the Synthesis of the Amphibole at Low Temperatures.—Chrustschoff, some years ago, published a description of a method for the formation of hornblende in which a mixture of silicic acid, alumina, lime, magnesia, ferrous and ferric oxides, and the alkalies, partly in solution, partly precipitated, were heated in sealed glass vessels at a temperature of 550° for three months.[*]

It seems to us that glass vessels of such extraordinary properties deserve to be better known, and that the experimenter should have given some details concerning them, especially where they can be obtained, together with some information about his temperature measurements.

The experiments which we shall describe were done in a steel bomb 16^{cm} long, 2·7^{cm} internal diameter, and 1·4^{cm} thick, which was made by boring out a piece of steel shafting. The bomb was closed by a plug also of steel having a total length of 8^{cm}, the screw of which was 4^{cm} in length and fitted into a thread cut in the end of the bomb. A tight joint was insured by a washer of annealed copper 3 or 4^{mm} thick. The steel surfaces in contact with it were planed smooth, and into each were cut a number of very narrow concentric grooves about half a millimeter deep. To close the bomb, the plug was

[*] Comptes Rendus, cxii, p. 677, 1891.

screwed in by a long heavy wrench until the copper filled the grooves. A new washer should be used for each experiment. The capacity of the bomb was great enough to admit a cylindrical platinum crucible holding about 30^{cc}. Temperature measurements were made by introducing an insulated thermo-element into a 7^{mm} hole in the plug, the end of which it reached within 5^{mm}. The source of heat was a Bunsen burner. To distribute the heat more evenly, the bomb was surrounded by a collar of asbestos and sheet iron with a hole on the under side through which the flame passed. The joint was shielded from the latter by an annular asbestos disk which was slipped over it.

For the synthesis of the amphibole, the magnesium was taken in soluble form, either magnesium-ammonium chloride or a mixture of magnesium chloride with a sodium bicarbonate solution; while the silica was used in the amorphous state or in combination as sodium metasilicate. Generally ·25 or ·50 gram of magnesia was dissolved in the equivalent quantity of hydrochloric acid, then the ammonium chloride or sodium bicarbonate was added, and finally the silica or sodium silicate. This mixture was poured into the platinum crucible with 25^{cc} or more of water, covered, and put into the bomb, which was then closed tight and heated from 3 to 6 days at temperatures ranging from 375° to 475°. Although in the course of these experiments the details were varied considerably, we were only able to ascertain that the products formed at the higher temperatures were usually better crystallized.

When the bomb was opened, it generally contained more or less water, sometimes several cc.; the inner wall of the bomb itself was coated with magnetite, and sometimes the platinum crucible was covered with beautiful octahedra of the same mineral. In some experiments in which the water was nearly all gone, the bomb showed when cold an internal pressure and the odor of ammonia was noticeable.

After removal from the bomb, the products were washed and dried. To the naked eye they were all much alike; they were white, and of a tough and spongy texture. Optically they left much to be desired.

They were mostly crystalline but invariably fine-grained, often cryptocrystalline, and had to be studied rather in the aggregate than in individual fibers. In all these preparations the substance present in predominant quantity consisted of complex groups of fibers which extinguished parallel to their elongation, this direction being that of the least ellipsoidal axis c; their refractive index was less than 1·60 and agreed with that of the magnesium amphibole, so far as such minute fibers admit of measurement. The birefringence was low.

In addition to this substance small amounts of both the orthosilicate and quartz were observed. The crystals of the former were frequently well developed and exhibited the characteristic crystal habit of fosterite; they extinguished parallel to the prism edge, had an average refractive index of about 1·66, and much stronger birefringence than either the metasilicate or quartz.

The quartz crystals were ordinarily very small and recognizable only by their refractive index. In one preparation, however, where the sodium silicate in the form of large lumps was heated with magnesium ammonium chloride for 3 days at 400°–450°, numerous quartz crystals were found, the longest of which measured nearly 3^{mm}. They were water-clear, doubly terminated, sharply defined crystallographically, and resembled crystals of the natural mineral. Both optical and crystallographic measurements were made on these crystals, the results of which have been described at length in another paper* on the minerals of the lime-silica series.

In the products much of the material was too fine even for approximate determinations and may have contained other substances than the three cited above. It is noteworthy, however, that the pyroxene form of the metasilicate was not produced, but apparently the low refracting amphibole.

IV.—*Orthorhombic Amphibole. Kupfferite.*†—If magnesium silicate be melted and cooled without any special precautions, there may usually be detected, under the microscope, in the crystallized product, patches of a substance which differs markedly in appearance from either of the forms I and II. The fact that it occurred more frequently in the outer zones of the mass near the walls of the crucible, led to the suspicion that rapid cooling favored its formation. Experience soon proved the correctness of this conjecture. After a very considerable amount of work on the conditions necessary for its formation, we find (1) that the mass must be cooled rapidly, but not so rapidly as to form glass; and that (2) for this reason, probably, the quantity of material must not be too large. A satisfactory rate of cooling is attained if a platinum crucible containing 15 or 20 grms. of the molten silicate is quickly drawn from the furnace and held, uncovered, by the operator until crystallization is complete. If the hot crucible be set at once on a tile,

* Day, Shepherd and Wright, The Lime-Silica Series of Minerals, this Journal, xxii, Oct., 1906.

† The name Kupfferite was applied originally to the natural monoclinic amphibole of this composition. In the course of time, however, the name has been shifted to designate the orthorhombic form of the same composition and like enstatite represents the pure magnesium member of the amphibole series kupfferite-anthophyllite. Hintze, however, objects to this change. Compare, Hintze, Handbuch d. Mineralogie, Bd. II, p. 1196, and E. S. Dana, System of Mineralogy, p. 384–385, 1900.

the cooling is less rapid and the monoclinic pyroxene and enstatite are more likely to form.   In the above way we succeeded in one instance in crystallizing 27 grams of the silicate entirely to amphibole.   Ordinarily, however, a charge of this weight cannot be cooled with sufficient rapidity to prevent crystallization of more stable forms.

Our observations appear to have established the fact that the amphibole is more likely to crystallize from the melt if the initial temperature is much above the melting point.   The experiments were made in a Fletcher furnace and temperatures were roughly measured by means of a thermoelement placed under the hood where the combustion gases emerge. Only rough relative measurements were necessary.   The variation in the crystalline product with the initial temperature to which the charge is heated before cooling, is given in the following table :

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

<div align="center">*Influence of the Initial Temperature of the Liquid on the Product of Crystallization.*</div>

Temperature in the top of the Fletcher furnace.	Charge.	Product obtained.
1430°	6 gr.	Silicate not melted.
1470	50 "	Just begins to melt.
1470	18 "	Charge had just begun to melt.
1480	6 "	Amphibole.
1485	6 "	Monoclinic pyroxene.
1490	6 "	" "
1500	6 "	" "
1500	6 "	" "
1500	6 "	" "
1500 −1510°	6 "	Amphibole.
1510	27 "	"
1520	50 "	Monoclinic pyroxene.
1525	8 "	Amphibole.
1530	6 "	"
1530	8 "	"
1530	12 "	Delay in removing the cover about three-fourths amphibole; one-fourth monoclinic.
1530	18 "	Amphibole and a little glass.
1535	6 "	Amphibole.
1535	6 "	"
1540	12 "	Amphibole and a little glass.
1545	12 "	Amphibole.

Tollens[*] found that the unstable form of monochloracetic acid crystallized with greater certainty if the liquid was first

* Tollens, Chem. Ber., xvii, i, 664, 1884.

raised considerably above the melting point, and Lehmann*
states that benzyl-phenyl-nitrosamine also yields an unstable
form when *strongly heated* and very rapidly cooled.

We have proved that (pp. 402 and 411), all other forms of
magnesium silicate change into the monoclinic pyroxene before
the melting point is reached. If the crystal structure depends
on crystal particles or units which consist of regularly arranged
chemical molecules, it is not impossible that some of these
groups might preserve their identity some time after fusion of
the substance, and become completely disintegrated only after
some lapse of time or at a higher temperature. The favorable
influence of a high initial temperature on the formation of
amphibole would then be due to the complete breaking down
of nuclei which condition the crystallization of the monoclinic
form.†

We tried the effect of dropping small portions of the solid
amphibole into the undercooled liquid in order that they
might serve as nuclei for crystallization, but the experiment
did not succeed. The silicate liquids are so viscous that the
nuclei do not seem to exert any influence on the crystalliza-
tion. The negative effect of nuclei is very strikingly brought
out in the following way : Magnesium silicate can be chilled
in such a manner as to yield radial spherulites of monoclinic
pyroxene embedded in glass. Now when this cake is heated
again at 900°, not only do the existing nuclei fail to grow, but
they exercise no orienting influence on the new crystals which
form.

As this substance has not been obtained before, some further
details regarding its crystallization may be of interest. It
usually begins on the upper surface of the melt next to the
walls of the crucible, forming a fringe of converging fibers
which grow toward the center, though sometimes a number of
rather widely separated nuclei start at points on the upper or
lower surface. This crystal form is characterized by a con-
siderably slower growth than the monoclinic. If, in a crucible
in which the amphibole has already begun to crystallize, the
still liquid portion be touched by a wire, the disturbance is
instantly followed by the appearance of a monoclinic nucleus.
The difference in the rate of growth of the two crystal forms
is then very striking. We early noticed a very marked differ-
ence in the rise of temperature during the crystallization of
these two forms, the monoclinic raising the temperature to a
dazzling white ; and though the difference must be partly due

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* O. Lehmann, Molekularphysik, vol. i, p. 211.

† A similar conception has been advanced in a paper by Day and Allen to
explain the superheating of the alkaline feldspars. This Journal, series (4),
xix, p. 124, 1905.

to the rapidity of the process, we were led to suspect what afterwards proved true, that the amphibole would pass over into the other with evolution of heat.   This and the method of its formation by sudden cooling are characteristic of mono-tropic forms.

Interesting results were obtained in an attempt to measure the approximate temperature at which the amphibole crystal-lizes.   As a determination of a physical constant the attempt failed, because the disturbance caused by touching the liquid with the element was sufficient to start the crystallization of the monoclinic form in every instance.   The following trials were made with the bare thermoelement dipped directly into the liquid, which above 1100° is easily penetrable with a wire.

Experiment 1.—As soon as crystallization began, the element was dipped into the center of the charge.   Temperature 1350°. All monoclinic pyroxene.

Experiment 2.—Amphibole started to crystallize in the outer zone.   Measurement as in 1.   Temperature 1300°.   Mono-clinic pyroxene started at once.

Experiment 3.—Same as 2.   Temperature 1300°.

Experiment 4.—Amphibole began to crystallize on the upper surface next the crucible wall as in 2.   The element was dipped in, on the boundary line, between solid and liquid, about 1^{cm} from the crucible wall.   Temperature 1150°. Monoclinic pyroxene started instantly.

Experiment 5.—Amphibole began to crystallize as usual.   We waited until it nearly covered the surface and then dipped the element into the liquid, which remained in the middle. Temperature 1180°.   When the charge was removed from the crucible, all but the upper layer proved to be mono-clinic pyroxene.

Experiment 6.—Like Experiment 4.   Temperature 1165°.

The rise of temperature with crystallization, the rapid radiation of heat from an unprotected crucible, the variation of temperature in different parts of the mass, all prevent any-thing better than rough temperature estimates, but the fact that the amphibole forms in a region near which a slight disturbance is sufficient to crystallize the glass to monoclinic pyroxene, is conspicuous and important.   This temperature has been shown in an earlier part of the paper to be above 1150°.

Properties of Orthorhombic Amphibole.—This amphibole appears white and porcelain-like, and crystallizes in radial spherulites and fibrous aggregates.   Since we have not yet been able to obtain crystals suitable for measurement, its identifica-tion rests solely on the correlation of its other properties, chiefly optical, with those of the natural mineral, kupfferite.

The fibers were too fine and too intimately intergrown to

show the cleavage plainly, still in a number of cases where fibers were tilted to a vertical position under the microscope an indistinct cleavage of about 120° was observed. Their hardness is 6. In transmitted light the aggregates do not appear so clear and transparent as the pyroxenes, but are usually of a pale brown color. The refractive indices were measured by the method of refractive liquids : $\gamma = 1\cdot591 \pm \cdot003$, $a = 1\cdot578 \pm \cdot003$, $\beta = 1\cdot585 \pm \cdot004$. Birefringence is not strong, $\cdot013$ approximately, and the interference colors are confined to the bright tints of the first and second orders. The extinction is usually parallel to the direction of elongation, although in a few sections a small extinction angle, $c : \mathfrak{c} = 3°\text{--}6°$, was observed, indicating intergrowths of orthorhombic and monoclinic amphiboles similar to those observed in nature. The plane of the optic axes lies parallel to the long direction ; the optic axial angle is large and the optical character apparently positive, determined on a section nearly perpendicular to an optic axis. The pleochroism is $\mathfrak{c} = $ brown, and b lighter brown ; absorption, $\mathfrak{c} > b$.

Lines of growth are often distinct within the crystallites and exhibit a plumose arrangement.

Although the above optical data do not suffice to prove definitely that this form of magnesium metasilicate is an amphibole, they do agree closely with the properties of the orthorhombic amphibole of similar composition found in nature. Unfortunately, the definite solution of this question must be deferred until after means have been devised to produce measurable crystals.

The specific gravity was determined on several different preparations, two of which (I and II) were very carefully examined microscopically and found to be practically pure ; the third, having been observed by the same method to contain small quantities of glass and the monoclinic form, was separated with great care by heavy solutions (methylene iodide and benzene), the separation of each portion being twice repeated and controlled by the microscope.

<div align="center">Specific gravity at 25° C.</div>

Prep. I.	2·858	Prep. II.	2·860	Prep. III.	2·855
	2·856		2·860		2·853
	2·857		2·860		2·854
Average,					2·857

Transformation of Orthorhombic Amphibole by Heat.—
The orthorhombic amphibole changes, like enstatite, and somewhat more rapidly, into the monoclinic pyroxene, when heated to a sufficient temperature. Here, too, the change is sluggish, as the following table indicates :

Table VII.

Change of Orthorhombic Amphibole to Monoclinic Pyroxene.

Time.	Temperature.	Observations.
1 day	1020°–1040°	No change.
2 days	1055 –1077	Indications of slight change.
20 hours	1100 –1100	No change observed.
18 hours	1120 –1140	Fragments dotted with pyroxene.
3 days	1127 –1153	All changed.
18 hours	1144 –1173	Partly changed.
2 days	1150 –1183	All changed.

It is possible that at the lower temperatures the amphibole passes into enstatite; the product is there so fine-grained that a microscopic distinction between the two pyroxenes cannot be made.

Part II.—Relations of the different forms to one another.

Stability relations.—The four forms of magnesium silicate having thus been prepared and studied in detail, the question of their relative stability arises. It is well known that a substance chemically homogeneous may exist in several different physical forms, which are called polymorphic when they yield identical liquids, solutions and vapors, in which case their chemical molecules, in distinction from those of isomers, are identical. Polymorphic substances are enantiotropic when, by heating, one form changes without melting into the other at a definite temperature called the inversion point, and on cooling again the reverse change takes place. In this case, the first form is stable below the inversion point only, the second above it. The form stable at lower temperatures inverts to the other with absorption of heat, and the reverse change takes place with evolution of heat.* An instance of the enantiotropic relation is the mineral wollastonite, which inverts at about 1190°, with absorption of heat, into a second form, pseudo-hexagonal in symmetry.

In another class of polymorphic substances there is no such inversion point, and one of the forms is more stable than the other at all temperatures below the melting point. These relations are best expressed by diagrams.

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* Given the relations of the vapor pressures, this follows from the second law of thermodynamics. Van't Hoff, Vorlesungen über Theoret. u. Phys. Chemie, Braunschweig, 1901, ii, 128.

Enantiotropy.—In fig. 7,

OT = axis of temperatures.
OP = axis of vapor pressures.
abc = vapor tension curve of liquid.
ed = vapor tension of solid stable below T_2.
db = vapor tension of solid stable above T_2.
T_2 = inversion point.
T_1 = melting point of form stable above T_2.
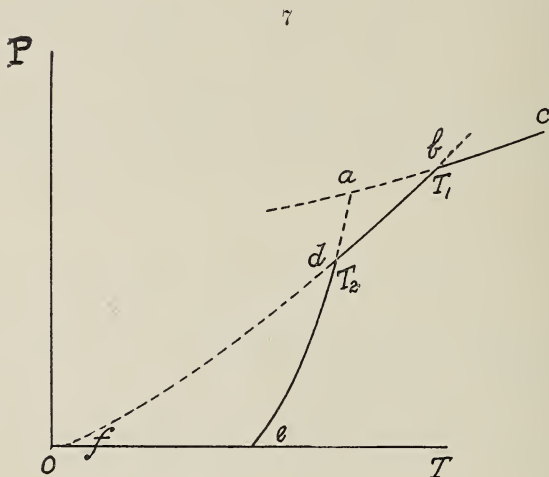
FIG. 7.   Vapor pressure curves in a case of enantiotropy ; *ed* is curve of solid stable below T_2 ; *db* is curve of solid stable above T_2.   The full lines represent a condition of stability, the dotted lines a condition of instability.

The two curves *ed* and *fb* intersect at *d* below the melting point curve.   At this point the two forms have the same vapor pressure, and are therefore in equilibrium, and the temperature, T_2, is the inversion point.   Likewise, the point T_1 is common to two curves, *bd* of the solid stable at higher temperatures, and *ac* of the liquid ; at that point, therefore, this solid and the liquid are in equilibrium, and T_1 is the melting point.   Since in general the curve *ed* cannot be prolonged so as to intersect with the curve *ac*, the solid stable at lower temperature usually has no melting point.   *bd* can usually be prolonged to low temperatures by sudden cooling or otherwise, a fortunate circumstance without which nearly all physical and chemical data upon the solids stable only at high temperatures would be unattainable.

Monotropy.—In fig. 8,

OT = axis of temperatures.
OP = axis of vapor pressures.
abcd = vapor pressure curve of liquid.
eb = vapor pressure curve of unstable solid.
fc = vapor pressure curve of stable solid.
T_1 = melting point of stable form.
T_2 = melting point of unstable form.

8
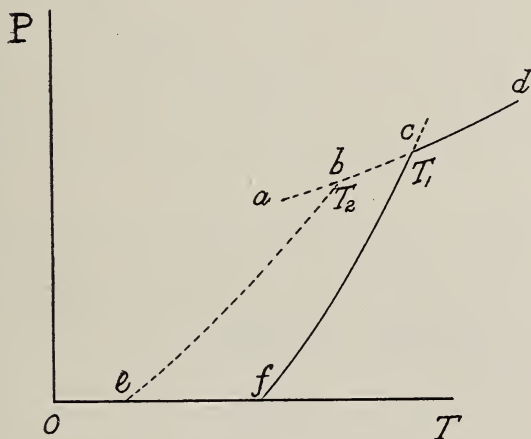
Fig. 8. Vapor pressure curves in a case of monotropy; *eb* is curve for unstable form; *fc* is curve for stable form.

This figure represents the relations between the vapor pressure curves of two monotropic solids and their corresponding liquid.   The curve differs from the preceding case only in that *fb* and *ed* do not intersect before reaching the melting point curve *abc*.   At *b* the vapor pressure of one solid is equal to that of the liquid, and the two are in equilibrium ; T_2 is therefore the melting point of this form.   Similarly, T_1 is the melting point of the second (stable) solid.   It will be noted that for a given temperature the vapor pressure of the first solid is always greater than that of the second ; the two curves do not intersect below either melting point and therefore are not in equilibrium at any temperature ; the solid of lower vapor pressure is more stable than the first throughout.   The melting point of the unstable solid is always lower than the other, but in practice the unstable form often changes into the more stable before its own melting point (T_2) is reached.

Although many solids, like the minerals under discussion, have a vapor tension much too low for measurement at these temperatures, the relations are as represented in the diagram.*

The stability relations of the four polymorphic forms of magnesium silicate may be shown in the same way by a simple diagram (fig. 9). These curves do not, of course, represent measured vapor pressures, but simply the order of the stability
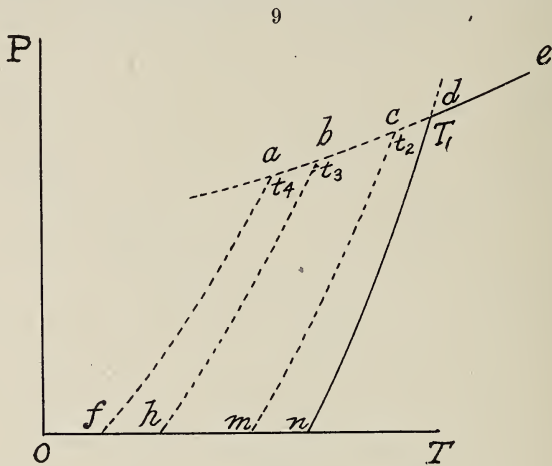
Fig. 9. *fa* is vapor pressure curve for orthorhombic amphibole; *hb* is vapor pressure curve for monoclinic amphibole ; *mc* is vapor pressure curve for orthorhombic pyroxene ; *nd* is vapor pressure curve for monoclinic pyroxene.

of the forms. As is proved by the experiments described below, the monoclinic pyroxene, at atmospheric pressure, is the most stable, and the others bear a monotropic relation to it, their relative stability being in the order indicated by the vapor pressure curves.

Two lines of evidence lead to this conclusion : (1) *a.*   Enstatite and the amphiboles, while still in the solid state, pass over at high temperatures into monoclinic pyroxene which cannot be changed back without passing through the amorphous state ; *b.* At much lower temperatures (about 800°) the same three forms can be dissolved and recrystallized simultaneously into the monoclinic pyroxene by means of fluxes ; (2) enstatite and the two amphiboles change into monoclinic pyroxene with evolution of heat.

(1) Although it was shown conclusively that the amphiboles change into monoclinic pyroxene above about 1150°, and

* Roozeboom, Heterogen Gleichgewichte, Heft. 1, 158–159, Braunschweig, 1901.

enstatite changes to the same form above 1260°, and that on cooling neither of the changes is reversible, these facts in themselves do not prove monotropy. In certain cases of enantiotropy, mere cooling of the form stable at high temperatures does not suffice to revert it to the other form, even when both forms are in contact and unlimited time is allowed.* This inertia is apparently due to the great internal friction between the molecules at temperatures below the inversion point. The molecular immobility may be overcome by the use of suitable fluxes in which solution of the unstable form and precipitation of the stable go on hand in hand, the unstable form being the more soluble. Thus pseudo-wollastonite is less stable than wollastonite below the inversion point, yet it does not revert to it at lower temperatures except by the aid of proper solvents. In this case, molten calcium vanadate proved well adapted to the purpose. The pseudo-wollastonite dissolved in it and cotemporaneously wollastonite crystallized out.

Similar tests with solvents were applied to the different forms of magnesium silicate with the result, as we have already recounted in detail (pp. 387 et seq.), that from a considerable number of solvents magnesium silicate was found to pass into solution and gradually to crystallize, invariably as monoclinic pyroxene, whatever crystal form was originally taken. This indicates that at atmospheric pressure the monoclinic pyroxene is the most stable form of magnesium silicate at all temperatures between about 800° and the melting point of the monoclinic form (1521°).

(2) In order to confirm this evidence of monotropy, we sought to ascertain the direction of the heat changes, whether exothermic or endothermic, for two of the unstable forms. The method first tried was that of Frankenheim, which consists in observing at regular intervals the rise in temperature of a mass of the substance. Heat was supplied by means of the electric resistance furnace used in this laboratory, and the temperature measured by a thermoelement.† The curves thus obtained by heating the different forms are perfectly smooth, showing neither absorption nor release of heat until the melting point of the monoclinic form is reached. The fact that all forms seem to have the same melting point indicates in itself that the other forms change into the monoclinic pyroxene before melting. The change, however, is so sluggish that it proceeds throughout a temperature interval of several hundred degrees, and the heat is therefore so uniformly distributed as not to be indicated by the curve.

* See "Wollastonite and Pseudo-Wollastonite," this Journ. ser. 4, xxi, p. 95, 1906.
† Day and Allen, Phys. Rev., xix, 184.

New Method for Detecting the Direction of Sluggish Heat Changes.—A substance in which a transformation progresses so slowly that the accompanying heat change cannot be detected by the ordinary method, should show it plainly if the change could be forced to proceed with sufficient velocity. The heat change would then be concentrated and become visible on the temperature-time curve.

In changes of this character, the rate of change depends on the temperature, and increases rapidly with it. If, therefore, a substance which is unstable at high temperatures be introduced into a furnace which is several hundred degrees above the lower limit of the unstable region, the heat effect is in general easily followed. In our experiments the apparatus shown in fig. 10 proved very satisfactory for the purpose. An empty
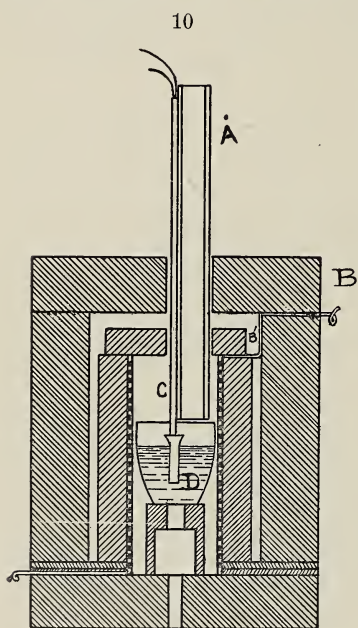
platinum crucible is first placed on a pedestal of refractory material in the electric resistance furnace. The unglazed porcelain tube, A, 1^{cm} in inside diameter and open at both ends, passes through holes drilled in the two covers, B and B′, and is then clamped in the position shown in the figure, the lower end of the tube reaching down to the top of the crucible. The thermo-element C is covered by a platinum shoe, D, which should occupy the same position in all the experiments, i. e., about the center of the charge. This is assured by clamping the tube in a fixed position and fastening the element securely to it by platinum wire. Care was taken to obtain like conditions in each experiment, especial attention being given to fitting together the parts of the furnace to obtain minimum radiation of heat, and in placing the crucible and thermoelement in the same relative position for each experiment.

The furnace is now brought to a constant temperature, which should be sufficiently high to insure a rapid change of state. In the particular substances which we investigated, temperatures ranging from 1425°–1475° were found best adapted to show the heat effect. A weighed portion of the substance (40

or 50 grams) is then quickly dropped through the tube into the crucible, after which temperature readings are made at half-minute intervals until the temperature of the crucible again becomes practically constant.

In a second experiment under the same conditions, the product of this first change is introduced into the furnace as before, and a second temperature curve determined under exactly the same conditions. A comparison of the two curves plainly indicates the direction of the heat change. If an evolution of heat has taken place, the temperature rate is accelerated and the curve of the unstable body lies to the left and above that of the stable form, as shown in curve I of fig. 11. On the other hand, if there has been an absorption of heat, the temperature rate is retarded and the curve of the unstable form lies to the right and below that of the stable form.

In order to test the method, substances were first tried in which the direction of heat change was known, e. g., wollastonite, which passes into pseudo-wollastonite with absorption of heat; wollastonite glass, which crystallizes with evolution of heat; and albite, which melts with absorption of heat,— all very slow changes. Fig. 11 contains the results obtained with wollastonite and wollastonite glass. The number of curves in a single figure and their general similarity of form have made it inadvisable to confuse the figures by attempting to show the observed points on each curve. The observed electromotive forces in microvolts are therefore tabulated separately (Table VIII). The corresponding temperatures are not important, as the point which we desire to establish depends merely upon the relative displacement of that portion of the curve in which a change of state may be expected to occur. The curves II are heating curves for pseudo-wollastonite, which is the stable form at the temperatures of the experiment, and therefore suffers no change of state. Curve I, the corresponding curve for wollastonite glass, lies to the left and above the curves for pseudo-wollastonite, and plainly indicates an evolution of heat, since all other thermal conditions are identical in the two cases. The curves for wollastonite, III, lag behind those for pseudo-wollastonite, and indicate heat absorption. The results for albite and albite glass are shown in fig. 12 (Table IX). It is interesting to compare these results for albite with those obtained for orthoclase (which resembles albite very closely in its thermal properties), in a previous investigation in this laboratory by the Frankenheim method (fig. 13).*

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* Arthur L. Day and E. T. Allen, "The Isomorphism and Thermal Properties of the Feldspars," this Journal, series 4, xix, 93, 1905.
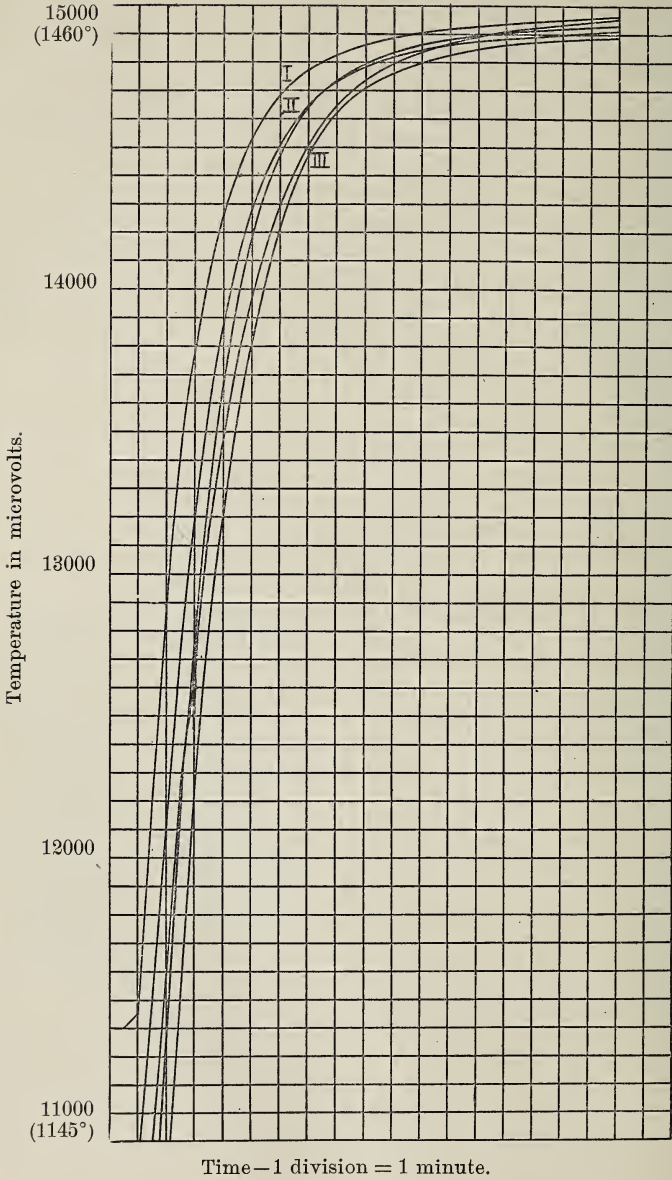
FIG. 11.

I = Wollastonite glass (one curve).
II = Pseudo-wollastonite (two curves).
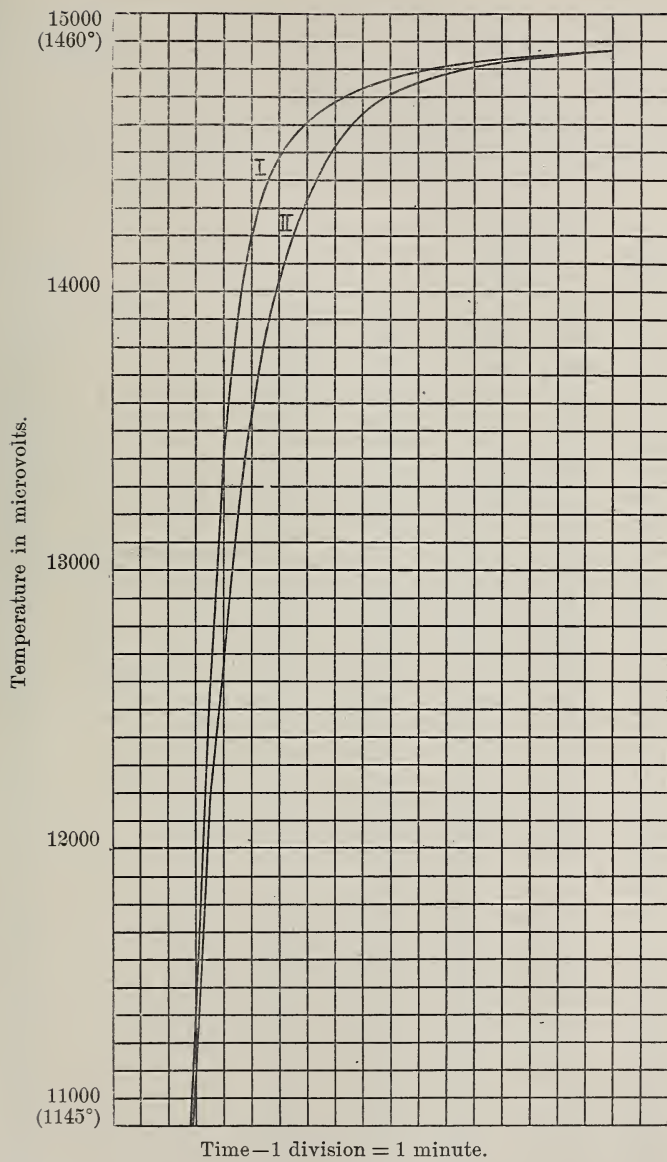III = Wollastonite (two curves).

12

FIG. 12.   I = Albite glass.
II = Albite.

The curves in this figure (fig. 13) were obtained by heating large charges (about 100 grams) of orthoclase to a temperature which caused a complete change of state. During the time of melting, which, in the alkaline feldspars, extends over quite an interval, the rate at which the temperature rises is retarded by heat absorption, but the change is so slow that this retardation is very slight. The indentation in the curve is

TABLE VIII (see fig. 11).

Time.	Wollastonite glass.		Pseudo-Wollastonite.	Wollastonite.	
0 min.	15000	15000	15000	15000	15000
	11400	11300	10600	9900	11100
1 "	11450	10905	9960	9170	10380
	12210	11450	10520	9700	875
2 "	12890	12115	11350	10585	11560
	13445	734	12175	11495	12215
3 "	790	13208	790	12245	715
	14065	595	13305	12840	13160
4 "	262	880	680	13215	484
	418	14114	970	550	760
5 "	529	281	14185	818	974
	619	416	350	14050	14154
6 "	683	514	474	225	292
	732	593	570	368	414
7 "	770	650	641	473	506
	801	696	695	558	585
8 "	825	731	738	620	646
	845	761	772	670	696
9 "	861	784	798	706	736
	875	801	819	735	770
10 "	885	816	835	759	795
	895	829	850	780	818
11 "	903	840	862	798	837
	911	850	872	812	851
12 "	917	858	880	824	867
	923	865	887	835	879
13 "	927	872	893	844	889
	932	877	899	852	899
14 "	937	882	904	859	907
	940	888	908	864	915
15 "	944	891	912	869	921
	948	895	915	873	928
16 "	951	898	919	877	933
	953	901	921	880	939
17 "	956	904	924	883	945
	961	908	927	885	950
18 "	964	911	929	887	954

TABLE IX (see fig. 12).

Time.	Albite glass.	Albite.
0 min.	15000	15000
	11100	11850
1 "	9900	315
	9900	720
2 "	10525	12250
	11430	800
3 "	12365	13140
	13145	478
4 "	695	716
	14075	919
5 "	300	14080
	448	221
6 "	543	334
	610	432
7 "	659	513
	699	584
8 "	727	636
	751	676
9 "	770	705
	785	728
10 "	800	747
	811	761
11 "	821	772
	830	782
12 "	838	790
	844	797
13 "	850	803
	855	809
14 "	859	813
	864	818
15 "	868	821
	872	825
16 "	876	828
	880	831
17 "	882	834
	885	837
18 "	887	840

made evident to the eye by continuing as a dotted line the course the curve would have followed, had no absorption of heat occurred.
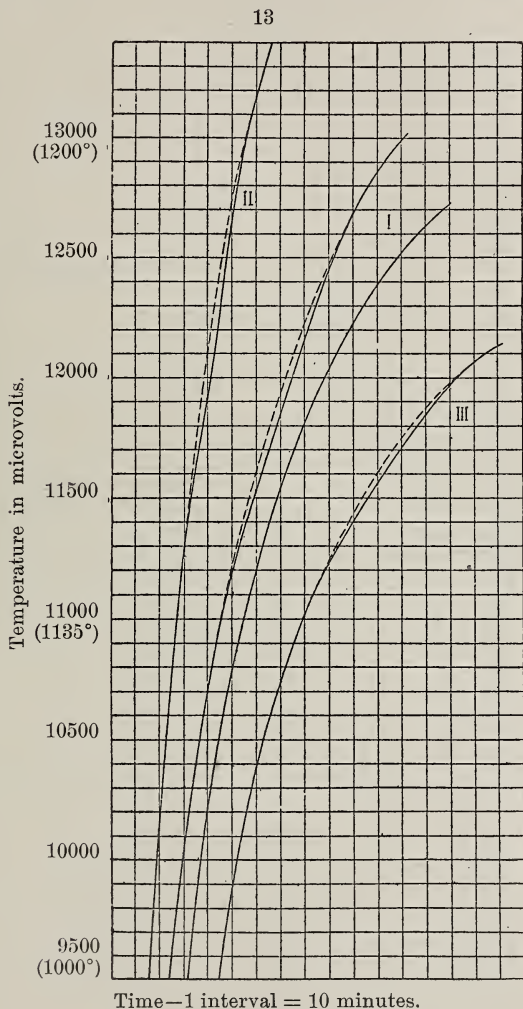
FIG. 13.   Curves showing heat absorption in melting orthoclase.

Figures 14–18 (Tables X–XIV), show the curves obtained by the new method on the different forms of magnesium metasilicate. The curves for the orthorhombic amphibole, enstatite and monoclinic pyroxene in fig. 14 (Table X) were obtained in preliminary experiments, and are less accurate than those obtained in the later experiments, due to the fact that the posi-

14
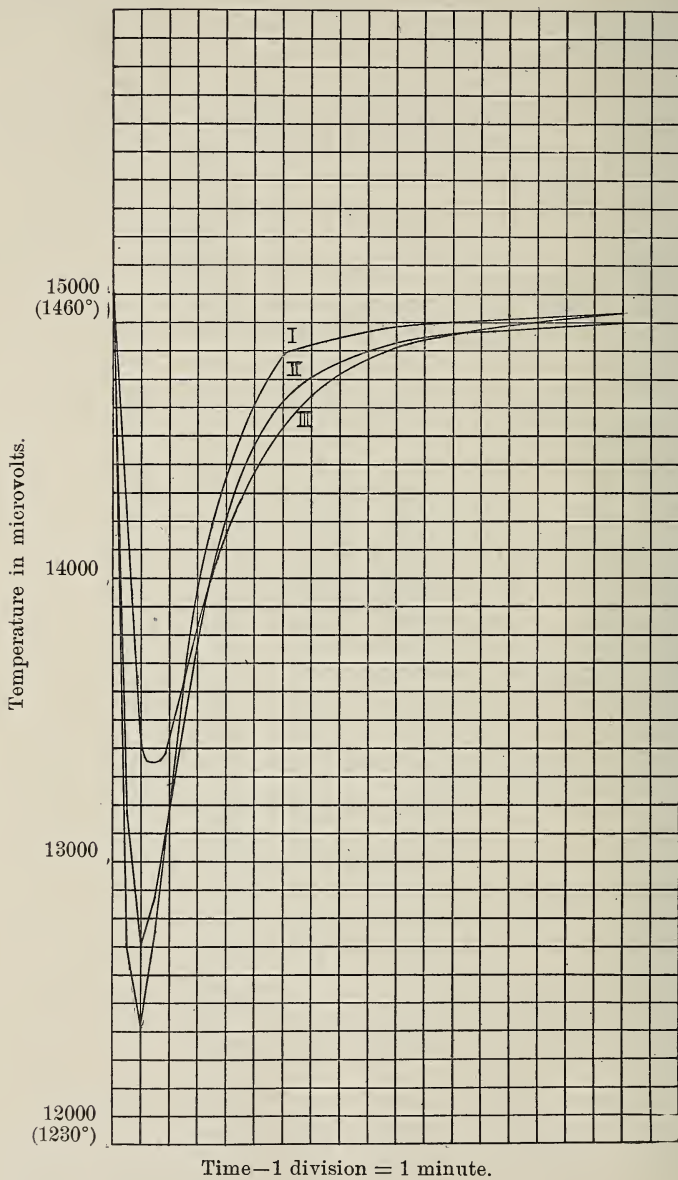
FIG. 14.   I = Orthorhombic amphibole.
                 II = Enstatite.
                 III = Monocline pyroxene.

15
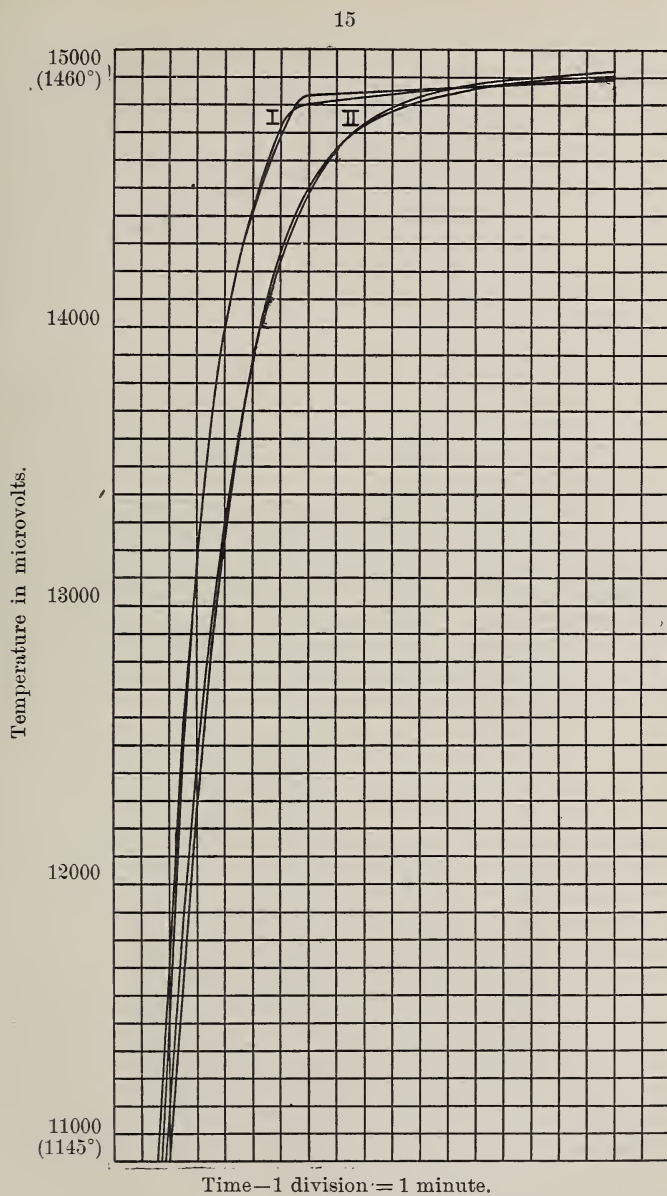
FIG. 15.   I = Orthorhombic amphibole (two curves).
II = Monocline pyroxene (two curves).

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Temperature in microvolts.

Time—1 division =.1 minute.
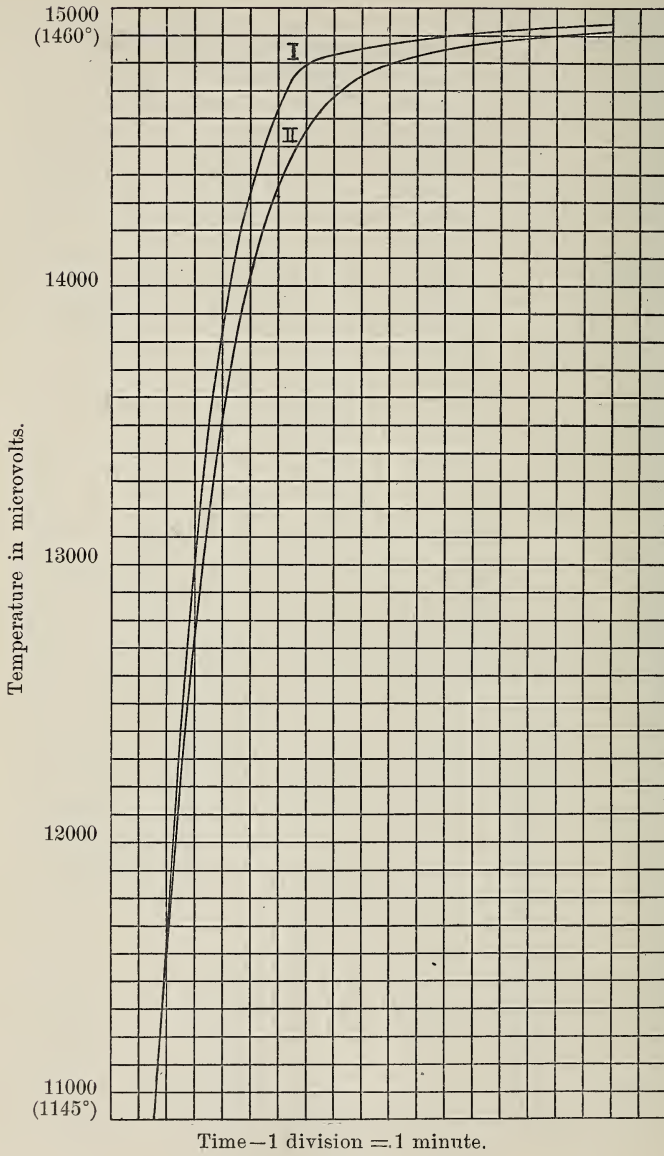
FIG. 16.   I = Orthorhombic amphibole.
               II = Monoclinic pyroxene.
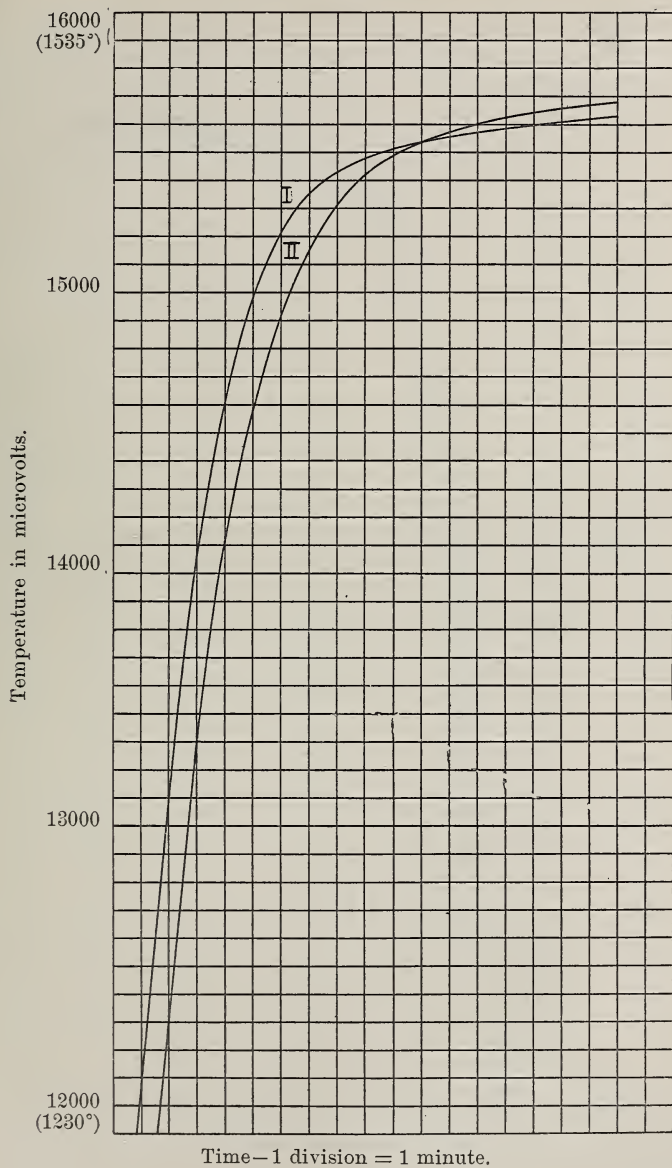
FIG. 17.   I = Enstatite.
            II = Monoclinic pyroxene.
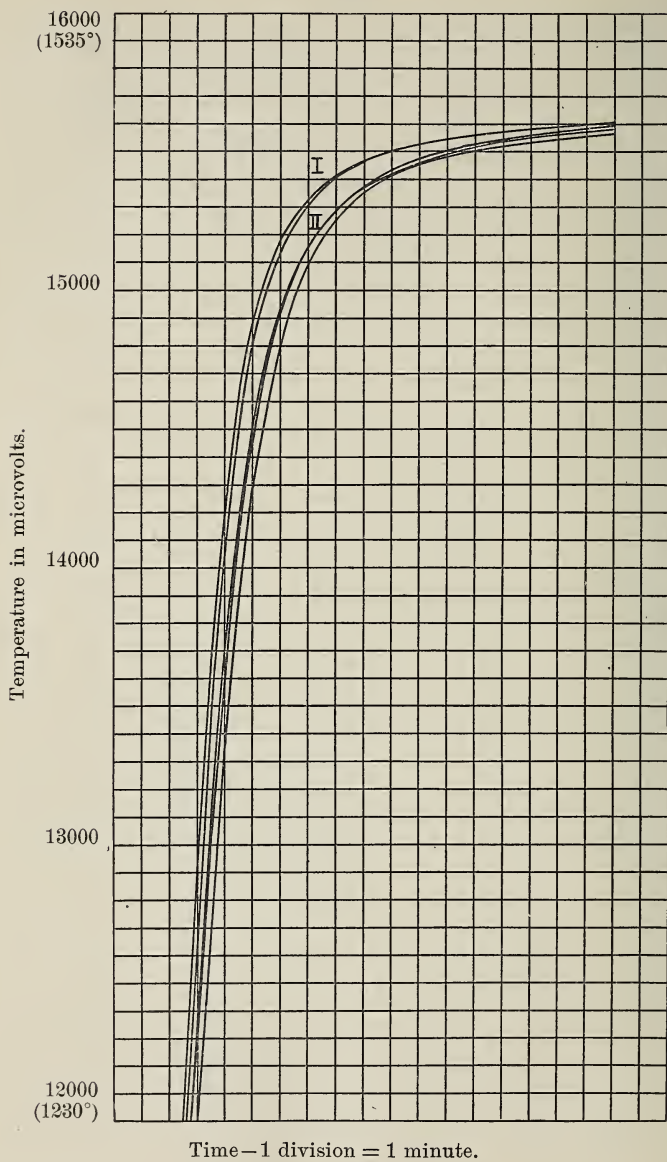
Fig. 18.   I = Enstatite (two curves).
                II = Monoclinic pyroxene (three curves).

TABLE X (see fig. 14).

Time.	Monoclinic pyroxene.	Amphibole.	Enstatite.
0 min.	15000	15000	15000
	12700		13170
1 "	13500	415	12707
	350	750	870
2 "	440	13200	13175
	625	630	505
3 "	830	930	780
	14000	14180	14017
4 "	145	350	200
	265	495	353
5 "	370	600	466
	455	706	555
6 "	530	785	618
	590	803	671
7 "	640	814	708
	680	831	738
8 "	716	841	761
	745	855	781
9 "	770	869	796
	790	878	808
10 "	810	886	819
	825	876	834
11 "	837	873	847
	848	877	857
12 "	859	890	862
	869	892	864
13 "	876	894	863
	884	898	866
14 "	891	905	871
	898	910	876
15 "	903	913	881
	909	917	884
16 "	915		888
	920	923	890
17 "	926	926	893
	931		895
18 "	934	933	898

TABLE XI (see fig. 15).

Time.	Monoclinic.		Amphibole.	
0 min.	15000	15000	15000	15000
	11250	11000	10850	11050
1 "	10200	10003	9950	10200
	10520	10280	10560	770
2 "	11185	915	11530	11710
	870	11650	12460	12575
3 "	12435	12285	13120	13170
	915	830	640	655
4 "	13290	13257	980	990
	613	610	14230	14240
5 "	860	880	407	424
	14070	14100	557	585
6 "	235	266	688	716
	375	400	797	785
7 "	479	500	833	801
	566	579	839	807
8 "	630	639	839	814
	687	687	847	821
9 "	728	724	847	827
	763	755	852	832
10 "	789	778	859	838
	811	796	857	844
11 "	828	811	858	849
	843	825	862	854
12 "	855	837	865	859
	866	847	869	863
13 "	874	856	874	867
	881	865	881	870
14 "	886	871	880	874
	891	877	887	877
15 "	896	882	891	880
	903	886	893	883
16 "	908	889	895	885
	912	893	896	887
17 "	917	897	898	890
	921	901	900	892
18 "	924	904	902	894
	927			
	930			

tion of the thermoelement was less carefully adjusted, but the relative position of the curves is clearly established. Figures 15 and 16 (Tables XI and XII) contain curves for the same amphibole and monoclinic pyroxene, and figures 17 and 18 (Tables XIII and XIV) for enstatite and the monoclinic pyroxene, which represent the results of experiments made

TABLE. XII (see fig. 16).

Time.	Monoclinic pyroxene.	Amphibole.
0 min.	15000	15000
	10920	10600
1 "	343	170
	890	825
2 "	11570	11625
	12210	12380
3 "	740	995
	13180	13490
4 "	520	840
	815	14120
5 "	14040	332
	223	500
6 "	360	630
	476	739
7 "	559	795
	627	818
8 "	678	830
	720	841
9 "	751	850
	778	860
10 "	798	868
	811	876
11 "	825	884
	838	891
12 "	849	897
	857	903
13 "	863	908
	871	913
14 "	877	917
	883	921
15 "	888	924
	893	928
16 "	897	931
	905	933
17 "	909	937
	913	940
18 "	916	942

TABLE XIII (see fig. 17).

Time.	Monoclinic pyroxene.	Enstatite.
0 min.	15800	15800
	12100	12380
1 "	11160	140
	700	670
2 "	12325	13200
	940	690
3 "	13410	14065
	805	370
4 "	14115	615
	375	820
5 "	584	980
	768	15115
6 "	915	215
	15048	295
7 "	152	352
	242	394
8 "	312	428
	372	455
9 "	418	476
	458	495
10 "	489	510
	515	523
11 "	536	533
	557	543
12 "	572	551
	588	558
13 "	601	565
	612	573
14 "	623	580
	631	587
15 "	639	594
	647	600
16 "	654	606
	661	612
17 "	666	616
	672	623
18 "	678	628
		631

with all the precautions which we have prescribed. The curves for both the enstatite and the amphibole lie to the left and above that for the monoclinic pyroxene. They therefore change into the latter with evolution of heat, and hence are monotropic with respect to it. The curve for the orthorhombic amphibole lies outside that of enstatite, and consequently the exothermic change is quantitatively greater

TABLE XIV (see fig. 18).

Time.	Monoclinic pyroxene.			Enstatite.	
0 min.	15700	15700	15700	15700	15700
	8500		10100	9800	10000
1 "	8645	9520	9400	8715	9765
	9300	9915	9848	9325	10210
2 "	9930	10615	10605	10415	11035
	10905	11475	11515	11640	12010
3 "	11800	12270	12315	12620	890
	12630	13005	13075	13475	13658
4 "	13325	605	715	14065	14205
	890	14113	14170	510	615
5 "	14290	455	510	797	877
	555	228	763	15000	15055
6 "	808	915	938	135	179
	975	15052	15068	238	265
7 "	15095	152	161	308	324
	185	230	233	366	372
8 "	242	289	287	407	410
	309	337	331	443	443
9 "	357	374	365	468	462
	386	406	394	482	481
10 "	416	431	417		499
	440	453	437		511
11 "	458	471	454		523
	476	488	469		533
12 "	492	501	481		542
	504	514	492		551
13 "	514	525	503		558
	524	534	511		565
14 "	533	543	520		570
	541	551	527		575
15 "	548	558	533		579
	555	565	539		585
16 "	561	571	545		588
	567	577	550		596
17 "	572	582	555		600
	577	587	559		605
18 "	581	592	563		604
	585	597	568		

for amphibole, which indicates that it is the least stable of the three forms. As compared with the curve of wollastonite glass, the form of the (orthorhombic) amphibole curve is significant. The change of the former begins at a much lower temperature and forms a smooth curve, while the latter changes at higher temperatures and, as a result, the influence of the heat change continues until the maximum temperature is almost reached; consequently the curve shows a sharp change in direction near the top.

Although this method is purely qualitative, repeated trials on all these substances have convinced us that the relative position of the curves is invariable. No *point* of change, of course, can be found.

In the consideration of these curves the fact must not be overlooked that they include two quantities which may be independently variable, the heat of fusion or inversion and the specific heat. In general it is undoubtedly true, and therefore a justifiable assumption in this case, that latent heats are of a greater order of magnitude than specific heats. Although glasses possess higher specific heats than the solids which crystallize from them, polymorphic forms of the same substance in all probability possess similar specific heats. For the purposes here described, we are, therefore, perfectly safe in assuming that the comparisons made are independent of *differences* of specific heat in the substances experimented upon. The results obtained for albite by this method are in full accord with well established existing data, although albite, of all the substances examined, might be expected to offer difficulties from this cause. A substance exhibiting a sluggish heat change might perhaps be found in which the relative magnitude of the specific heats of it and its product, when compared with the latent heat of the change, would be such that the latter would have less influence on the form of the curve. In such a case, the method would lead to erroneous conclusions.

It goes without saying that if the change to be investigated does not take place during the time the substance is in the furnace, the method is useless. We found this true in the case of quartz. When the temperature of the furnace was held at 1560°, only about 1 per cent of the quartz was changed during the twenty minute period of experiment, even though other evidence has shown that tridymite is the stable form above a point at least as low as 800°.[*]

Order of Stability.—We have seen (pp. 402, 410 that the orthorhombic amphibole and enstatite both pass over into the monoclinic pyroxene under circumstances which point to the greater stability of the last named form ; that the heat effect which accompanies this change of state is exothermic in all cases, but quantitatively greater in the change—amphibole $\longrightarrow$ monoclinic pyroxene. The amphiboles are, therefore, less stable than enstatite, a conclusion which is substantiated not only by the greater difficulty of forming the amphiboles, but by the closer resemblance of all the properties of the two pyroxenes. The fact that the monoclinic amphibole probably forms directly from the orthorhombic amphibole in the presence of water at 375°−475°, though the orthorhombic form is all the while in

[*] Day, Shepard and Wright, loc. cit.

excess, indicates the greater stability of the former.   In connection with this it should be noted that the two amphiboles resemble each other as closely as do the two pyroxenes, the monoclinic forms being the stabler in both cases.   The order of stability of the four forms is represented in the diagram (p. 414).

Volume Relations.—Although theoretically there is no reason requiring it, the facts show that the specific gravities, and therefore the specific volumes, of the four forms of magnesium silicate lie in the order of their stability:

Specific gravity of glass_ 2·743
    "   "   " orthorhombic amphibole_ _ _ _ _ _ 2 857
    "   "   " monoclinic   "   _ _ _ _ _ _ _ _ _ _*
    "   "   " orthorhombic pyroxene _ _ _ _ _ _ 3·175
    "   "   " monoclinic   "   _ _ _ _ _ _ 3·192

Geological Inferences.

Conditions of Formation of Meteorites.—It has been shown above, that the monoclinic magnesian pyroxene, though not generally recognized as a mineral, does occur in nature.   After it had been found to be the stablest form of magnesium metasilicate, its occurrence seemed altogether likely.   An examination of the literature then developed the fact that Fouqué and Lévy had already discovered it in meteorites.†   Still their proof lacked one essential point; they assumed the composition of the mineral.   The optical study of the material of the Bishopville meteorite, which has been shown to be practically pure magnesium silicate,‡ supplied the missing link in the chain: a careful measurement of all its important optical constants, and a comparison of these with the constants of our monoclinic form, established the identity of the two.   Fouqué and Lévy state that in some meteorites the monoclinic form, in others the enstatite, is in excess.   In the Bishopville and other meteorites, this form is intergrown with enstatite.   In the similar intergrowths of enstatite with a "monoclinic pyroxene" so frequently observed in rocks, it is very probable that in some cases the latter has the same composition as the enstatite.

The parallel growths of enstatite and the monoclinic pyroxene which are characteristic of meteorites, we were able to reproduce by cooling a molten mass of pure magnesium silicate at a rather rapid rate.   The slower the cooling, the more of the

* The specific gravity of this form has not been determined, because the substance has not been obtained free from other forms.   Its average index of refraction is very close to that of the orthorhombic amphibole, but appears to be a trifle higher, so that we assume with some degree of probability that the specific gravities of the two amphiboles are related just as those of the two pyroxenes.

† Bull. Soc. Min., iv, 279, 1881.

‡ J. Lawrence Smith, this Journal (2), xxxviii, 225, 1864.

monoclinic form is obtained; hence we conclude that the Bishop-
ville meteorite was probably cooled rather rapidly from a high
initial temperature.   The occurrence of similar intergrowths of
the same minerals in many other meteorites indicates that the
above mode of formation is a general one, though ferrous sili-
cate, which is generally present, would lower the temperature
of crystallization.

Occurrence of unstable forms of the metasilicate in nature.—
Since the monoclinic magnesian pyroxene is the stablest form,
the question naturally arises, why does it not occur more fre-
quently in nature.   The probable explanation is that the mag-
nesium silicate of nature generally crystallized from solutions
or magmas, the temperature and viscosity of which conditioned
the formation of the enstatite or amphibole.

In the foregoing, it has been proved that under atmospheric
pressure the monocline pyroxene is the most stable form of
magnesium silicate, and it has been shown how various solvents
may transform the other polymorphs into this one.   Yet it is a
very common thing for unstable forms of enantiotropic, as
well as monotropic, substances to crystallize first[*] from solu-
tion, whether we start out with a stable or unstable form, pro-
vided the solution is not in contact with the stable solid; and
in one instance, that of mercuric iodide,[†] crystals of the unsta-
ble yellow variety sometimes form even in the presence of
nuclei of the red (stable) form, though they soon pass over into
the latter.

We had already found that the unstable amphibole forms
from *water* solutions at temperatures of 375°–475°, and it
seemed worth while to make the attempt to produce enstatite as
well as the orthorhombic amphibole from *silicate* (magmatic)
solutions at higher temperature.   We used for these experiments
portions of 50 to 60 grams, the solutions consisting of magne-
sium silicate mixed with about 10 per cent of its weight of vari-
ous other substances.   The results are recounted briefly below:

1. 40 grams magnesium silicate and 5 grams of ferric oxide were
   fused in a Fletcher furnace.   The heat was then turned off
   and the crucible allowed to cool in the covered furnace in
   which, as the walls are thick, the temperature falls at such a
   moderate rate that the pure magnesium silicate crystallizes
   almost entirely in the monoclinic form.   A microscopic exam-
   ination showed that the ferric oxide had not greatly influ-
   enced the crystallization.

* Regarding the crystallization of suphur, see Gmelin-Kraut, Handbuch
der Chemie, vol. 1, part 2, p. 155; and for similar facts about phosphorus,
see vol. 1, part 2, p. 10.   See also O. Lehmann, Molekular-Physik, vol. 1,
p. 193, for many other instances of this kind.
† Kastle and Reed, Am. Chem. Journ., xxvii, 217, 1902.

2 42 grams of magnesium silicate and about 4 grams of labradorite (Ab₁An₁) were melted and cooled under similar conditions. The magnesium silicate crystallized chiefly as monoclinic pyroxene with some enstatite present. Small amounts of glass, probably plagioclase glass, filled the interstices between the pyroxene laths.

3. To solution 1, 5 grams of orthoclase were added ; the whole was then fused and crystallized as before. This time a quantity of coarsely crystalline enstatite was produced. The orthoclase remained as glass.

4. 50 grams of magnesium silicate and 5 grams of albite were fused and cooled as before. The magnesium silicate crystallized mostly as enstatite, with the characteristic properties: paralled extinction, $c = c$, cleavage prismatic with an angle of about 90°, birefringence not strong, optically positive; 2E apparently larger than usual. The section consisted of clear enstatite laths and intercalated patches of a cryptocrystalline, dust-like aggregate which appears to contain albite and enstatite—perhaps a eutectic mixture of the two. Parts of the aggregate had a refractive index apparently equal to that of albite.

5. 46 grams magnesium silicate, 4 grams sodium metasilicate, and 1 gram potassium metasilicate were fused and cooled under the usual conditions. The cake was filled with beautiful prismatic crystals, the longest of which was 23^{mm} in length. Most of the magnesium silicate had crystallized as enstatite, though there was some of the monoclinic form. The optic axial angle of the enstatite was apparently larger than usual.

6. Preparation No. 4, consisting of the metasilicate with 10 per cent albite, was remelted and cooled more rapidly than the previous solutions. The product consisted chiefly of the low refracting, orthorhombic amphibole form of the metasilicate. Many of the fragments of the product were clearer and showed brighter interference colors than the amphiboles; they consisted of finely intergrown fibers of refractive index slightly less than that of the amphiboles (about 1·560) which may have been due to a solid solution of albite in the amphibole.

7. 4·6 grams of albite were added to 46 grams of the magma described under 6, giving a solution containing about 20 per cent as much albite as silicate of magnesium. The fusion was cooled like 6 and the low refracting amphibole formed. The grains were not clearly transparent and exhibited the dusty appearance observed in the albite-enstatite mixture of product No. 4. The refractive index and other optic properties coincided closely with those of the magnesium amphibole from pure melts.

Silicate solutions can probably be prepared from which the amphibole will crystallize by a process of slow cooling such as prevails in nature, but thus far we have not hit upon a composition which is effective.

In explaining the formation of enstatite in the above cases, the influence of temperature is doubtless of importance. When pure magnesium silicate is cooled slowly enough, i. e., when crystallization occurs at a temperature not too far below the melting point, only the stable monoclinic form is obtained; if cooled more rapidly, enstatite begins to form; still more rapidly, and we have amphibole; and finally, when we chill very suddenly, glass is the result. In all these cases, the temperature at which crystallization occurs is the lower the more rapid the cooling.

The first influence of these solvents is, therefore, no doubt, to lower the temperature at which crystallization takes place, though not all of them are equally effective; the addition of labradorite and ferric oxide makes less difference than albite, orthoclase and the alkaline silicates.

This explanation is, however, an incomplete one, otherwise why should fluxes like the vanadates of magnesium and calcium, tellurous oxide, and magnesium chloride, always give the monoclinic form even at considerably lower temperatures. Comparing these solutions with those which give rise to enstatite, we note at once that the one property which serves to distinguish the two classes is the viscosity. The monoclinic variety is obtained from thinly fluid solutions. At first sight it might appear otherwise with the vanadates, because the whole mass of silicate and vanadate from which we crystallize the silicate seems little more than pasty. The most of the mass is indeed undissolved solid, but the molten vanadates are comparatively thin and so no doubt is the solution which covers the surface of the grains of silicate and colors it yellow. The enstatite, on the other hand, was obtained from solutions which are comparatively viscous at the temperature of crystallization.

The influence which the viscosity of a solvent exerts on the transformation of unstable crystals which stand in contact with it, has been very well shown by Kastle and Reed.* The substance which they investigated was mercuric iodide, an enantiotropic substance with an inversion point at 128°. The yellow form is only stable above this point, yet below that it is always obtained from solutions whatever the solvent may be. The rate at which this form passes over into the red variety, stable at ordinary temperatures, depends on the viscosity of the solvent. Thus with certain mobile solvents like water, the transformation was complete in a very short time, while under a concentrated sugar solution the red appeared only after several days, in glycerine after two weeks, and in vaseline none appeared after a year and a half. In the case of mercuric iodide, so far as known, the unstable form always

* Loc. cit.

crystallizes no matter what the solvent, but this is not true in many other instances. It seems entirely reasonable to expect that if a solvent by its viscosity can hinder a transformation in the solid state, it may also in certain cases restrain the molecules in the act of crystallization from assuming the configuration characteristic of the stablest structure. And we might also expect viscosity to be especially effective where the transformation of the unstable form into the stable is effected with comparative difficulty, as it is in the case of the magnesium silicates. This would explain why enstatite comes out of a viscous silicate solution at a temperature much higher than that at which the monoclinic form is obtained from thinner solutions. At first thought one might be inclined to regard viscosity as directly conditioning the form of the crystal, and to look upon the temperature as merely influencing the viscosity, but further reflection convinces that this can not be so, for we obtained the amphibole from aqueous solutions at 375°–475°. The properties of aqueous solution in general, however, differ widely from others. It is probable that those movements of the molecule which depend directly upon temperature have a very important influence on crystallization. Although temperature and viscosity are certainly important factors in the formation of unstable modifications, the knowledge of the subject is still insufficient, and what we have is too little systematized to generalize in an entirely satisfactory way.

Formation of Amphiboles.—Regarding the formation of forms III and IV, it seems quite beyond the bounds of probability that they should be formed in nature by the rapid cooling, which, on a small scale, is effective. On the other hand, assuming that these forms are really amphiboles, the formation of at least one of them from aqueous solutions, at a temperature of 375°–475°, is consistent with recognized geological forces; at any rate, our experiments indicate that the two amphiboles form at lower temperatures than the pyroxenes. We are inclined to regard the pressure in these experiments as an unessential factor, except in so far as it is necessary to prevent the escape of water at these temperatures, because in the first place it has been seen that both substances (III and IV) could be obtained without pressure, and secondly, the specific volume of these amphiboles, as of all others, for that matter, is greater than that of the corresponding pyroxenes. According to Le Chatelier's principle, pressure should tend to produce the system of smallest volume.

Relation between Pyroxenes and Amphiboles.—Though we refrain from generalizing as yet in regard to the two great mineral groups, the amphiboles and the pyroxenes, we can say that the demonstration of an irreversible (monotropic) relation between each of the two magnesian amphiboles and the stable pyroxenes accords with the experience of many other investi-

gators that, experimentally, amphiboles may be readily changed into pyroxenes but not pyroxenes into amphiboles.

False Equilibria in Nature.—Since these studies have shown the instability of enstatite and the amphiboles of the composition $MgSiO_3$, it may be at once inferred that not all natural minerals are stable. The occurrence of the unstable forms alone constitutes what is commonly called a metastable condition (apparent false equilibrium of Duhem), in which it is generally assumed that equilibrium may be brought about by contact with the stable phase. In another part of this paper it has been demonstrated that such a contact is inadequate, in the case of the magnesium silicates, to determine equilibrium during periods of time which are within the limits of laboratory observation.

Duhem, in his Thermodynamique et Chimie (p. 436), draws a very apt comparison between chemical and mechanical systems. The statics of both are commonly treated as if the systems were frictionless, whereas in both we have to deal with a resistance which in the former is ordinary friction, in the latter an internal friction between the molecules. Chemical systems, in the majority of cases so far studied, seem capable of reaching a true equilibrium, or at least a state which approaches it within measurable limits, but where the systems are composed of viscous liquids or more especially of solids at low temperatures, true equilibrium may not be reached even after an indefinite time, the condition finally attained being not alone the result of molecular forces as conditioned by temperature and pressure, but of these retarding forces which offer an internal resistance of by no means negligible magnitude. (Duhem's genuine false equilibria.) We find in nature false equilibria of this kind, e. g., intergrowths of pyrite and marcasite[*] among the sulphides, and among the silicates intergrowths of sillimanite and andalusite, and enstatite with monoclinic pyroxene.[†] It has been generally supposed that the monoclinic pyroxene in the last-named case was a diopside, but our experiments show that similar aggregates form in artificial systems which contain no calcium and that they exist in the Bishopville meteorite. In some cases it is not at all impossible that these systems are in process of very slow change, but there is no optical evidence that this is true of the above-mentioned silicates; in other cases it may be that the two forms were deposited at different times, though in some it would appear that they were actually crystallized together; the important fact to note in them all is that they are systems which are not in equilibrium. Because a rock or mineral aggre-

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[*] Stokes, H. N., U. S. Geol. Survey, Bull. 186.

[†] We have also obtained intergrowths of the two magnesian amphiboles. Therefore the aggregates of monoclinic and orthorhombic amphiboles in nature probably form another example of this principle.

gate is found in nature, therefore, where it might be supposed to have had sufficient time for attaining equilibrium, is not a sufficient reason for assuming that it has actually reached the state of greatest stability.

Summary.

1. There are four crystal forms of magnesium metasilicate: (I) a monoclinic pyroxene, having the characteristic prismatic cleavage (92° and 88°), and a similar axial ratio $a : b$, but a ratio $c : a$, which varies widely from that of the pyroxenes; (II) an orthorhombic pyroxene identical with enstatite and optically very similar to (I); (III) a monoclinic modification corresponding to an amphibole in its optical properties; (IV) an orthorhombic form, optically also an amphibole and resembling (III) very closely. These forms, with the exception of (III), have been prepared in pure condition or with only traces of other forms; their optical properties have been studied, their specific gravities have been determined, their behavior on heating has been investigated, and, in the case of (I), measurable crystals have been obtained.

Forms (I) and (II) occur in nature, usually in mixed crystals with ferrous silicate, and it is quite probable that the same is true of (III) and (IV).

2. (I) is formed in pure condition by crystallizing a melt a little below the melting point (1521°), which may be readily accomplished by cooling slowly. Measurable crystals are obtained by heating any form of the metasilicate to about 1000° in molten magnesium chloride traversed by a stream of dry hydrochloric acid gas. Calcium vanadate, magnesium vanadate, magnesium tellurite, and other fluxes yield crystals which are not so well developed. All the other forms of magnesium silicate pass into (I) at temperatures between 1150° and 1300°, depending on the crystal form taken. (II). This form (enstatite) crystallizes at lower temperatures than (I); the purest preparation, containing only traces of other forms, is made by heating the glass of the same composition at a temperature between 1000° and 1100°; large crystals of enstatite (up to 23ᵐᵐ in length) were obtained in silicate (magmatic) solutions. (III) forms in very small quantities by rapidly cooling the melt; there is also evidence that it forms from (IV) when the latter is heated with water in a bomb to a temperature of 375°–475°. When an aqueous solution of magnesium-ammonium chloride, or magnesium chloride and sodium bicarbonate is heated with amorphous silica or sodium silicate, this substance is probably formed, though the crystal fibers are too small to decide whether the product is identical with (III) or with (IV). (IV) is obtained by heating the molten silicate high above the melting point, say to 1600°, and then cooling rapidly in air; it cannot be formed by heating the glass.

3. Of the four polymorphic forms of magnesium metasilicate, (I) is the stable form at all temperatures and the others are monotropic toward it, the order of stability being I, II, III, IV. This order is established by changing one form into another at various temperatures and by proving that (II) and (IV) change to (I) with evolution of heat. (III) has not been obtained in sufficient quantity for this test. Though enstatite and the amphiboles are not stable, any more than glasses are, on account of the great internal friction of the molecules, they have less tendency to change, when once formed, than many glasses. We cannot state definite limits of stability for the various minerals, as it is possible to do where the relation is enantiotropic; it is possible, however, to fix certain temperature limits below which one of these forms may crystallize from a melt of pure magnesium silicate. Thus enstatite could only form below about 1250°, since above that temperature it passes into the monoclinic form; but it must be remembered that in the silicate solutions of nature this limit would probably always be lower on account of the general occurrence in them of such compounds as ferrous silicate.

4. The specific gravities of the four forms, in the order of their stability, are: (I) monoclinic pyroxene, 3·192; (II) orthorhombic pyroxene (enstatite), 3·175; (III) monoclinic amphibole, not determined directly, but its relation to (II and (IV) is fixed by its index of refraction; (IV) orthorhombic amphibole, 2·857.

5. While our experiments do not settle completely the mysteries of the formation of unstable bodies, they do show that temperature and viscosity are two factors of prime importance. Thus, from melts or from silicate solutions, the stable monoclinic form of magnesium metasilicate crystallizes at the highest temperature, enstatite next, and the amphiboles probably lowest of all. From *thin solutions* the stable form is obtained at still lower temperatures, 800°–1000°, while from *aqueous solutions* at 375°–475° an amphibole results.

6. Our study of the Bishopville meteorite indicates that it must have been cooled very rapidly from a high initial temperature, and there is evidence that the same is true of other meteorites.

7. The intergrowths of enstatite with the monoclinic pyroxene, and of the two amphiboles, which we obtained in close resemblance to those of nature, are cases of falsee quilibrium, and their occurrence establishes the fact that it cannot be assumed that all rocks or mineral aggregates are systems in true equilibrium.

8. In the course of the investigation a useful method has been developed for detecting sluggish heat changes.

Geophysical Laboratory,
　　Carnegie Institution of Washington, July, 1906.

Art XXXVIII.—*Contributions to the Geology of New Hampshire: No. II, Petrography of the Belknap Mountains;* by L. V. Pirsson and H. S. Washington.

In a former paper* we presented the results of our studies in the field of the igneous rock masses composing the Belknap Mts. in New Hampshire, and in the present one we purpose to give the results of our investigations of them in the laboratory by microscopic and chemical methods. We have found that the following rocks, classified both in the quantitative and in the older systems, are present:

Class	Order	Rang
Persalane	Britannare	Liparase
Persalane	Britannare	Toscanase
Persalane	Canadare	Pulaskase
Dosalane	Germanare	Monzonase
Salfemane	Gallare	Camptonase

Subrang		Older System
Liparose	(I. 4.1.3)	Aplite
Lassenose	(I. 4.2.4)	Adamellite
Pulaskose	(I. 5.2.3)	Syenite
Akerose	(II. 5.2.4)	Spessartite
Camptonose	(III. 5.3.4)	Essexite and Camptonite

These will be described in the above order and the article will end with a discussion of the petrologic history and of the chemical characters of the district.

Liparase. Aplites.

As previously stated in the foregoing geological description of the district, the Belknap massif and the surrounding metamorphic rocks are cut by dikes and intrusions of fine-grained to dense granitic, quartzose rocks, whose general characters place them under this rang. In Rosenbusch's system of classification they would be aplites, both in the broader and in the more special application of this term. A similar material serves also as the cement of the brecciated zone on Locke's Hill. They have all been studied in thin section, but for purposes of chemical analysis an average type has been selected whose description follows herewith.

Biotitic-grano-liparose (*aplite*).

Locality.—Dike on upper southwest slope of Mt. Belknap. *Megascopic.* — Phanerocrystalline; fine-grained; flesh-colored; persalic and dominantly feldspathic; faintly dotted with

* This Journal, vol. xx, pp. 344–352, 1905.

gray to black specks; apparently equigranular in texture but subporphyritic, with occasional phenocrysts of feldspar 2-3^{mm}; of a sugar granular habit; fracture easy and brittle; superficially slightly weathered.

Microscopic.—Alkalic feldspar and quartz essential; biotite, iron ore, allanite and zircon accessory.

Alkalic feldspars consist of orthoclase and albite in roughly equidimensional anhedral grains. Some albite-oligoclase noted, subtabular to subprismatic in form; albite and Carlsbad twinning. Phenocrystic feldspars roughly equidimensional or cuboidal, of orthoclase with much perthitic intergrowth of soda-microcline and albite. *Quartz*, equidimensional, anhedral, sometimes micrographic with feldspar. Quartz and feldspar of groundmass average 0·5^{mm}. *Biotite* dark brown, pleochroic, tabular, platy and in shreds, subhedral; about 0·2^{mm}, thinly scattered. *Hornblende* very rare, pleochroic, dark green

	I	II	III	IV	V	VI	VII
SiO$_2$	75·65	76·49	76·05	76·64	76·03	74·12	1·261
Al$_2$O$_3$	12·89	11·89	11·68	13·50	11·76	12·39	·126
Fe$_2$O$_3$	0·89	1·16	0·34	0·50	1·99	0·31	·006
FeO	1·11	1·56	1·05	n.d.	n.d.	0·21	·015
MgO	0·20	tr.	0·29	0·12	0·27	0·42	·005
CaO	0·48	0·14	0·42	0·65	0·45	0·30	·009
Na$_2$O	3·71	4·03	3·79	3·48	3·36	3·22	·060
K$_2$O	5·50	5·00	5·09	5·51	5·61	5·07	·059
H$_2$O 110°+	0·15	0·12	1·36	n.d.	0·63	2·17	----
H$_2$O 110°−	0·08	0·38	----	----	----	2·22	----
TiO$_2$	0·05	tr.	0·05	----	----	----	----
P$_2$O$_5$	n.d.	----	----	----	----	...	----
MnO	"	tr.	----	----	----	tr.	----
ZrO$_2$	"	----	·42	----	----	----	----
	100·71	100·77	100·54	100·40	100·10	100·33	

I. Biotitic-grano-liparose (aplite); dike on upper southwest slope of Mt. Belknap. H. S. Washington analyst.

II. Riebeckite-phyro-liparose (paisanite); Magnolia, Mass. Washington, Jour. Geol. vii, 1899, p. 113.

III. Liparose (quartz porphyry); Drammen, Norway; Lang, Nyt. Mag. xxx, p. 40, 1886; P. Jannasch analyst.

IV. Liparose (granitite); Arild, Kullen, Sweden; A. Hennig, Act. Univ. Lund, xxxiv, 1898. Hennig analyst.

V. Liparose (quartz porphyry); Thal, Thüringerwald, Baden; K. Futterer, Mitth. Bad. Geol. Ld. Anst. II. p. 58, 1893.

VI. Liparose (trachyte); Wantialable Creek, Gowen Co., New South Wales; G. W. Card, Rec. Geol. Surv. N. S. W., iv, p. 116, 1895. Mingaye analyst.

VII. Molecular proportions of No. 1.

and yellow, in shreds or anhedral grains, 0·1 to 0·05^{mm}. *Allanite* rather rare, strongly pleochroic, clear dark brown and orange yellow, zonally built; well crystallized; about 0·1^{mm}; commonly attached to iron ore or biotite. *Zircon* rare, colorless, equidimensional subhedral grains, about 0·2–0·1^{mm}. *Iron ore* uncommon; anhedral; about 0·1^{mm}. Traces of chlorite and kaolin. Fabric porphyritic, but not markedly so, the phenocrysts being rare; remaining grains somewhat grading in size but tending to be equidimensional and interlocked.

Mode.—The chemical analysis and the calculation of the norm show that there cannot be over 4 per cent of iron ores, biotite, hornblende, allanite, zircon, etc., present, the remainder being feldspars and quartz in the proportions indicated in the norm. The mode is therefore normative.

Chemical Composition.—This is shown in No. 1 of the table.

For the sake of comparison a number of analyses of liparose from other localities have been added and it is of interest to observe how these almost identical magmas under varying physical conditions have assumed different textures, so that under systems of classification where texture plays an important part they have been given quite different names and are widely separated in the system. They are all magmas of alkalic nature, as will be shown later.

Norm and Classification.—By using the molecular ratios given in No. VI of the above table we may calculate the norm to be as follows:

$$
\left.
\begin{array}{ll}
\text{Quartz} & 31\cdot02 \\
\text{Orthoclase} & 32\cdot80 \\
\text{Albite} & 31\cdot44 \\
\text{Anorthite} & 1\cdot95
\end{array}
\right\} \quad \text{Sal} = 97\cdot21 \quad \frac{\text{Sal}}{\text{Fem}} = \frac{97\cdot2}{3\cdot3} = 29,\ \text{I},\quad \text{Persalane}
$$

$$
\frac{\text{F}}{\text{Q}} = \frac{66\cdot19}{31\cdot02} = 2\cdot1,\ 4,\quad \text{Britannare}
$$

$$
\left.
\begin{array}{ll}
\text{Diopside} & 0\cdot46 \\
\text{Hypersthene} & 1\cdot46 \\
\text{Magnetite} & 1\cdot39 \\
\text{Water, etc.} & 0\cdot28 \\
\hline
\end{array}
\right\} \quad \text{Fem} = 3\cdot31
$$

$$
\frac{K_2O' + Na_2O'}{CaO'} = \frac{119}{7} = 17,\ 1,\quad \text{Liparase}
$$

$$
\frac{K_2O'}{Na_2O'} = \frac{59}{60} = 0\cdot98,\ 3,\quad \text{Liparose}
$$

Total .... 100·80

From the consideration of the analysis and the above norm and by the study of the section it is easily seen that the iron ore, allanite and biotite, are present in negligible amounts and that, as previously stated, the rock has a normative mode. It is therefore normative granophyro-liparose, but if the slightly porphyritic nature which is in no wise characteristic be neglected and the small amount of biotite be taken into con-

sideration this would become biotitic grano-liparose. In the prevailing terminology it would be a granite aplite.

Alkalic character of the rock.—The alkalic nature of rocks, which, like this one, are of high silica content, is to a great extent masked by the large dilution with silica. In a general way we might compare magmas to mixed solutions of salts in water. The ratios of the salts or the oxides which compose them and which give the mixture its general chemical character remain the same whether the compound solution be dilute or concentrated. While the analogy with molten magmas is not exact, since the silica plays a rôle different from water, it will serve in a general way, as the ratios of the metallic oxides are a very characteristic feature. In rocks containing about 55 per cent of silica, the expression of the alkalic nature becomes most evident, so that in speaking of alkalic rocks petrographers are apt to have in mind those which contain about this percentage of silica. Yet rocks with high silica percentages may be as alkalic relatively to the other components as with low. This may be illustrated as follows. Let us take the liparose just described and reduce the silica to

	I.	II.		Ia.	IIa.
SiO_2	75·65	55·02	Quartz	31·02	----
Al_2O_3	12·89	23·14	Orthoclase	32·80	58·38
Fe_2O_3	0·89	1·60	Albite	31·44	4·19
FeO	1·11	1·99	Nephelite	----	28·12
MgO	0·20	0·36	Anorthite	1·95	3·89
CaO	0·48	0·86	Diopside	0·46	----
Na_2O	3·71	6·66	Hypersthene	1·46	----
K_2O	5·50	9·87	Olivine	----	2·11
H_2O	0·23	0·41	Magnetite	1·39	2·32
TiO_2	0·05	0·09	Water, etc.	·28	·62
Total	100·71	100·00	Total	100·80	99·63

55 per cent, or in other words, we will subtract 45 per cent of silica from the magma, leave all the other oxides in the original proportions, and reduce the whole to 100. The result is seen in columns I and II of the above table, and their calculated norms, or those minerals which they would naturally form if in a state of dry fusion without the aid of the mineralizers necessary to condition the formation of such alferric minerals as mica and hornblende, are seen in Ia and IIa. II and IIa show the chemical and mineral composition of a characteristic " foyaite," of a somewhat potassic character. To change this to the granite of I it is necessary to dilute it with 82 per cent of its own weight of silica, a figure which shows the great amount of dilution the alkalic magmas of high silica content

suffer, with the consequent masking in large degree of their true character. In the quantitative classification this is obviated to a great extent, for such rocks fall in peralkalic rangs, which fact at once reveals their nature.

At first thought all this may seem merely a rather forceful way of putting well known facts, but the application of it serves to bring out some points in a disputed field. In the endeavor to use the genetic relations of igneous magmas for purposes of classification, it is often implied, if not expressly stated, that we should not expect to find strictly alkalic rocks associated with those of other series, with the granite-diorite or diorite-gabbro families of Rosenbusch, alkalicalcic or docalcic magmas in the new classification. If the idea of alkalic rocks is however broad enough to include those greatly diluted with silica but in which the other oxides are in the proper proportions, as it rightfully should be, then numerous examples which contradict the general supposition mentioned immediately come to mind. Thus in the Yellowstone Park region, as shown by Iddings,* the main lavas extruded have been "rhyolites, andesites and plagioclase basalts," a really typical granito-diorite-gabbro series. An examination of the analyses of these lavas† shows that many of the rhyolites, such as those of Obsidian Cliff, are of highly alkalic nature, belonging in peralkalic rangs which with less dilution by silica would have formed trachytes or phonolites.

Liparase.—The type just described was selected as illustrative of the granitic dikes in the area. There is some variation among them in texture, but so far as one can tell by study of the sections they are certainly peralkalic persalanes and apparently are quardofelic. They fall therefore in liparase and judging by analogy are probably sodipotassic and belong in liparose. This last, however, could not be definitely determined without making chemical analyses, a work whose results would not justify the time and labor. A few words may be added concerning the textural variations of the different occurrences.

Gunstock Dike.—The summit of Mt. Gunstock is cut by a dike three feet wide with the following megascopic characters : phanerocrystalline ; inequidimensional ; usually porphyritic with medium phenocrysts ; pale flesh color ; phenocrysts of orthoclase 2–5^{mm}, ill defined, cuboidal to subtabular, scattered ; groundmass fine-grained 1^{mm} or less, dotted with minute gray-black specks. Under the microscope the minerals are the same as those mentioned in the type described, including allanite ; the groundmass is similar but is thickly crowded with

* Quar. Jour. Geol. Soc., vol. liii, 1896, pp. 606–617.
† Bull. U. S. Geol. Surv., 228, p. 120, 1904.

subhedral phenocrysts of alkali feldspar. The rock is grano-phyro-liparase or quartz syenite porphyry.

Belknap Dikes and other Occurrences.—On the upper slopes of Mt. Belknap dikes are found of widths varying from a few inches to twenty feet, of branching and anastamosing character. A large one, 20 feet in width, occurs on the shoulder of the west spur of Mt. Gunstock. They are also found as narrow dikelets in the massive rock composing the lower west slopes of Locke's Hill. They are flesh-colored rocks, compact, dense, microcrystalline, showing occasional, scattered phenocrysts of feldspar. Under the microscope they are very fine-grained to almost crypto-crystalline mixtures of quartz and alkali feldspar. In those where the grain is coarser shreds of biotite appear. The feldspar phenocrysts are sometimes of oligoclase but mostly alkalic feldspar and offer nothing of especial interest. In those with the finest grain the material is apt to be arranged in micropoikilitic patches. They are too fine for metric analysis, but their whole character and relations are such that we have placed them provisionally under liparase, though it is possible that sometimes they are quarfelic instead of quardofelic and should be classed as alaskase. In Rosenbusch's system they would probably be termed quartz-bostonites, especially if their relations and genetic associations with the syenite and camptonite be taken into account.

Other instances are found in dikes cutting outward through the enclosing schists at the west foot of Mt. Gunstock. These are fine-grained, megascopically even granular or homometric rocks of pale yellowish to flesh color whose average diameter of grain is about 1^{mm}. They evidently belong under this heading and no further description of them is necessary. In the older systems they would be classed as fine-grained granites or aplites. They stand in evident relation with the pegmatitic masses of quartz and feldspar found in the schists at the head of the Gunstock River.

The Breccia Cement.—As already described in the foregoing part on geology, there is on the lower southwest foot of Locke's Hill a brecciated mass consisting of blocks of various character and of all sizes embedded in a fine-grained aplitic granite intrusion. The study of a number of sections of the latter rock shows that it belongs here in liparase. It is composed of alkalic feldspar and of quartz with occasional larger phenocrystic alkalic feldspars, which are mostly alkalic but sometimes oligoclase. Occasional shreds of biotite, grains of iron ore and zircon occur.

The rock is so like the type analyzed and described and the Gunstock dike that it must be considered as of the same mag-

matic character and probably contemporaneous with them, as will be shown later. In its deficiency of plagioclase feldspar it is unlike the aplitic lassenose (adamellite) of the border facies of the main mass next described, and this fact, which is of importance, will be discussed later.

Biotitic-grano-lassenose (*adamellite aplite*).

As previously mentioned in the geological part of this paper, the Belknap massif of grano-pulaskose shows on nearly all sides a marginal facies of a light-colored granitic rock into which it gradually passes. Examples of this from various parts of the area have been studied and it has been found to have on the whole a pretty constant composition and character. Its geological occurrence and relationships have been described under the heading of the contact facies of fine-grained granite, using the latter name as a field term.

For purposes of analysis, detailed microscopic study and description, a type specimen was selected from the south end of Piper Mountain, where it is exposed in a cliff near the high road running through the notch to Young's Pond.

Megascopic.—Phanerocrystalline; fine-grained; light brownish gray; dominantly quartzo-feldspathic but dotted with minute specks of black biotite and shining white muscovite; of an even granular texture with sugar granular habit and feel; distinctly gneissoid and with perceptible eutaxitic structure; of an easy fracture and rather friable.

Microscopic.—Alkalic feldspar, andesine and quartz essential, biotite and muscovite accessory. Essential minerals present in approximately equal amounts. Average size of grain 0.2^{mm}: occasional individuals much larger but not phenocrystic; some smaller. *Alkalic feldspar*, OrAb, equidimensional anhedral. *Andesine*, Ab_5An_3, equidimensional anhedral to subtabular or subprismatic; albite twinning common, Carlsbad not common, pericline rare. *Quartz* equidimensional anhedral, often spheroidal. *Biotite* brown with not intense pleochroism, in form tabular to scaly. *Muscovite* tabular and scaly.

Mode.—For the determination by Rosiwal's method of the relative amounts of minerals making up the rock, 150 measurements were made in a distance of 3000 units. The average size of grain was 0.2^{mm}. Reduced from volumes to percentages by weight this gave:

Quartz	33·50
Orthoclase	30·86
Andesine (Ab_5An_3)	31·04
Biotite	3·77
Muscovite	·83
	100·00

If we neglect the small amount of K_2O which is in the micas and consider all of the lime and alkalies shown by the analysis as in feldspar, the total weight of the latter thus calculated would be 60·15 per cent while the above by measurement gives 61·90 per cent. The andesine was determined as Ab_5An_3 by a number of measurements. If we take the amount of lime shown by the analysis and convert it into Ab_5An_3 it gives 34·30 per cent and the amount of soda-orthoclase remaining would be 25·85, which is not a bad agreement with that obtained from the measured areas, especially if one takes into account the fact that some of the untwinned areas of andesine are liable to be measured as orthoclase.

Chemical Composition.—This is shown in the following analysis, No. 1 of the table:

	I	II	III	IV	V
SiO_2	69·76	69·70	69·43	68·11	1·163
Al_2O_3	18·22	18·72	15·74	15·80	·178
Fe_2O_3	0·25	0·65	0·93	1·97	·002
FeO	1·59	0·79	3·35	1·87	·022
MgO	0·40	0·45	1·35	0·96	·010
CaO	2·68	2·25	2·07	2·43	·048
Na_2O	4·06	5·01	4·56	4·40	·066
K_2O	2·06	1·68	2·99	2·80	·022
H_2O 110°+	0·50	0·71	·10	0·54	----
H_2O 110°−	0·15	----	----	·16	----
CO_2	none	----	---- x=	·75	----
TiO_2	0·36	----	----	.07	·005
Total	100·03	99·96	100·52	99·87	

I. Biotitic grano-lassenose (granite-diorite-aplite ?). South end of Piper Mt., Belknap Mts., N. H. H. S. Washington analyst.

II. Lassenose (quartz porphyry) ; Kawishiwi River, Minnesota (Grant, An. Rep. Geol. Nat. His. Surv. Minn., p. 43, 1893). A. D. Meeds analyst.

III. Lassenose (andengranit) ; Juncal Valley, Argentina (Stelzner, Btr. Geol. Arg. Rep. I, p. 208, 1885). H. Schlapp analyst.

IV. Lassenose (granite) ; Mühlberg, Odenwald, Hesse (Chelius, N. J. 1884, II, p. 419, x = P_2O_5 0·62 ; SO_3 0·13).

V. Molecular ratios of No. I.

While some of the combined water shown by the analysis is of course in the micas, the amount seems too large for the percentage of these minerals present. The high alumina, which as seen in the calculation of the norm cannot all be referred to feldspar, is also too great for them and the micas. This might indicate some kaolin, but the rock appears remarkably fresh under the microscope and kaolin is absent. It is difficult to know to what to attribute the high alumina. Nothing seen in

the section exactly explains it, and the analyst is confident that it is not to be attributed to admixture of magnesia.

In comparing the composition of this rock with similar ones, as seen in the table, the predominance of soda over potash, producing as it does an amount of plagioclase equal to the alkalic feldspar, causes a certain difficulty, if one pays attention to the older systems of classification. This may be seen by referring to the analyses included under the subrang of lassenose in the tables of analyses recently published by one of us.[*] One sees under this subrang, which includes rocks of a similar chemical composition, types which have been called granites, syenites and quartz diorites, as well as rhyolites, dacites, andesites and trachytes, indicating the middle position which such a magma holds.

Classification.—In the quantitative system the norm of the rock calculated from the molecular ratios is as follows :

Qz	30·72	30·72		
Or	12·23			
Ab	34·58	60·15	95·15	
An	13·34			
Co	4·28	4·28		
Hy	2·98			
Mt	·46	4·20	4·20	
Il	·76			
H₂O	·65			

$$\frac{Sal}{Fem} = \frac{95 \cdot 15}{4 \cdot 20} = 22 \cdot 6 \quad \text{Persal-ane, 1}$$

$$\frac{Q}{F} = \frac{30 \cdot 72}{60 \cdot 15} = 0 \cdot 51, \quad \text{Britan-nare, 4}$$

$$\frac{K_2O' + Na_2O}{CaO} = \frac{88}{48} = 1 \cdot 8, \quad \text{Toscan-are, 2}$$

$$\frac{K_2O'}{Na_2O'} = \frac{22}{66} = 0 \cdot 33, \quad \text{Lassenose, 4}$$

Total, 100·00

Place formula, I, 4, 2, 4.

The extra alumina above that needed to produce feldspars is shown above by the production of 4·28 per cent of corundum among the normative minerals. The texture is granular, the micas are not present in notable amount and the mode is therefore normative. If it is desired to note the small amount of biotite present the rock is therefore a biotitic-grano-lassenose.

In the prevailing qualitative systems it is somewhat difficult to place this rock. It is a marginal facies of a syenite mass with aplitic habit showing some fluidal structure, and it stands mineralogically exactly on the line between the granite and diorite families. If we determined it as an aplite from its minerals and texture and used Brögger's definition of the monzonite family, it would be a quartz monzonite aplite or adamellite aplite.[†] Or it might be called a grano-diorite aplite, using grano-diorite, as many have done, to signify a transition rock between the granite and diorite families.

[*] Chem. Anal. Ign. Rocks, U. S. Geol. Surv., Prof. Paper 14, 1903, p. 173.
[†] Brögger, Predazzo. Vid. Selsk. Skrift. M-N. Kl. 1895, No. 7, p. 60.

Inclusions in Lassenose.—In the border facies of the mass are to be seen, as noted by Hitchcock, dark inclusions or schlieren of variable size. Sometimes these are angular and of definite shape. Under the microscope they show the characteristic minerals, such as quartz, brown mica, iron ore, etc., and the fabric seen in certain hornfels, and are no doubt fragments of schists, etc. caught up and metamorphosed by the magma. In other cases, as in the occurrences on the slopes above Point Belknap, they may have no definite form but are streaks and smears through the rock. The study of them in thin section reveals a type of rock closely allied to monzonase, monzonites in the current nomenclature. They are composed of a colorless to pale green pyroxene, green hornblende and brown biotite, labradorite and alkalic feldspar with accessory iron ore, apatite, etc. The labradorite is in stout laths which serve as cores for irregular ragged masses of feldspar, the plagioclase core passing outwardly into alkalic feldspar mantles. Broad areas of the soda orthoclase also occur poikilitically enclosing other minerals. The amount of the ferromagnesian minerals, though variable from place to place in kind, is in amount nearly equal to the feldspathic. The masses in fact closely recall types from Monzoni and Yogo Peak, Montana. They are believed to be of magmatic and not of foreign origin, and the study of the brecciated zone on the west side of Locke's Hill, as described elsewhere, throws light on their origin.

Hornblendic-grano-pulaskose (*syenite*).

This is by far the most important rock in the area from the geologic point of view, as it forms the major part of the great massif. A certain type of it appears to be rather uniform over the exposed area, although minor variations which will be described occur from place to place. For purposes of chemical and microscopical analysis and study a representative specimen was selected from a ravine on the west slope of Mt. Belknap about a third of the way from Morrill's farm house to the top of the peak.

Megascopic. — Phanerocrystalline; medium to coarse-grained; pale reddish, white to gray; dominantly feldspathic but sparsely dotted with anhedra of black hornblende and of biotite; of a granular to subporphyritic fabric; feldspars mostly equidimensional, occasionally larger than the average and subtabular to prismatic; fracture rather crumbly; superficially somewhat altered.

Microscopic.—Alkalic feldspar and hornblende essential; biotite, iron ore, apatite, oligoclase-andesine, quartz and zircon accessory.

The *feldspars* consist of orthoclase with microperthite intergrowths of soda microcline. In a section perpendicular to c and nearly parallel to *b* (010), oriented by the good cleavage of *c* (001) and rough parting parallel to *m* (110) and by the arrangements of inclusions giving the direction of the vertical axis and a measured angle for *β* of 64°, the main feldspar extinguished at 7° from the trace of the base *c*, that of the microperthite intergrowths at 11° in the obtuse angle *β'*. Thus the main crystal is of orthoclase, the intergrowths of soda-microcline (anorthoclase). The amount of these intergrowths is very large, indeed in most cases they appear to be as great as, or even greater in volume than, that of the host crystal. Sometimes these intergrowths show distinct multiple twinning and the optical properties prove them to be of oligoclase-andesine (Ab_2An_1). Feldspars enclose all the other minerals save quartz. They are in formless masses, at times having poor tabular development, with Carlsbad twinning common. No microcline was observed, and the feldspars are somewhat kaolinized.

The *hornblende* is in anhedral masses, at times poorly developed as short columns. Prismatic cleavage is good. It is strongly pleochroic: c, olive-green to deep green; b, olive-brown; a, pale brown; absorption medium strong, $c>b>a$. Angle of *c* on $c = 18°–20°$. From these properties it is probably a mixture of the common hornblende and barkevikite molecules. It rarely contains a paler green core, and includes iron ore, zircon, apatite and biotite. In some places it is altering into a reddish substance, probably göthite. The rock at the summit of Gunstock contains 13·4 per cent of hornblende; the type analyzed has somewhat less, probably not over 8 per cent.

Biotite is quite subordinate in amount, while in other varieties of the massif it becomes more abundant, increasing with the amount of quartz, and in the marginal facies, which are rich in the latter mineral, it entirely replaces hornblende. It is of the type of common biotite, brown, strongly pleochroic, with inclusions of iron ore, apatite and zircon and with pleochroic halos. It is older than hornblende and automorphic against it, and quite unaltered. *Iron ore* occurs in occasional scattered grains. *Zircon* is present in crystals varying from excessively minute microlites to some of good size, rather common and sowed through all the later minerals. It is well crystallized with *m* (110) and *p* (111) well developed. *Apatite* is also common in slender microlites and larger stout prisms.

Quartz is seen in very small amount in the type specimen in small xenomorphic masses, serving as a cement between the other minerals. It is too rare to characterize the rock as quartz-bearing. In a variety on the top of the hill beside the road from Gilford to West Alton it is entirely lacking in two thin

sections. In the lassenose marginal facies of the massif, as noted above, it becomes quite abundant.

In addition to the above, two or three small sections of an indeterminable brown mineral were noted. It is strongly pleochroic, varying from a clear chestnut brown to practically opaque, like ænigmatite. The refractive index is about that of hornblende; birefringence not high, but as the sections are cut nearly perpendicular to an optic axis whose bar crosses the field, in conjunction with the deep absorption, this cannot be well told, nor can any other optic characters be determined. The bar crosses the field without apparent bending, but it is not certain that the mineral is uniaxial. The color is unusual for tourmaline, the absorption too strong for cassiterite; if biaxial the color and absorption much deeper than ordinarily seen in allanite and much like that of ænigmatite, but the mineral associations scarcely suggest the latter. It seems most probable that it is an unusually deep-colored allanite.

ANALYSES OF PULASKOSE, ETC.

	I	II	III	IV	V	VI
SiO_2	60·75	60·20	65·54	63·71	63·20	1·013
Al_2O_3	19·68	20·40	17·81	18·30	17·45	·193
Fe_2O_3	1·54	1·74	0·74	2·08	3·60	·010
FeO	2·98	1·88	1·15	2·52	n. d.	·041
MgO	0·81	1·04	0·98	0·09	0·75	·020
CaO	2·29	2·00	1·92	1·18	1·40	·041
Na_2O	4·89	6·30	5·55	6·39	6·90	·079
K_2O	5·90	6·07	5·58	6·21	5·88	·063
H_2O 110°+	0·08	0·23	0·54	0·17	0·50	....
H_2O 110°—	0·24	0·10	....	0·09	....	....
CO_2	....	none	....	....	....	- ..
TiO_2	0·63	0·14	0·11	tr.	0·46	·008
P_2O_5	tr.	0·15	tr.	....	....	....
SO_3	....	0·13	....	....	....	....
Cl	....	0·09	....	....	....	....
MnO	tr.	tr.	tr.	tr.	....	....
Total	99·79	100·47	99·92	100·74	100·14	

I. Pulaskose (syenite). West slope of Mt. Belknap, N. H. Washington analyst.

II. Pulaskose (pulaskite). Fourche Mountain, near Little Rock, Arkansas. Washington analyst (Jour. Geol. ix, 1901, p. 609).

III. Pulaskose (syenite). Highwood Peak, Highwood Mts., Montana. Pirsson and Mitchell analysts. (This Jour. i, 1896, p. 295.)

IV. Phlegrose (pulaskite). Salem Neck, Essex Co., Mass. Washington analyst. (Jour. Geol. vi, 1898, p. 806.)

V. Nordmarkose (nordmarkite). Tönsenas, near Christiania, Norway. G. Forsberg analyst. (Brögger, Zeitschr. Kryst. xvi, 1890, p. 54.)

VI. Molecular ratios of No. I.

Mode.—The rock is too coarse-grained to determine the actual mineral composition on ordinary sections by the Rosiwal method with any degree of accuracy, but from measurements made on the hand specimen with a millimeter scale it appears that about 10 per cent of alferric minerals, chiefly hornblende, are present, the remainder being alkalic feldspar with a little quartz.

Chemical Composition.—The analysis of the specimen gave the result shown in No. I of the foregoing table:

The very small amount of water yielded in the analysis proves that the rock is really in a very fresh and unaltered condition and that the pink color and slight staining are quite superficial.

For comparison two other analyses of pulaskose are added, one the typical rock from Arkansas and one described by one of us from Montana, and also a phlegrose from Massachusetts. In some ways the rock is closely related to nordmarkose from Norway and the analyses are not very different. The greater amount of lime in the Belknap rock throws it in the domalkalic rang and the larger relative amount of potash compared with the soda into the sodipotassic subrang, nordmarkose being peralkalic and dosodic.

Classification.—In the quantitative system the norm is calculated to be:

Quartz .... 2·04
Orthoclase . 35·03
Albite ..... 41·39
Anorthite .. 11·40
Corundum.. 1·02

} 90·88

$$\frac{\text{Sal}}{\text{Fem}} = \frac{90·88}{8·61} = 10·05, \text{ I,} \quad \begin{matrix}\text{Persal-}\\ \text{ane}\end{matrix}$$

$$\frac{Q}{F} = \frac{2·04}{87·82} = 0·02, \text{ 5, Canadare}$$

Hypersthene 5·30
Magnetite .. 2·09
Ilmenite ... 1·22
Water 32

} 8·61

Total ...... 99·81

$$\frac{K_2O' + Na_2O'}{CaO'} = \frac{142}{41} = 3·4, \text{ 2,} \quad \begin{matrix}\text{Pulas-}\\ \text{kase}\end{matrix}$$

$$\frac{K_2O'}{Na_2O'} = \frac{63}{79} = 0·8, \text{ 3, Pulaskose}$$
(I, 5, 2, 3.)

From this table and from what has been stated regarding the fabric and component minerals, the rock should be termed a normative-hornblendic grano-pulaskose.

The lime-alumina molecules which form anorthite in the norm are divided between the oligoclase-andesine and hornblende of the mode, but the latter of these minerals is not present in sufficient amount to render the mode abnormative. In the prevailing qualitative systems the rock would be a typical syenite and would belong to the Albany type of Rosenbusch.

Variations from the type.—The rock described may be assumed to be about the average of the Belknap massif, as it agrees with the microscopic examination of most of the specimens. Indeed all of them are obviously of the perfelic order and of the sodipotassic subrang. While most of the material undoubtedly belongs to the persalane class there is a distinct tendency in some to be dosalic, through increasing content in alferric minerals. Similarly labradorite appears and may be present in variable amount so that the rang will vary from peralkalic to domalkalic, the latter being the more common as in the type specimen.

In order to test the amount of variation which, as stated in the geologic description, appears to take place chiefly as the outer border is approached, the mode of two other specimens was determined by Rosiwal's method with the results given below. Of these No. I is from the exposure in a ravine in the little drainage on the south west side of Locke's Hill and not far from the contact. No. II is from the very summit of Gunstock peak.

	Mode.			Chem. composition.			Mol. ratios.	
	I.	II.		I.	II.		I.	II.
Qz	16·06	4·25	SiO_2	68·16	59·91		1·106	·998
Or	72·31	67·95	Al_2O_3	15·27	15·82		·150	·155
Ab_3An_4	0·00	2·53	Fe_2O_3	0·88	2·93		·006	·018
Hb	0·35	13·38	FeO	1·87	4·61		·026	·064
Bt	9·93	7·59	MgO	1·26	1·64		·032	·041
Mt	1·15	3·82	CaO	0·15	1·92		·003	·034
Ap	0·20	0·48	Na_2O	4·30	4·52		·069	·073
			K_2O	7·06	6·61		·075	·070
Total	100·0	100·00	H_2O	0·37	0·43			
			TiO_2	0·59	1·39		·007	·018
			P_2O_5	0·09	0·22		·001	·002
				100·00	100·00			

	Norms.	
	I.	II.
Qz	13·62	1·86
Co	0·61	- - - -
Or	41·70	38·92
Ab	36·15	38·25
An	- - - -	3·34
Di	- - - -	3·65
Hy	4·92	6·00
Mt	1·39	4·18
Il	1·06	2·74
Ap	0·24	0·50
H_2O	0·37	0·43
	100·06	99·87

From this No. I is I, 4, 1, 3 = liparose and No. II is II, 5, 1, 3, = ilmenose. While these two norms are not entitled to quite the weight of that derived from the chemical analysis, yet, as the modes were determined on sections of large size (50×40^{mm}, rock surface) and from a very large number of measurements, a fair degree of confidence may be placed in them.* Suitable compositions were assumed for the hornblende and biotite in working out the chemical composition, and since their amounts are not large the error in this direction must be inconsiderable. Assuming this, it is evident that considerable variation exists in the outer exposed portion of the Belknap massif, especially in regard to the amount of alferric minerals, determining the class, the amount of quartz determining the order, and that of lime which determines the rang.

It is to be noted that the rock from Locke's Hill is from near the contact, and on this account, as seen in its high silica content, it is to be regarded as homologous with the siliceous border facies which has been already mentioned in the geological description, though it differs from this texturally in being much coarser-grained.

On the other hand, the rock from the summit of Gunstock may reasonably be supposed to represent a more central part of the mass of magma than the specimen analyzed, which came from a spot presumably much nearer the border. There is thus a successive decrease in alferric minerals with an increase in quartz from center to circumference. This is more fully treated in another place.

In a specimen from the top of Piper Mountain which is megascopically similar to that from Gunstock, the section showed the presence of a colorless diopside associated with the hornblende and more or less intergrown with it. Some oligoclase also appears and these minerals, as will be shown later, point to a small increase in lime in the massif towards the south end. Otherwise the rock is similar to that from the summit of Gunstock.

Hornblende-trachi-akerose (spessartite).

As previously stated, the brecciated intrusive zone at the west foot of Locke's Hill contains in an aplitic liparase cement blocks of various rocks brought up by the ascending magma. Some of these are clearly masses of the gneisses and schists, some are of the Gilfordal camptonose (essexite), while some are of a dense lamprophyric type. It was thought that a detailed study of one of these latter would be of interest and might

* It is probable that the orthoclase is somewhat sodic, so that the K_2O is rather too high and the Na_2O too low, but to what extent is uncertain.

shed some light on the sequence of magmatic eruptions in the area, and a specimen was selected from a large angular block several feet in diameter embedded in the liparase.

Megascopic. — Phanerocrystalline; fine-grained, too dense for the individual minerals to be recognized but perceptibly granular; very dark stone gray, almost black; tough with hackly fracture. Rare, very inconspicuous, equidimensional, dull hornblende phenocrysts $0.5-1.0^{mm}$. Speckled here and there with small grains, streaks and minute veinlets of pink feldspar and quartz, the grains sometimes $2-3^{mm}$ with feldspar cleavage and of ragged, broken or irregular contours, evidently included or injected material and not normal phenocrysts.

Microscopic.—The section shows iron ore, apatite, hornblende, plagioclase, alkalic feldspar and quartz.

The iron ore occurs in two forms; as scattered grains, somewhat rounded, about $0.02-0.05^{mm}$, and as minute spheres, ovoids and rods about 0.001^{mm}, sprinkled through all the minerals and especially the feldspar, where they are often aligned into small systems. They distinctly suggested the iron ores seen in contact hornstones.

Apatite occurs in excessively minute needles in the feldspars. Hornblende is of a green color, strongly pleochroic into tones of pale yellow; it includes occasional grains of iron ore and some pieces have the central part blackened by separated iron ore dust and needles much like those which in lavas have suffered partial resorption. It is in irregular forms with a tendency to columnar development. Occasional flakes of biotite are sometimes associated with it.

The plagioclase is zonally developed with the customary more calcic cores and passing to alkalic feldspar mantles. It shows both albite and Carlsbad twinning, but much is untwinned and distinguished from alkalic feldspar only by its zonal development. The cores are of labradorite, the outer portion passing into andesine. It has a somewhat columnar development parallel to the a axis, but like the hornblende the boundaries are irregular.

The alkalic feldspars are similar in form to the plagioclase and are not always easily distinguised from them when untwinned. From the analysis it must be concluded that they are very rich in soda.

The small spots and streaks mentioned above are irregular fragments of alkalic, rarely plagioclase feldspar, often much filled with sericitic muscovite sometimes accompanied by quartz. They are clearly exotic, included or injected material, and do not belong to the rock proper.

Mineral Composition or Mode.—By Rosiwal's method the rock was measured and calculated to have the following composition:

Alkalic feldspar _____ 20·0
Plagioclase feldspar _____ 27·2
Hornblende _____ 35·3
Biotite _____ 0·9
Iron ore _____ 14·8
Apatite _____ 1·**7**

Total _____ 99·9

In obtaining this a part of the rock was selected free from inclusions to give the normal composition. On account of their characters the feldspars could not be accurately discriminated and the two were measured together and their relative amounts then estimated, the result being checked by the alkalies shown in the analysis. Thus while their total amount relative to the other minerals is nearly correct, their proportions to each other are only approximate. The small grains of iron ore in the feldspars could not be measured and a small amount was deducted for them and added to the measured ore areas. The apatite also could not be measured but is obtained from the

	I.	II.	III.	IV.
SiO_2 _____	52·95	50·97	52·85	·883
Al_2O_3 _____	14·96	15·56	13·25	·147
Fe_2O_3 _____	2·44	4·43	2·36	·015
FeO _____	7·03	7·62	8·71	·097
MgO _____	3·86	4·28	6·84	·097
CaO _____	6·76	7·05	8·47	·121
Na_2O _____	4·95	5·04	4·72	·080
K_2O _____	1·64	1·26	1·53	·017
$H_2O \ 110° +$ ____	0·55 ⎫		0·93	____
$H_2O \ 110° -$ ____	0·09 ⎭	1·58	____	____
CO_2 _____	0·00	____	____	____
TiO_2 _____	3·90	1·98	0·35	·049
P_2O_5 _____	0·76	0·43	0·40	·005
S _____	0·05	0·16	____	____
ZrO_2 _____	0·02	____	____	____
MnO _____	trace	0·38	____	____
BaO _____	0·00	____	____	____
Total_____	100·16	100·74	100·41	

I. Hornblende-akerose (spessartite). Belknap Mts., N. H. Washington analyst.

II. Augite-andose (augite kersantite). Cordillera de Doña Ana, Coquimbo, Chile. (F. v. Wolff, Zeitschr. d. deut. Geol. Ges., li, 1899, 529) ; Soenderop analyst.

III. Hypersthene-kilauose (basalt). Cerro San Miguel, Puebla, Mexico. (Felix and Lenk, Beitr. Geol. Mex., ii, 1899, p. 215). Hoppe analyst.

IV. Molecular ratios of No. I.

P_2O_5 of the analysis. With these corrections the composition is as stated above and it must be reasonably correct.

Chemical Composition.—This is shown in the analysis given below and it will be seen that the rock has the usual characters of a lamprophyre. The most notable feature is the predominance of soda over potash. The rock most nearly related to this one, both in magma composition and in geologic occurrence, of which we have found an account in the literature, is one from Chile given in No. II, while another of similar composition from Mexico is given in III. It should be remarked here that the analysis (I) probably does not represent quite accurately the composition of the pure normal rock, since the small included fragments of feldspar and quartz previously mentioned were unavoidably present to a limited extent. Their influence must be very minute, but the silica, alumina and alkalies are a trifle too high on that account.

Texture.—The average grain of the rock is about 0.05^{mm} and the hornblendes and feldspars approximate quite closely to this and do not vary much in size. The fabric is that commonly seen in rocks of lamprophyric character, and which Rosenbusch has designated as "panidiomorphic granular" in which the constituents appear of equal age, interlock with one another and yet have a distinct tendency to a columnar form. This fabric, however, is not clean cut and clear, as one often sees it, for the hornblendes are somewhat rounded, as are the ore grains, and the feldspars are irregular in outline and everywhere dotted with the little spheroids and rods of iron ore. Thus in plain light there is a distinct impression of the hornfels fabric with its rounded grains and dots, but when the nicols are crossed this disappears and the normal fabric is revealed. This is of interest because it shows that the original fabric has been affected to some extent by the immersion of the blocks in the liparase magma, and further evidence is seen in the separation of the iron ore in the hornblendes and in the sericitic mica in the large feldspars previously described.

Classification.—In the quantitative system the calculation of the norm of the rock and its position are given below.

Qz	0·96	⎫
Or	9·45	⎬ 66·23
Ab	41·92	⎭
An	13·90	
Di	12·33	
Hy	8·11	
Il	7·45	⎫
Mt	3·48	⎪
Ap	1·68	⎬ 33·05
Rest	0·71	⎭

Total   99·99

$$\frac{\text{Sal}}{\text{Fem}} = \frac{66\cdot23}{33\cdot05} = 2 = \text{II, Dosalane}$$

$$\frac{Q}{F} = \frac{1}{65} = 0\cdot01 + 5, \text{ Germanare}$$

$$\frac{K_2O' + Na_2O'}{CaO'} = \frac{97}{50} = 1\cdot94 = 2, \text{ Monzonase}$$

$$\frac{K_2O'}{Na_2O'} = \frac{17}{80} = 0\cdot21 = 4, \text{ Akerose}$$

The texture cannot be very well described in one word; it approaches roughly to the trachytic; but is not porphyritic. The mode on account of the large amount of hornblende is abnormative and thus the rock is a hornblende-trachi-akerose.

In Rosenbusch's system of classification the rock belongs in the vogesite-odinite series of lamprophyres and corresponds in general with the spessartite of this group; the hornblende is, however, not brown but common green and the considerable quantity of alkalic feldspar shows relations to the vogesites in which this mineral dominates the plagioclase feldspars.

Mt. Belknap Dike.—A rock which is practically the same as that just described forms a dike, six feet in width, which cuts the top of Mt. Belknap with an east and west trend. It differs in that it contains numerous phenocrysts of labradorite with tabular development, 0.5^{mm} long by 0.1^{mm} broad on the average, which are quite thickly sprinkled through the dark gray groundmass. The latter in thin section is similar to the type just described, without however the suggestion of the hornfels texture.

It may be also noted here that the above rocks mineralogically are quite similar to certain facies of the grano-camptonose (essexite) mass in which the latter passes locally into a monzonose (monzonite) phase. They differ of course texturally and they do not contain so much biotite, but the relation is a significant one for the explanation of the origin of these dikes, as will be mentioned later.

[To be continued.]

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *The Preparation of Pure Ethyl Alcohol and Some of its Properties.*—Since commercial absolute alcohol contains one or two per cent of water, and is usually contaminated also with aldehyde, L. W. WINKLER has worked out a method for purifying it, and has incidentally determined the specific gravity and boiling point of the pure substance. The aldehyde is first removed by adding very finely divided silver oxide and allowing it to act for several days with frequent shaking at ordinary temperature. At the same time, a little caustic alkali is added to combine with the acetic acid produced by the oxidation of the aldehyde. For dehydration, metallic calcium in the form of filings is used. An amount of this metal corresponding to about two per cent of the alcohol is added in the distilling flask, and a gentle heat is applied, so that little alcohol distils over, until the evolution of hydrogen is slight. Distillation then gives a product containing about 99·9 per cent of alcohol, and this when redistilled with about one-half per cent of calcium gives alcohol which is unchanged in specific gravity by further treatment. It is important that a small portion of each distillate coming over at first should be discarded. Specific gravity determinations of alcohol purified in this way gave results practically identical with those of Mendeléeff between 0° and 15°, but between 15° and 30° they were slightly lower than Mendeléeff's. The results gave the following formula based upon weights *in vacuo* and water at 4°:

$$\text{Sp. gr. } 0-30° = ·80629 - ·000838t - ·0000004t^2.$$

The boiling point was found to be 78·37° at 760^{mm} and 77·69° at 740^{mm}, the variation for 1^{mm} being ·034°.—*Berichte*, xxxviii, 3612. H. L. W.

2. *Double Salts of Mercuric Chloride with the Alkali Chlorides.*—In continuation of similar work previously carried out in the Sheffield Laboratory by Professor H. W. Foote, FOOTE and LEVY have studied the sodium-mercuric, potassium-mercuric and rubidium-mercuric chlorides by the solubility method, which shows very precisely and conveniently all the double salts that are formed at a given temperature. The results show that only one sodium salt, $NaCl.HgCl_2.2H_2O$ is formed at 25° and at 10°. Three potassium salts, all of which had been described by Bonsdorf, were found:

$$2KCl. HgCl_2. H_2O$$
$$KCl. HgCl_2. H_2O$$
$$KCl.2HgCl_2.2H_2O$$
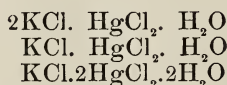
Five different rubidium compounds were prepared, none of which corresponded to three supposed salts previously described by Godeffroy. They have the following formulæ:

$$2RbCl. HgCl_2. H_2O$$
$$3RbCl.2HgCl_2.2H_2O$$
$$RbCl. HgCl_2. H_2O$$
$$3RbCl.4HgCl_2. H_2O$$
$$RbCl.5HgCl_2.$$
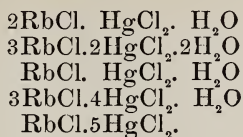
It is interesting to observe that only the last member of this series corresponds to one of the five cæsium-mercuric chlorides that exist, viz. :

$$3CsCl. HgCl_2$$
$$2CsCl. HgCl_2$$
$$CsCl. HgCl_2$$
$$CsCl.2HgCl_2$$
$$CsCl.5HgCl_2.$$
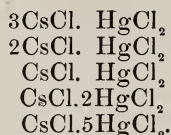
There are two corresponding salts in the potassium and rubidium series, but the slight analogy existing between double salts of such closely related metals as cæsium and rubidium is remarkable. —*Amer. Chem. Jour.*, xxxv, 236.   H. L. W.

3. *The Atomic Weight of Tantalum.*—The accepted atomic weight of this element, 183, depends solely upon Marignac's results obtained in 1865 by analyses of the compound K_2TaF_7. Since these results are subject to some uncertainty from various causes, Hinrichsen and Sahlbom have made some new determinations of this atomic weight. They were unable to obtain concordant results by the method of Marignac, but they had, apparently, better success by determining the weight of Ta_2O_5 produced by heating the metal in oxygen. The metal was obtained from Siemens and Halske, who now prepare it for commercial purposes, and no impurities could be found in the material used. The results of five determinations made in this way indicate an atomic weight of 181, which is two units lower than the accepted one. The results varied from 180·59 to 181·77. It may be mentioned that this atomic weight adapts itself to Mendeleéff's periodic system somewhat better than the old one, since it is three units lower than tungsten, 184.—*Berichte*, xxxix, 2600.

     H. L. W.

4. *The Isomorphism of Northupite and Tychite.*—The octahedral mineral tychite, $2MgCO_3.2Na_2CO_3.Na_2SO_4$, was described by Penfield and Jamieson in this Journal of September, 1905, having been found among exactly similar crystals of northupite, $2MgCO_3.2Na_2CO_3.2NaCl$, from Borax Lake in California. In connection with the description of tychite, its artificial preparation was also carried out. A. de Schulten, who had previously prepared northupite artificially, has now succeeded in making crops of crystals which appear to contain both chloride and sulphate in the same individuals, thus indicating that the two compounds are perfectly isomorphous. He finds that the tychite is much more stable than the northupite.— *Comptes Rendus*, clxiii, 403.

     H. L. W.

5. *Separation of Antimony and Tin.* — A new method for this somewhat difficult separation is given by A. Czerwek. It depends upon obtaining a solution in nitric and tartaric acids, heating to boiling and adding phosphoric acid, whereby the tin is completely precipitated. The precipitate, after being washed with water containing ammonium nitrate, is dissolved in ammonium sulphide, and the tin is precipitated and determined in the usual manner. The antimony and other metals that the filtrate may contain must also be precipitated as sulphides in order to separate them from the phosphoric acid present. Satisfactory results are given in a number of test analyses.—*Zeitschr. Analyt. Chem.*, xlv, 505. H. L. W.

6. *Lehrbuch der Allgemeinen Chemie;* by Dr. W. Ostwald. Volume II, Part III.—The third part of Volume II of the Lehrbuch has appeared in sections, and we have just received the first part of the second section. The book is so divided into volumes and parts and sections that it is a little confusing in this respect. The work is so well known to students of general chemistry that it is unnecessary to speak of it as a whole. The part which has just been issued covers solid solutions more fully than this has been done before and begins the chapter on adsorption.

H. W. F.

7. *Radio-activity.* — The literature of this subject increases very rapidly. Apart from the numerous observations on the various forms of radio-active substances and their multifarious manifestations, there are certain aspects of radio-activity which have a broad bearing upon the constitution of the sun and the radio-active constitution of this earth and its atmosphere. A recent paper on the radio-activity of the ashes and lava thrown up by the late eruption of Vesuvius (August Becker, Ann. der Physik, No. 8, 1906) is of much interest. Since it has been shown by various observers that radio-activity is widely present in the earth's crust, the question has arisen, whether it would not be possible to connect the phenomena of radio-activity with the earth's temperature? Under the assumption of a mean value of 0·006 for the heat conduction of the earth's crust, and a temperature fall of 1° C. for 30 meters, Liebenow estimates the quantity of radium per cubic meter evenly distributed, which would give the observed heat as approximately 2×10^{-7}g. Since the quantity of radium observed is 1000 times this, we must conclude that the heat production diminishes rapidly as we recede from the crust and that at great depths there cannot be radio-active substances. Strutt corroborates the results of Liebenow and concludes that at a depth of 75^{km} radio-activity fails. Becker, therefore, submitted to test the ashes and lava of the eruption of Vesuvius, and corroborates in general the observations and conclusions of Strutt, pointing out, however, that we are unable to estimate conditions of pressure and temperature at the depth from which the lava and ashes came, presumably 30^{km}.

Professor E. Rutherford, in the Philosophical Magazine for August, 1906, has an article on the "Retardation of the α-particle from Radium in passing through Matter." "The photographic effect of the α-particles toward the end of their path in air decreases far more rapidly than the kinetic energy of the α-particles themselves. It is possible to determine with accuracy the value $\dfrac{m\mathrm{V}}{e}$ for the α-particles emitted by radium, radium A, and radium F by measurements of the retardation of the α-particles of the single product radium C in passing through matter. Such a result affords an almost certain proof that the value of e/m is the same for the α-particles expelled from each of these products." The same author discusses the intensity of radiation from radio-active sources, and contrasts the photographic effect of radium emanations through apertures of various forms with the radiation of the sun. In the case of the latter, Lambert's law of cosines applies ; that is, the intensity of radiation from any point varies as the cosine of the angle between the normal and the direction of the emitted light. This law does not apply to a thin layer of radio-active substance. Hence we find great inequalities in the distribution of the photographic effects. A number of photographs accompany the paper (Phil. Mag., August, 1906).

The September number of the same journal contains an article by M. Levin, "On the Origin of the β-rays emitted by Thorium and Actinium." M. Levin has been working with Professor Rutherford. It was found that actinium by itself is a rayless substance. A remarkable similarity was found to exist between the modes of transformation of thorium and actinium. The same journal contains a paper "On the Radioactive Matter in the Earth and the Atmosphere," by A. S. Eve, communicated by Professor Rutherford. The author believes that emanation exists in the atmosphere, but thinks that more experimental work must be done before any exact value can be assigned to the number of ions produced.

"About 1.8×10^{-11} grams of radium bromide is the estimated equivalent of the active matter per c.c. present in the earth's crust sufficient to account for the penetrating radiation. This appears to be about four times as large as the average amount found by Strutt by direct observation of rock specimens. The ionization of the atmosphere is due partly to penetrating radiation from the active matter in the earth, partly to α-radiation from the emanation in the atmosphere." J. T.

8. *Velocity of X-Rays.* — E. Marx describes minutely his investigation of this velocity. The method depends primarily upon the property which the X-rays possess of ionization of a gas. Electric waves were produced along parallel wires according to Lecher's system. The velocity of these waves was assumed to be the same as the velocity of light. A Röntgen tube was, therefore, so connected with the Lecher system, that the differences of potential due to the presence of nodes or ventral seg-

ments of the electrical waves, influenced the emanation of the X-rays. The rays from such a X-ray tube proceeding through an aluminium window struck an electrode contained in a Faraday cylinder ; this electrode was connected with an electrometer. Changes in wave length were produced by moving a bridge on the two wires of the Lecher system. The X-ray tube was moved to and fro until maximum effects of ionization were produced in the receiving tube. These efforts produced corresponding deflections of the electrometer. The relation of the doubled displacement of the bridge in the Lecher system to the displacement of the X-ray tube gave the ratio of the velocity of light to the velocity of the X-rays. The ratios differ only one-half per cent from the value of light.—*Ann. der Physik*, No. 9, 1906, pp. 677–722. J. T.

9. *Formation of Ozone from Oxygen and Atmospheric Air by Silent Discharges of Electricity.*—E. WARBURG and G. LEITHÄUSER state that silent discharges between small spheres are necessary for the formation of ozone from atmospheric air. A number of tables are given of the output, in the case of spheres, charged in one case positively and in another case negatively. The results are plotted and appear in the form of straight lines.— *Ann. der Physik*, No. 9, 1906, pp. 734–742. J. T.

10. *Oxidization of Nitrogen by Silent Discharges in Atmospheric Air.*—E. WARBURG and G. LEITHÄUSER show that :

(1) Nitrose gases in the presence of ozone are easily absorbed by dilute soda lye.

(2) With silent brush discharges from the positive terminal sphere in atmospheric air, at the room temperature, independently of the moisture of the air, 10 liters of NO is oxidized by an ampere hour.

(3) The oxidized quantity of nitrogen mixture increases with increasing temperature and then decreases with the formation of the ozone.

(4) A quantity of N_2O_4, indicating 1^{cc} NO in 1500^{cc} lessens the formation of ozone when the silent discharge occurs in atmospheric air.—*Ann. der Physik*, No. 9, 1906, pp. 743–750.

J. T.

11. *Influence of Moisture and Temperature on the Ozonizing of Oxygen and of Atmospheric Air.*—E. WARBURG and G. LEITHÄUSER show that with a silent discharge, moisture effects the ozonization more in the case of air than with oxygen, and that a rise of temperature to 80° and constant pressure, produces little effect in the case of both oxygen and atmospheric air.—*Ann. der Physik*, No. 9, 1906, pp. 751–758. J. T.

II. Geology and Mineralogy.

1. *The Tenth International Geological Congress at Mexico City.*—The Congress began its sessions on Thursday, September 6, 1906, and adjourned on Friday, the 14th of the same month. Previous to the opening meeting excursions were made, as follows : To the south for eight days to view the Archean and Tertiary in the narrow canyon of the Tomellin on the way to Oaxaca, the Lower Cretaceous in the mountains west of Tehuacan, and the ancient ruins at Mitla. To the west for twelve days, two excursions were given,—one to Jorullo to see the volcanoes Toluca and Jorullo, and the other to the only active volcano in Mexico, Colima, and the geysers. The best attended excursion before the Congress was the one to the east for three days, to see the deeply eroded Cretaceous at the edge of the high mesas down which the railroads descend to the dissected Miocene level, and then to the present ocean level at Vera Cruz. On the way back to Mexico City a stop of a few hours was made at Orizaba to view the symmetrical volcano of the same name and the nearly vertical strata of the Middle Cretaceous. The most extensive and varied excursion was the one for three weeks immediately after the meetings of the Congress, to the north as far as El Paso and east to Tampico. On alternate days, during the sessions of the Congress, excursions were given to Cuernavaca, to San Juan Teotihuacan to examine the work of restoring the great pyramids of the Sun and Moon, and to the Pachuca silver mines. These excursions were of great profit to all, while the hospitality received en route was lavish.

The opening session of the Congress was held on the morning of September 6, at eleven o'clock, in the Salon de Actos of the School of Mines, in the presence of the President of Mexico, his cabinet, his personal and official staff, and the ministers of foreign countries. A short opening address was given by Sr. Luis Salazer, Director of the School of Mines. The address of welcome was read by the Subsecretary of Fomento and the Honorary President of the Congress, Sr. Andrês Aldasoro. The retiring President of the Congress, Prof. Emilio Tietze, made a very pleasing address, and was followed by the President-elect, Sr. Josê G. Aguilera, Director of the National Geological Institute of Mexico. The Secretary-elect, Sr. E. Ordóñez, outlined the work of the sessions. The President of the Republic then pronounced the Congress opened. The succeeding meetings were held in the Geological Institute, a building just completed and containing accommodations for the excellent equipment, collections, library, and staff of the Mexican Geological Survey.

The following are the officers of the present Congress, who either in 1909 or 1910 will turn over the machinery of the Tenth Congress to the Eleventh, to be held at Stockholm :

President, Sr. Josê G. Aguilera.

Secretary General, Sr. E. Ordóñez.

Vice Presidents : Austria, C. Diener ; Germany, H. Credner, A. Rothpletz, and F. Frech ; France, A. Offret ; Great Britain, T. Anderson ; Norway, E. Brögger ; Sweden, H. Sjögren ; Russia, Th. Tschernyschew ; Roumania, G. Stefanescu ; Italy, V. Sabatini ; Spain, C. R. Arango ; Hungary, von Szadeczky and B. de Inkey ; Canada, F. D. Adams and A. P. Low ; United States, T. C. Chamberlin, C. W. Hayes, S. F. Emmons, and A. Heilprin ; Philippine Islands, M. D. McCaskey ; Mexico, E. Böse ; Cuba, S. de la Huerta ; Venezuela, E. Urdaneta ; Australia, T. W. E. David ; Japan, T. Iki.

The members actually participating in the Congress numbered 292. Of these 130 were from Mexico, from America 58, Manila 1, Canada 8, Honduras 1, Cuba 2, Germany 44, Austria 6, France 11, England 4, Belgium 3, Russia 3, Finland 2, Italy 2, Sweden 1, Roumania 3, Bohemia 1, Australia 1, and 1 from Japan. In other words, Europe was represented by 80 members, and the Americas by 207. At this Congress, however, the percentage of non-geologists was probably greater than usual, and of ladies there were 27.

The Russian Spendiaroff prize was awarded to Tschernyschew in recognition of his great work entitled " Die obercarbonischen Brachiopoden des Ural und des Timan."

Through the death of von Zittel the Paleontologia Universalis lost its President, and to this vacancy the Council of the Congress elected Prof. Frech of Breslau. To the American Committee was added R. Ruedemann, the other members being C. D. Walcott, H. S. Williams, and Charles Schuchert. Canada is represented by J. F. Whiteaves and Mexico by E. Böse and C. Burckhardt.

A large geological map of North America, including Greenland, was distributed to the members. It is the joint work of the National Surveys of Canada, United States, and Mexico, and was printed by the U. S. Geological Survey for the Congress. It is understood that this map will undergo further revision and will also eventually appear as one of the Professional Papers of the U. S. Geological Survey. It will supply a great lack in American geology.

In the main, the following are the titles of papers read by their authors at this Congress :

F. D. Adams : Explanation of the Geological map of North America, distributed to the members of the Congress.

T. Anderson : On the principal results of the Swedish Antarctic expedition. Read by H. Sjögren.

H. F. Bain : Some relations of paleogeography to ore depositions in the Mississippi Valley.

C. Burckhardt : Sur l'existence dans le Jurassique supérieur mexicain d'Ammonites et Aucelles.

A. P. Coleman : Interglacial periods of Canada.

N. H. Darton : Geologic classification in the north-central portion of the United States.

T. W. E. DAVID : On the morphology and evolution of the Australian continent, and particularly in regard to the Cambrian and Permo-Carboniferous glacial climates.

H. L. FAIRCHILD : Pleistocene of western New York.

F. FRECH : Ueber die Klimaänderungen der geologischen Vergangenheit. Ueber Aviculiden von paleozoischen Habitus aus der Trias von Zacatecas.

A. HEILPRIN : The concurrence and interrelation of volcanic and seismic phenomena. On the Martinique eruptions.

E. O. HOVEY : La Sierra Madre Occidentale de l'État de Chihuahua.

B. DE INKEY : Sur la relation entre l'état propylitique (Grünstein) des andésites et la genèse des filons liés à cette roche.

K. KEILHACK : On the onyx deposits at Etla in the State of Oaxaca.

J. F. KEMP : Ore deposits at the contacts of intrusive rocks and limestones.

J. KÖNIGSBERGER : Ueber den Verlauf der Geoisothermen in Bergen und seine Beeinflussung durch Schichtstellung, Wasserläufe und chemische Processe.

L. DE LAMOTHE : Le climat de l'Afrique du Nord pendant les Périodes Pliocène et Pleistocène.

A. C. LAWSON : The earthquake of San Francisco, California. On the Quaternary history of California.

W. LINDGREN : On ore deposition.

M. MANSON : The causes of the glacial epoch.

W. G. MILLER : The Pre-Cambrian rocks of Central Canada.

K. RENZ : Ueber das ältere Mesozoicum Griechenlands.

V. SABATINI : Sur la dernière eruption du Vésuve.

G. STEFANESCU : Description du squelette d'un nouveau genre de Dinotherium gigantissimum.

J. D. VILLARELLO : Sur le remplissage de quelques gîtes métallifères.

W. H. WEED : Origin and classification of ore deposits.

<div align="right">C. S.</div>

2. *A Descriptive Catalogue of the Tertiary Vertebrata of the Fayûm, Egypt,* based on the collection of the Egyptian Government in the Geological Museum, Cairo, and on the collection in the British Museum (Natural History), London ; by CHARLES WILLIAM ANDREWS, D.Sc. 4to. Pp. xxxviii, 324 with 25 plates and 48 text-figures. London, 1906 (published by order of the Trustees of the British Museum).—This fine quarto volume gives not alone a full descriptive catalogue of the collections in the Cairo Museum and in the British Museum (Natural History) which were made in the Fayûm ; but a general discussion of the physiography and geology of the region and of the characters and relationships of the remarkable forms which ancient Egypt, ever the land of wonders, has brought to light. Mr. H. J. L. Beadnell, the maker of the Cairo collection, has given a very full account of the topography and geology of the Fayûm province in Egypt and upon his detailed report the sketch contained in the catalogue is based.

The Fayûm is situated west of the Nile valley in a latitude some 57 miles south of Cairo. The region is a roughly circular depression the lower part of which is occupied by a large brackish-water lake, the Birket-el-qurun, about 25 by 6 miles in extent. During Pleistocene times this lake was of vastly greater area, the deposits of the former waters being rich in vertebrate and molluscan remains. Numerous stumps of trees in one or two places

indicate that formerly portions of the surrounding country were wooded. Along the northern side of the lake nearly the whole of the vertebrate remains have been gathered from beds of middle and upper Eocene age. Of these vertebrates all classes except the Amphibia have been found, though bird fragments are referable to one species only. By far the most abundant are the Mammalia, which are followed in numbers by the reptiles.

The Mammalia are divided into three sections; (1) the land mammals which seem to be truly endemic to the Ethiopian region; (2) forms of which close allies occur in other regions in approximately contemporary deposits; and (3) the aquatic mammals. It seems probable that some of the last are also of endemic origin, having arisen from native land mammals.

Of the first series, curiously enough, all are ungulates of the less specialized orders. The most notable of these is Arsinoitherium, a most bizarre creature of elephantine proportions and massiveness, and which bore upon the snout two great upward and forwardly projecting horn cores, while above the orbits were two more though of much smaller dimensions. Andrews, while expressing doubt as to the relationships of Arsinoitherium, thinks that it may have originated from the same stock that gave rise to the Hyracoidea. The latter are quite abundant in the Fayûm, but remains throw little or no light upon the history of the group.

The light thrown upon the past history of the Proboscidians is the feature of the greatest scientific interest because of the extreme deficiency of our previous knowledge of the order, as none were known older than the Miocene before the Fayûm forms came to light. Osborn, among others, had pointed out the probability that Africa would be found to be the original home of the Proboscidea, the Hyracoidea, and several other families, believing that a succession of migrations from Africa to Europe occurred, notably at the end of the Eocene, at the beginning of the Miocene and again in the earliest Pliocene. It was in the early Miocene migration that the elephants passed out of Africa for the first time. The earliest known proboscidian is Mœritherium, which occurs first in the Quaer-el-Sagha (middle Eocene) beds and persists until the upper Eocene. This creature suggests the tapir in size and general appearance, and while the dental formula is almost complete, many elephantine characters are foreshadowed in the skull. The next proboscidian genus is Palæomastodon, of which some of the smaller species are evidently intermediate between Mœritherium and the later elephants. The larger Palæomastodons were about the size of a half-grown Indian elephant and were elephant-like in appearance except for the elongated symphysis of the lower jaw, which was prolonged beyond the skull and was covered only by the fleshy snout. The neck was still somewhat long and the creature could reach the ground with its lower incisors and with the probably prehensile muzzle. The further evolution of the group is shown in Tetrabelodon from the

European lower Miocene, a creature similar in size and appearance to the Indian elephant except that the trunk was inflexible because of its being supported by the more elongated symphysis. In Mastodon however the symphysis shortens, leaving the trunk free; at the same time vestiges of the elongated condition of the jaw occur in some mastodons and in the peculiar sharp process of the symphysis of modern elephants.

The Fayûm researches have also thrown light upon the probable community of origin of the Sirenia, the Proboscidea and the Hyracoidae.

The Creodonts are also present of the family Hyænodontidæ and the development of the Zeuglodonts from a creodont ancestry is shown. The zeuglodonts of the Fayûm, taken together with a species, *Procetus atavus*, from the near-by Mokattan Hills, form a series showing a complete transition so far as the teeth are concerned from the Creodonts to the Zeuglodonts.

The bird remains seem to be that of a true Ratite and suggest the Ethiopian region as a point of origin of some at least of the main sub-divisions of the Ratitæ.

The Reptilia are represented by crocodiles, turtles, and snakes. There are no Amphibia and the fishes are either Elasmobranchs or Siluroids and of no great interest.

The summary points to the great importance of Africa as a center of mammalian evolution, not alone of modern true mammals, but of their Theriodont ancestors. This being the case, not only the Tertiary, but the Mesozoic deposits of this region may be expected to throw much light upon the history of the Mammalia. The Dark Continent seems to be a veritable land of promise to the vertebrate paleontologist. R. S. L.

3. *Geology of the Owl Creek Mountains with Notes on Resources of Adjoining Regions in the Ceded Portion of the Shoshone Indian Reservation, Wyoming ;* by N. H. DARTON. *United States Geological Survey. Senate Document No. 219, 59th Congress, 1st Session.* Pp. 48, with 11 plates and 1 text figure. Washington, 1906.—This paper, of the general form of the bulletins of the U. S. Geological Survey, is published as a Senate document in response to a request from the Senate for such information relating to the geology and natural resources of that portion of the Shoshone Reservation which was to be opened for settlement in July, 1906, as was in the possession of the U. S. Geological Survey. The report has a geological map on the scale of 4 miles to the inch, and many attractive photographic illustrations. J. B.

4. *The Copper Deposits of the Robinson Mining District, Nevada ;* by ANDREW C. LAWSON. *Univ. of Cal. Publications, Bull. of the Department of Geology,* vol. iv, No. 14, pp. 287–357. May, 1906.—This bulletin gives a good account of the geology of the Egan Range, one of the larger members of the Basin Range system of mountains traversing eastern Nevada. The Archean basement is not exposed, the rocks ranging in age from the Cam-

brian to the Carboniferous and holding in places intrusive masses of granitic and monzonitic rocks. Intrusive porphyries and extrusive rhyolites are also present. Considerable space is devoted to the contact phenomena and their relations to the ores.

J. B.

5. *The Montana Lobe of the Keewatin Ice Sheet;* by FRED. H. H. CALHOUN. Professional Paper No. 50, U. S. Geol. Surv., 1906. Pp. 62, with 7 plates and 31 figures.—This report covers a region of much interest to glacialists, an area which lay between the Keewatin ice sheet and the mountain glaciers coming from the west. In studying this region four important subjects were considered—the eastern drift, the mountain drift, the deposits on the intervening area (which was not glaciated), and the relations of these three surface formations to one another. It was found that for thirty miles back from the margin the average slope of the glacier must have been about 50 feet per mile. It is further stated that this ice sheet also undoubtedly turned the Missouri from a northern course and made it tributary to the Mississippi River. J. B.

6. *Les Lac Alpins Suisses. Étude Chimique et Physique;* par le Dr. FÉLIX-ERNEST BOURCART. Pp. 130, with plates and 22 figures. Genève, Georg & Co., Editeurs, 1906.—This work, to which was awarded a prize by the Helvetian Society of Natural Sciences, was undertaken at the suggestion of Professor Duparc as a subject for a thesis. Thirty-three lakes were examined in detail and complete observations made upon the color of the water, transparency, the temperature at the surface and at maximum depth and other features. Chemical analyses were also made of the waters and the results are finally tabulated. The report thus brings together a valuable body of data. J. B.

7. *The Species of Botryocrinus;* by F. A. BATHER. Ottawa Nat., vol. xx, pp. 93–104, August 15, 1906.—This paper contains a comparison of all previously described species, with fresh diagnoses based on the dorsal cups. The species are : Swedish, *B. ramosissimus* Ang., *B. cucurbitaceus* (Ang.): British, *B. ramosus* Bather, *B. decadactylus* Bather ex Salter MS., *B. pinnulatus* Bather, *B. quinquelobus* Bather ; Australian, *B. longibrachiatus* Chapman ; N. American, *B. nucleus* (Hall), *B. polyxo* (Hall), *B. crassus* (Whiteaves), *B. americanus* Rowley. All these are Silurian except the two last, which are Devonian and approach the Carboniferous *Barycrinus* in shape. American workers are invited to consider the relations of *Botryocrinus* to *Cosmocrinus, Barycrinus,* and *Vasocrinus.* [Author's abstract.]

8. *Soils, their Formation, Properties, Composition and Relations to Climate and Plant Growth in the Humid and Arid Regions;* by E. W. HILGARD. Pp. xxvii, 593, with 89 figures. —Every student of soils will welcome this volume from one of the oldest and ablest soil investigators in North America. The book is unique because of the full comparison between soils of humid and arid regions and its special emphasis upon the physics

and chemistry of arid soils, a natural result of the author's long experience in the arid west. The book is further characterized by its strong treatment of the effect of soil character upon native vegetation, for the value of which the author has been contending for half a century. The fundamental question of classification as involving the relative value of physical and chemical properties in plant production and as a convenient means of reference to cultural values, is discussed in a thoroughly convincing manner. In view of the recent discussions on the relation of soil texture and chemical constitution to the composition of the soil-water, Hilgard's conclusions are of the highest interest and value, and strongly contravene the assertion that natural solutions of water-soluble soil ingredients are essentially of the same composition in all soils. A commendable feature of the soil analyses is their statement in terms which insure application. They really constitute a sort of restatement of refined analyses such as give the conclusions an immediate and practical value to the agriculturist. **I. B.**

9. *Brief Notices of some recently described Minerals.* — KLEINITE is an oxychloride of mercury described by A. Sachs from Terlingua, Texas, and named after Prof. Carl Klein of Berlin. It occurs in slender hexagonal crystals of a sulphur-yellow to orange color ; hardness 3–4 ; specific gravity = 7·441. The composition deduced is $H_4Cl_2O_3$. Sachs regards this mineral as identical with one noted by Moses (" No. 5," this Journal, xvi, 263) and also with that announced by Hillebrand (Ibid., xxi, 85). —*Sitzungsber. Akad. Berlin*, Dec. 21, 1905 ; *Centrbl. Min.*, 200, 1906.

BELLITE is a chromo-arsenate of lead from the Magnet Silver mine, Magnet, Tasmania ; it is named after Mr. W. R. Bell by W. F. Petterd. It occurs in delicate tufts and velvety coatings lining cavities in a soft iron-manganese-gossan ; minute hexagonal crystals are sometimes visible. The color is bright crimson to orange-yellow ; hardness 2·5 ; specific gravity 5·5. An analysis by J. D. Millen gave :

As_2O_3	CrO_3	PbO	P_2O_5	V_2O_5	Al_2O_3	SO_3	Cl	SiO_3
6·55	22·61	61·68	0·04	0·11	0·01	0·05	0·52	7·59 = 99·16

GIORGIOSITE is a name given by Lacroix to a basic hydrated magnesium carbonate forming a white powder with sodium chloride and other salts at the fumaroles of Santorin at the eruption of 1866. The powder consists of minute radiated spherules. This is inferred to be identical in composition with a salt described by Fritzsche having the formula $4MgCO_3.Mg(OH)_2.4H_2O$. Another associated substance in white flocculent masses is probably hydromagnesite.—*Bull. Soc. Min.*, xxviii, 198.

SILICOMAGNESIOFLUORITE, as its name expresses, is essentially a fluosilicate of magnesium. It is described by P. Zemiattschenski from Lupikko, Finland. It occurs in crystalline aggregates of half-spherical or spherical forms with radiated and fibrous

structure. The color is ash-gray or light greenish and bluish with satin luster; hardness 2·5; specific gravity 2·91. The empirical formula deduced is $H_2Ca_4Mg_3Si_2O_7F_{10}$, which may be written $5RF_2.2RSiO_3.H_2O$.—*Zeitschr. Kryst.*, xlii, 209.

STILPNOCHLORAN is an alteration-product of thuringite described by Kretschmer from the iron mines of Gobitschau near Sternberg, Moravia. It forms aggregations of small cleavable scales, sometimes irregularly grouped, also radiated or fan-shaped. The color is yellow to bronze-red; hardness 2 to 3; specific gravity 1·82. An analysis gave:

SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	H_2O	P_2O_5
33·30	4·37	44·33	0·34	1·22	1·73	14·10	0·37 = 99·76

The formula calculated is $H_{24}(Ca, Mg)(Al, Fe)_{16}Si_9O_{46}$.— *Centralbl. Min.*, p. 203, 1905.

MORAVITE is a chloritic mineral closely resembling thuringite, also described by Kretschmer from a locality near Gobitschau (see above). An analysis gave:

SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	K_2O,Na_2O	H_2O	C	P_2O_5
49·30	22·71	5·04	13·99	*tr.*	1·82	1·10	4·95	0·55	*tr.* = 99·46

The formula deduced is $H_4(Fe, Mg)_2(Al, Fe)_4Si_7O_{24}$.— *Centralbl. Min.*, p. 293, 1906.

PARAVIVIANITE is a variety of vivianite containing small amounts of manganese (2·01 p. c. MnO) and magnesia (1·92 MgO), described by S. Popoff from the limonite deposits of the Peninsula Kertsch.

The same author has given the name KERTSCHENITE to a hydrated basic iron phosphate from the same region. This occurs in dark green to black crystalline aggregates with a hardness of 3·5 and specific gravity of 2·65. The mean of two analyses gave:

P_2O_5	Fe_2O_3	FeO	MnO	MgO	CaO	H_2O
28·20	32·93	9·49	1·92	1·55	0·47	24·98 = 99·54

The calculated formula is $(Fe, Mn, Mg)Fe_2P_2O_{10}.7H_2O$. — *Centralbl. Min.*, p. 112, 1906.

OTAVITE is a new cadmium mineral described by O. Schneider from Otavi in German Southwest Africa. It occurs in crystalline crusts with upper and lower surfaces covered with minute rhombohedrons. The color is white to reddish and the luster brilliant adamantine. Qualitative tests lead to the conclusion that it is a basic carbonate of cadmium. The same locality yields azurite, malachite, cerussite, linarite, etc., also greenockite as a yellow powder on malachite.— *Centralbl. Min.*, p. 388, 1906.

CHLORMANGANOKALITE is a name provisionally given by H. J. Johnston-Lavis to a double chloride of manganese and potassium occurring in canary-yellow rhombohedral crystals in cavities in ejected masses found on the flanks of Vesuvius after the eruption of last April. *Nature*, lxxiv, 103. Associated with this are fine cubes of a potassium-sodium chloride corresponding to 6KCl. NaCl, which the same author calls CHLORNATROKALITE.

Doughtyite, described by W. P. Headden, is a hydrated basic sulphate of aluminium occurring as a white precipitate in connection with some of the Doughty Springs in Delta County, Colorado. The composition of the air-dried material is given by the formula: $Al_2(SO_4)_3.5Al_2(OH)_6.21H_2O.$ — *Proc. Colo. Sci. Soc.,* viii, 66.

III. Astronomy.

1. *Parallax Investigation of 162 Stars, Mainly of Large Proper Motion.* Transactions of the Astronomical Observatory of Yale University: Volume II, Part I, pp. 207, Folio. Published by Frederick L. Chase, Mason F. Smith and Wm. L. Elkin.—The results of Dr. Elkin's work with the Repsold Heliometer on the parallax of 10 first magnitude stars of the northern heavens were published in 1902, as Part VI of vol. I of these Transactions. It may be noted here that nine of these stars have a reliable parallax, varying from $0.02''$ to $0.33''$, and it is somewhat significant that two of the three of inconsiderable parallax have also inappreciable proper motion, while the seven remaining have noticeably large proper motion, varying from $0.20''$ to $2.29''$, while the average parallax of $0.11''$ represents a distance of 29 light-years.

During the progress of this work, which together with the triangulation of the Pleiades and that of the Group in Coma Berenicis by Dr. Chase had demonstrated the capacity both of these observers and their instrument for the highest order of parallax work, plans were formed for an investigation of all the stars of known large proper motion across the line of vision convenient for observation (designated rather loosely in the report as "all the rapid moving stars"). This work has developed in the course of its prosecution so far beyond the limits anticipated that it has occupied the larger part of the time of Dr. Chase for 13 years, Dr. Elkin having been interrupted by ill health and largely occupied by work in meteorite photography. It has also enlisted the services of Mr. M. F. Smith since 1901.

By 1895 about 100 stars had been measured at two epochs of greatest parallax effect, the original design being to detect parallax without attempting the fullest determination of its magnitude, but the discussion of these measurements promised such valuable results that it was decided to both enlarge and intensify the work by including more stars and extending the measurements over four periods, the last two being taken in reverse order, as well to eliminate more completely the effect of proper motion as to guard against the effect of systematic error which might possibly be considerable in a limited number of observations.

The precautions taken against systematic errors, whether resulting from habits of observation, direction of comparison stars or difference in their color or brightness, as well as from

imperfections in the micrometer screw or progressive change in its scale value, must impress the reader as original, judicious and comprehensive ; and as the value of the parallax work depends chiefly on the completeness of these eliminations, the inferences drawn by the authors as to the sigificance of their results may be accepted with great confidence because of the high order of this part of the work.

An interesting example of the thoroughness of the investiga - tion of sources of systematic error is the discussion by Dr. Chase of the effect of difference of color between the parallax star and its star of comparison. It is assumed that the light of a red star being refracted less than that of a white comparison star, the angular distance between them will be affected.

The treatment of this topic is of such intrinsic interest and so typical of the thoroughness of the whole investigation of sources of systematic error that it seems well to reprint it here entire from the text of the report—the tables of measurements, occupy- ing many pages, being omitted.

" *Observations of red stars for color effect.*—The work of the preceding pages, in which every precaution to eliminate known sources of error was employed, appears to us to be free from all systematic error, except perhaps one due to the star's color. Any perceptible difference in the mean refrangibility of the light of two stars might possibly produce an effect upon the meas- ured distance between them which would be a function of the hour angle, and hence affect their apparent relative par- allax, since it is generally impossible for practical reasons with our instrument to make observations at the two different parallax epochs otherwise than on opposite sides of the meridian. To ascertain whether an error due to this cause is appreciable in actual observation, Dr. Chase, in 1898 and 1899, made a series of observations on five highly colored stars selected from Krüger's *Catalog der Farbigen Sterne*, carrying out the investigation in the following manner :

The plan was at the epoch when the star culminates about midnight to measure the distances between the red star and each of two nearly equally distant comparison stars, one preceding and the other following, and as nearly as possible on the same parallel of declination, at rather large hour angles both east and west of the meridian. By taking two comparison stars we were able, as in the parallax work, to correct for any change in the scale value, and to eliminate any errors varying with the time.

The refraction of two stars with light of a different mean refrangibility being represented by

$$\beta \tan z, \text{ and } (\beta + \Delta\beta) \tan z$$

the measured distance between two such stars should receive, besides the correction for differential refraction, the additional correction

$$\Delta\beta \tan z \cos (p - q)$$

where z denotes the zenith distance, p the position angle of the red star from the comparison star, q the parallactic angle, and $\Delta\beta$ the supposed color effect.

The following pages give the measures corrected for refraction and aberration, the value of $\tan z \cos (p-q)$ for each observed distance, and the sums, differences, corrections for temporary scale value, and corrected differences, as in the series for parallax determination. These last, by their variation from an assumed mean difference, furnish the equations of condition which follow, in which x and x' represent the required corrections to the assumed mean difference for each epoch, $\Delta\beta$ the quantity to be determined, whose coefficient is the difference of the values of $\tan z \cos (p-q)$ for the two distances, and the second member the observed difference for each night minus the assumed mean difference. The star Krüger 1181 was specially selected because it had a close neighboring star presumably of average color, and as a test of the value of the method this latter also was observed with respect to the same comparison stars in conjunction with the red star and symmetrically with it, so that the conditions should be absolutely the same. For both stars, likewise, the treatment and solution were carried out in precisely the same manner. . . . .

If we arrange the results of the previous pages in the order of the stars' redness as given by Krüger, we have—

Krüger	985	Color 6·0	$\Delta\beta = -0\cdot019''$	$\pm$	$0\cdot019''$	Wt. 63·6
	1080	7·0	$+0\cdot005$	$\pm$	$0\cdot020$	64·4
	1078	7·1	$+0\cdot009$	$\pm$	$0\cdot015$	16·0
	1181	7·8	$+0\cdot014$	$\pm$	$0\cdot018$	55·7
	1108	8·7	$+0\cdot046$	$\pm$	$0\cdot017$	45·2
W. B. 15^{h},	745	--	$-0\cdot003$	$\pm$	$0\cdot021$	55·6

An inspection of these results would seem to indicate that there is a discernible color effect conforming with theory, the mean light of the red star being apparently refracted less than that of the comparison stars, except in the case of Krüger 985, although the amount is very small except for very red stars. This conclusion is corroborated by a comparison of the results for Krüger 1181 and W. B. 15^{h}, 745, investigated under exactly the same conditions. The result for the latter coming out so nearly zero is a most satisfactory confirmation of the accuracy of the work. That the color effect is not greater rather tends to confirm Sir David Gill's opinion that the heliometer observer's tendency is to bring the similarly colored parts of the stars' spectra rather than the brightest parts into coincidence.

Now what influence this possible source of error, if real, may have upon our parallax results can be easily shown. Scarcely any of the measures were made at a zenith distance greater than 60° and the average was about 50°. The following table gives the value of the factor $\tan z \cos (p-q)$ for each twenty degrees of declination at 50° zenith distance, assuming p, the position angle of the red star from the comparison star to be 90°, for which

value the difference of the factors for east and west observations is found to be a maximum. And taking the average double parallax factor to be 3·50 the last column gives the extreme correction that would have to be applied to the parallax, in which for $\Delta\beta$ is to be taken its value for a star of the same degree of redness.

Decl.	q	$\dfrac{\tan z \cos (p-q)}{}$		$\dfrac{E-W}{3\cdot 50}\Delta\beta$
		East	West	
0°	30·3°	−0·59	+0·59	−0·34 $\Delta\beta$
+20	52·3	−0·94	+0·94	−0·54
+40	65·0	−1·08	+1·08	−0·62
+60	74·4	−1·14	+1·14	−0·65
+80	77·5	−1·15	+1·15	−0·66

Thus considering that the color effect for a most highly colored star is not likely to be greater than $0\cdot66 \times 0\cdot046'' = 0\cdot03''$ we feel justified in concluding that any vitiation in our parallax results, due to this cause, is presumably well within their probable error."

Appreciating the rigorous methods employed in the work we can accept with confidence the inferences drawn by the authors from the analysis of the parallaxes obtained.

These are best summarized by again quoting from the text :

" The present investigation furnishing, as it seems to us, a homogeneous series of parallax values, we have thought it of interest to make a number of classifications of the results independent of the material hitherto obtained by other observers. While we cannot claim any very great precision for the individual results, determined as these are from such a comparatively limited number of observations, yet we do attach considerable weight to the mean values of the various groups we have formed, and consider these values of unquestionable significance.

These classifications are comprised in the five following tables. Table I gives an arrangement in order of the size of the proper-motion of the star under consideration ; Table II, a similar one in order of the star's magnitude ; Table III, in order of the size of the parallax ; Table IV, in order of Right-Ascension, subdivided into two classes north and south of Declinations +30°, and finally Table V, according to the spectral type and classes as given in the Draper Catalogue."

Of the results shown in these tables the following are the most interesting :

Table I reveals, as might be expected, a distinct interdependence of parallax and proper motion, especially in the group with proper motions exceeding $1''$. The data of Table II point to a small but undoubted relation between parallax and magnitude. Table III emphasizes the connection between proper-motion and parallax, none of the negative parallaxes corresponding to proper-motions greater than $1''$, and a marked progression being very apparent.

Table V does not conform to the law deduced by Kapetyn of connection between parallax and types of spectra, but the data are hardly sufficient to disprove the law.

The parallaxes grouped in order of magnitude appear as follows :

Number of stars with negative parallax, −0·13″ to −0·00″ _ _36
        small   "   +0·00 to +0·02 _ _40
        considerable   "   +0·04 to +0·09 _ _49
        large   " ·   +0·10 to + 0·20 _ _38

Of the last group the average magnitude is 5·8 and the average parallax 0·163″, corresponding to a distance of 20 light-years, which is two-thirds that of the 9 first magnitude stars. The average proper motion of the group is 0·90″, one and one-half times that of the first magnitude stars.

Two results of more popular interest may be stated as follows :

Proper motion is a far more reliable guide than brightness in estimating distance.

There is probably not more than one star in the northern heavens nearer to us than 61 Cygni.

In the last group is found the noteworthy addition to our knowledge of astronomy furnished by this work. All of its stars will be subjects of study in the observatories of the world for many years.   **W. B.**

2. *Publications of the United States Naval Observatory,* Superintendent, Rear-Admiral Asa Walker, U. S. N. Second Series, 4to, Volume IV, in four Parts, Parts I to III.—Part I contains Transit-Circle Observations of Sun, Moon, Planets and Miscellaneous Stars, 1900–1903. Part II contains Transit Circle Observation of Sun, Moon, Planets and Comets, 1866–1891. Part III contains Transit Circle Observation of Standard and Zodiacal Stars, 1901–1902.

Part IV forms a separate volume and is largely devoted to a discussion of observations made at the total solar eclipses of May 28, 1900, and May 17, 1901, with numerous illustrations. At the former, stations were occupied on the central line at Barnesville and Griffin, Georgia, and at Pinehurst, N. C. For the eclipse of 1901 an expedition was sent to Sumatra under the charge of Prof. A. N. Skinner and several stations occupied at which successful observations were made yielding important results, especially as regards the form of the corona. This subject is illustrated by a series of excellent plates.

IV. Miscellaneous Scientific Intelligence.

1. *A Text-Book in General Zoology* ; by Henry R. Linville and Henry A. Kelly. Pp. x + 462, with 233 illustrations. New York, 1906 (Ginn & Company).—This is an elementary text-book designed particularly for secondary schools. It contains, however, a vast amount of matter of interest to the general reader and in this respect differs widely from most books of the kind. The pupil or reader will here find the dry bones of anatomy and classification clothed with interesting accounts of habits, life history, relationship, and evolution, while the bearing of each fact on the general principles of biology is indicated. The book is to be accompanied by a pamphlet of suggestions for laboratory work. With a suitable laboratory course and judicious selection of topics the study of this book should arouse in the mind of the young student a love of nature and an eagerness to make the personal acquaintance of the animals considered, although many elementary courses are conducted in such a way as to secure an exactly opposite result. A large part of the illustrations are original and are unusually attractive. w. r. c.

2. *Illustrations of British Blood-sucking Flies with notes ;* by Ernest Edward Austen. Pp. 74 ; 34 plates. London, 1906 (Printed by order of the Trustees of the British Museum).—This work consists of reproductions of colored drawings prepared for exhibition in the British Museum, with interesting comments in popular language on each of the species illustrated. The 34 plates are well printed by the three-color process and represent the insects many times natural size, with few exceptions each figure occupying the whole of a large octavo plate. They might, therefore, be used to advantage to accompany the actual specimens in museums other than the one for which their originals were intended. This is particularly the case because many of the species are of very wide distribution, occurring not only in Great Britain, but also throughout Europe, Asia, and North America, and some in Africa and Australia. w. r. c.

3. *A Synonymic Catalogue of Homoptera. Part I. Cicadidæ ;* by W. L. Distant. Pp. 207. London, 1906. (Printed by order of the Trustees of the British Museum. Sold by Longmans & Co., etc.)—This first part of the British Museum Catalogue of Homoptera is devoted to Cicadidæ, and is prepared by Mr. W. L. Distant, who has given particular attention to this family of the Rhynchota. The fact that there has been no catalogue of the family published recently gives especial value to this exhaustive work.

Obituary.

Dr. Ludwig Boltzmann, Professor at the University of Vienna and eminent for his contributions to theoretical physics, died by his own hand in September last at the age of sixty-two years.

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ART. XXXIX.—*On the Relative Activity of Radium and Thorium, measured by the Gamma-Radiation;* by A. S. EVE.

THE recent work of Boltwood[*] and of Dadourian[†] proves that about one-half of the radio-thorium in radio-active minerals is abstracted in the chemical processes of preparing the commercial salts of thorium. This fact was established independently by the two observers, the one measuring the a-activities of the minerals and the salts, the other comparing the activities of their respective emanations. Thus they found per gram of thorium more radio-thorium in thorianite than in thorium nitrate, the ratio being about 2·1 or 2·6 to 1. Boltwood further states that "the specific activity of thorium with its equilibrium quantities of disintegration products is constant."

The present paper deals with the following points :—

I. To determine the ratio of the gamma-activities of radium and thorium when both are in radio-active equilibrium.

II. To ascertain the relative amounts of radio-thorium in thorianite and thorium nitrate respectively, by measurement of the gamma-radiations.

The object of the experiment was not to verify the work of Boltwood and of Dadourian, but to test the γ-radiation method, ascertaining if the results obtained by it were in good agreement both with the a-ray method and with the emanation method. Such was found to be the case.

[*] This Journal, June, 1906, pp. 409, 415.   [†] Ibid., p. 427.

In a previous paper* I have proved that the γ-rays from radium and from thorium are absorbed at a precisely equal rate during their passage through lead, whilst the γ-rays from uranium are much more readily absorbed. In the same paper, the ratio of the γ-activities of radium and thorium was also stated, but erroneously, inasmuch as thorium nitrate was used for the determination, and we now know that the thorium was therefore not in radio-active equilibrium. Furthermore, it has been shown† that the observable γ-radiation from radium in equilibrium is due solely to radium C. In the case of thorium it is known that the γ-rays are due to thorium C. Therefore, the γ-radiation of thorium C, which is, in due sequence, a disintegration product of radio-thorium, is a measure of the radio-thorium present. We should, therefore, expect the γ-radiation of a thorium mineral or salt to be proportioned to the amount of radio-thorium present. So that the results of γ-ray observations ought to be in agreement with those made by the *a*-rays or by the emanation method.

In the experiments the gamma-radiation was measured in the usual manner by an electroscope.

The substances compared were as follows :

(1) Radium bromide, equivalent to $\cdot 25^{mg}$ as compared with the sealed standard at the Physics Building, McGill University. This standard consists of $3\cdot 69^{mg}$ of radium bromide, which Rutherford found gave per gram a heating effect of 110 gram-calories an hour.

(2) Thorianite, Ceylon, 454 grams, containing 11 per cent of uranium and 79 per cent of ThO_2.

(3) Thorium nitrate, prepared by Eimer and Amend, received from them a year ago, which contains 47 per cent of ThO_2.

The activities of these three substances, measured by their γ-radiation, were respectively proportioned to

$$(1) \quad 18\cdot 5$$
$$(2) \quad 8\cdot 34$$
$$(3) \quad 1\cdot 38$$

These are the means of several observations under varied conditions, and are the actual divisions per minute observed with the electroscope.

Specific Activities.

(1) The activity of the radium bromide, under the conditions of the experiment, was $18\cdot 5/\cdot 25$ per mg. or 74,000 per gram.

(2) The specific activity of the thorium in the thorianite requires some consideration. Of the 454 grams of thorianite employed, 360 grams consist of ThO_2, and 50 grams of uranium. The γ-radiation of the uranium itself can be ignored, as it could not produce a sufficient effect through the thickness of lead employed. But with the uranium there will be an amount of radium present in the proportion determined by Rutherford and Boltwood. Thus the 50 grams of uranium are associated with $50 \times 3 \cdot 8 \times 10^{-7}$ grams of radium, or the equivalent of $3 \cdot 3 \times 10^{-5}$ grams of radium bromide. But $\cdot 25^{mg}$ of radium bromide had an activity of $18 \cdot 5$ as measured by the electroscope, and, therefore, the radium in the thorianite would produce a deflection of $18 \cdot 5 / \cdot 25 \times 3 \cdot 3 \times 10^{-2}$ or $2 \cdot 47$ divisions a minute. Deducting this from the total activity of the thorianite, namely, from $8 \cdot 34$, we have an activity of $5 \cdot 87$ due to the thorium and all its products, so that the specific activity is $5 \cdot 87 / 360$ or $\cdot 0163$.

(3) An analysis of the thorium nitrate showed that $47'$ per cent of ThO_2 was present, so that 213 grams of ThO_2 had an activity of $1 \cdot 38$, or a specific activity of $\cdot 0065$.

The specific activities here given are dependent on the electroscope used, on the thickness of the lead employed and on the distance of the substances from the electroscope. But the *ratios* of the specific activities is independent of the conditions of the experiments, except for a small correction due to the fact that the substances cannot be concentrated at a point.

The following results are, therefore, deduced :—

(a) The thorium and its products in the thorianite is more active than the thorium and its products in the thorium nitrate in the ratio of $\cdot 0163$ to $\cdot 0065$, or of $2 \cdot 5$ to 1. This is in very good agreement with Boltwood's results.

(b) Radium bromide in radio-active equilibrium is more active than an equal mass of ThO_2 in radio-active equilibrium in the ratio of 74,000 to $\cdot 0163$ or of $4 \cdot 5 \times 10^6$ to 1.

Therefore, *radium* is $6 \cdot 9 \times 10^6$ times as active as *thorium* when both are in radio-active equilibrium, when the activity is measured by the γ-rays.

In a previous paper the writer suggested that a kilogram of commercial thorium nitrate might be a convenient standard for γ-ray measurement. This suggestion was not a good one, because recent work has shown that radio-thorium would be continually increasing in such a standard, so that the activity would vary at a rate at present unknown. The only feasible

plan for providing standards seems to be by comparison with a sealed standard of radium bromide of known weight and purity.

Results.

(1) Radium bromide is $4 \cdot 5 \times 10^6$ times as active as ThO_2, or *radium* is $6 \cdot 9 \times 10^6$ times as active as *thorium*, measured by the γ-rays, when both are in radio-active equilibrium.

(2) The ratio of the quantity of radio-thorium per gram of thorium present in thorianite and in thorium nitrate has been measured by Boltwood, using the a-ray method; by Dadourian, using the emanation method; and, subsequently, by the writer, using the γ-ray method. The results obtained by these different methods are in good agreement.

With much pleasure I acknowledge the helpful advice of Professor Rutherford.

McGill University, Oct. 1906.

Art. XL.—*A Fossil Bird from the Wasatch;* by F. B. Loomis.

So far as the writer is aware, no bird has ever been described from the Wasatch Lake basin; so that any part of one from this lower portion of the Eocene becomes a matter of importance, especially if the remains are those of a land bird. When unpacking the collections of the Amherst College expedition of 1904, a number of bones in a better state of preservation than the rest were sorted out of a lot collected for Eohippus. These proved to be the fragmentary upper end of the femur, the upper end of the tibia and fibula, the distal end of the
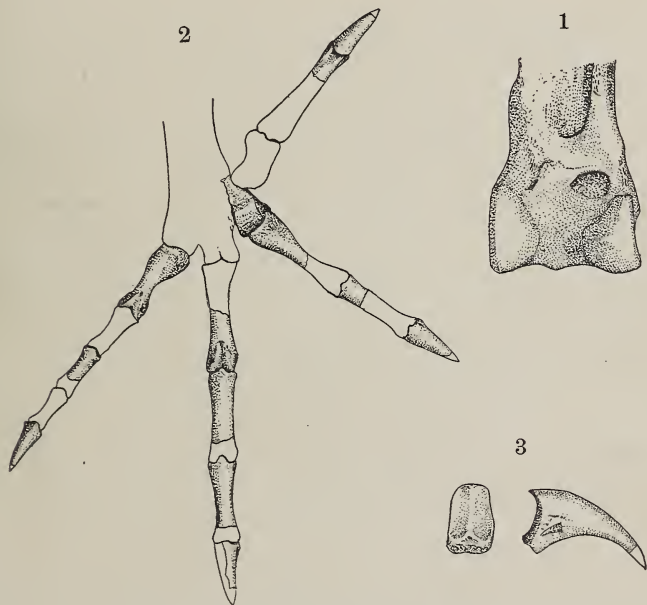
Fig. 1. *Gallinuloides prentici.* Distal end of the tibio-tarsus, front aspect; nat. size; co-type.

Fig. 2. *Gallinuloides prentici.* Outline of the left foot, with those phalanges found shaded in; ½ nat. size; type.

Fig. 3. *Gallinuloides prentici.* Claw of digit 4; articular face and side view; nat. size.

tibio-tarsus, eight more or less complete phalanges, and four claws, all belonging to the left leg of a bird; this bird was about half as big again as a turkey and of rather heavier build. Beside these a second specimen, consisting of the distal end of the left tibio-tarsus was found in the same layer about 100

yards off.   Both came from the basal layers of the Wasatch, near the head of Elk Creek, some ten miles west of Otto, Wyoming,

The bones belonged to a gallinaceous bird, having the same type of epitendinous bridge near the distal end of the tibio-tarsus, the deep groove on the distal end of the phalanges, and claws neither so curved as those of a bird of prey nor as blunt as those of a wading bird, though they are rather more pointed than the claws of the turkey or fowl.   However, without other portions of the skeleton, exact generic comparisons are difficult; so until more complete material is found, I would assign the fossils to the Bridger genus Gallinuloides, and I propose for the Wasatch fossil bird the specific name *prentici*, after Mr. E. P. Prentice, whose interest was instrumental in making the find.

The accompanying figures show the more characteristic features.   The type is No. b4 of the 1904 collection, the better bones from which are shown in figures 2 and 3, while figure 1 is of the second specimen.   The tibio-tarsus is a heavy bone 16^{mm} wide in the middle of the distal end, and 20^{mm} across the front of the articular condyles.   The depression on the articular end of this bone is shallower than on the tibio-tarsus of the turkey.   Of the tarso-metatarsus only the external articular head is preserved, which head is laterally compressed and the articular surface unusually flat.   Of the first row of phalanges those preserved are almost identical in appearance with those of a turkey, although larger and heavier.   The proximal phalanx of the fourth digit is complete and measures 20^{mm} long by 8^{mm} wide at the proximal end.   The distal end has a moderately deep groove about like that of the fowls.   The claws are rather narrow and deep, being produced into a sharp point and strongly curved so as to suggest perching habits.   The fourth claw measures 13^{mm} in length (at least 1^{mm} should be added for the tip broken off), 5^{mm} wide and 7^{mm} deep at the articular end.   The ridge or tongue on the articular face is low and rounded.   Below this articular surface there is a pronounced projection for the attachment of tendons, evidence of powerful ligaments for controling the use of the claws.

Amherst, Mass.

Art. XLI.—*The Iodometric Determination of Basic Alumina and of Free Acid in Aluminium Sulphate and Alums;* by Seth E. Moody.

In the exact analysis of aluminium sulphate and commercial alums the determination of the total alumina (soluble) and of the free. acid (the sulphuric acid actually free or present in an acid sulphate in excess of that amount needed to form neutral salts with the bases found) or of the "basic alumina" (that amount of base reckoned as Al_2O_3, left over after all sulphuric acid has been combined with the bases found to form neutral salts) is of importance.

This paper is an account of an attempt to apply an iodometric process to the determination of the total alumina and the free acid and basic alumina in aluminium sulphate and alum.

It is well known that sulphuric acid reacts immediately with potassium iodide and potassium iodate in mixture, with liberation of iodine in definite amount, according to the equation,

$$3H_2SO_4 + 5KI + KIO_3 = 3K_2SO_4 + 3H_2O + 6I$$
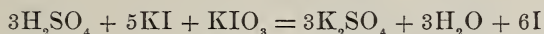
The determination of the free iodine by titration with sodium thiosulphate gives a measure of the sulphuric acid entering into the reaction.

It has been shown in previous papers[*] that various sulphates undergo hydrolysis when boiled with water, and that in presence of the iodide-iodate mixture iodine is liberated proportionately to the sulphuric acid thus formed. Aluminium sulphate undergoes complete hydrolysis when boiled with the iodide-iodate mixture for a sufficient length of time, and, as Stock[†] has shown, the aluminium hydroxide precipitated in the process is especially adapted to filtration and gravimetric determination.

The decomposition of an aluminium sulphate by this hydrolytic process in presence of the iodide-iodate mixture makes possible the gravimetric estimation of the total alumina and the iodometric estimation of the sulphuric acid formed in the hydrolysis. From the results thus obtained it is easy to calculate the *basic alumina* (the amount of alumina in excess of that required to form the neutral sulphate) or the *free acid* (the sulphuric acid, free or in an acidic sulphate, in excess of that needed to form the neutral sulphate), as the case may be.

[*] This Jour. xx, p. 181, 1905.
[†] Ber. Dtsch. Chem. Ges., xxxiii, i, p. 548, 1900.

The commercial aluminium sulphates, including the alums, may contain sulphates other than aluminium sulphate, which are susceptible to hydrolytic action. Ferrous sulphate, ferric sulphate and zinc sulphate are common impurities; and ammonium sulphate is a constituent of ammonium alum. The effect of each of these sulphates in liberating iodine has, however, been studied. Potassium sulphate and sodium sulphate, if present, do not set free iodine from the boiling solution containing the iodide-iodate mixture. The determination of the ferrous iron, the ferric iron, the zinc, and the ammonia will furnish data from which the equivalent amounts of sulphuric acid, to be taken into account in the reckoning of the free acid or basic alumina, may be calculated. The behavior of these commercial products toward the iodide-iodate mixture should, therefore, afford an easy method of determining basic alumina or free acid, as the case may be.
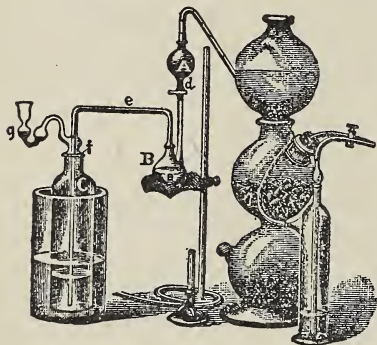
Following are d e t a i l s of treatment, and the results obtained in applying this method of analysis to certain samples of commercial alum, kindly submitted for the purpose by Dr. F. S. Havens, whose courtesy I desire to acknowledge.

Of the f i n e l y powdered material a portion of 15 grms. was weighed and treated with water. The solution was filtered and made up to 1 liter. The material which did not dissolve was dried at 100° and weighed as *insoluble material;* of the solution a portion of 25^{cm^3} was titrated directly with standard potassium permanganate to find the amount of iron in the ferrous salt, and from this was calculated the *ferrous oxide.*

Another portion of 25^{cm^3} was reduced with zinc in the usual manner and titrated with the permanganate to give the total iron. From the difference between the total iron and the ferrous iron was reckoned the *ferric oxide.*

To determine the zinc a portion of 25^{cm^3} was diluted to 50^{cm^3}, treated with 3 grms. of sodium acetate and 1^{cm^3} of acetic acid, and electrolyzed with the use of the rotating cathode[*] and a current of about 2 amperes for 30 minutes. The deposit of zinc, including some iron, was washed with alcohol, dried and weighed. The solution of the deposit in sulphuric acid was titrated with permanganate, the amount of

[*] This Journal, xv, 320.

iron thus found deducted from the total weight of the deposit to give the amount of zinc. From the zinc was calculated the *zinc oxide.*

The next step was to determine the amount of iodine set free by the action of the iodide-iodate mixture. Of the alum solution a portion of 25^{cm^3} was drawn from a burette into the Voit flask of the distillation apparatus, a solution (10^{cm^3}) containing 0·3 grm. of potassium iodate and 1 grm. of potassium iodide was added, the mixture boiled, and the iodine, collected in the receiver charged with water containing 3 grms. of potassium iodide (and acidified with sulphuric acid in case the substance contains ammonia), was titrated with sodium thiosulphate.

Aluminium sulphate undergoes complete hydrolysis, according to the equation,

$$Al_2(SO_4)_3 + 5KI + KIO_3 + 3H_2O = 2Al(OH)_3 + 3K_2SO_4 + 6I$$
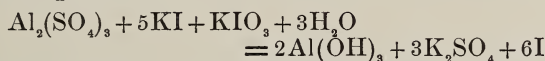
Ferric sulphate, like aluminium sulphate, undergoes complete hydrolysis according to the similar equation,

$$Fe_2(SO_4)_3 + 5KI + KIO_3 + 3H_2O = 2Fe(OH)_3 + 3K_2SO_4 + 6I$$
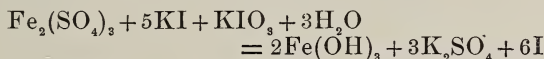
Ferrous sulphate likewise undergoes complete hydrolysis, but the ferrous hydroxide first produced is oxidized at the expense of the potassium iodate to form ferric hydroxide. This secondary reaction, however, affects in no way the amount of iodine liberated in consequence of the hydrolysis.

$$3FeSO_4 + 5KI + KIO_3 + 3H_2O = 3Fe(OH)_2 + 3K_2SO_4 + 6I$$
$$6Fe(OH)_2 + KIO_3 + 3H_2O = 6Fe(OH)_3 + KI$$
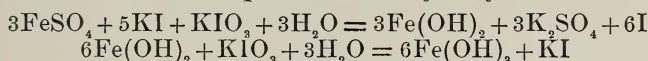
Zinc sulphate, on the other hand, does not undergo complete hydrolysis* but the insoluble product formed when a solution containing zinc sulphate and the iodide-iodate mixture is boiled in a one-fifth basic sulphate holding zinc and sulphuric anhydride in proportions indicated by the symbol $Zn_5(OH)_8SO_4$, and the reaction may be expressed by the equation,

$$15ZnSO_4 + 2KI + 4KIO_3 + 12H_2O = 3Zn_5(OH)_8SO_4 + 12K_2SO_4 + 24I$$
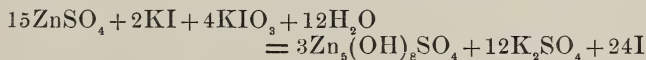
Ammonium sulphate is hydrolyzed on boiling with the iodide-iodate mixture† according to the equation,

$$3(NH_4)_2SO_4 + 5KI + KIO_3 = 3K_2SO_4 + 2NH_3 + 6I$$
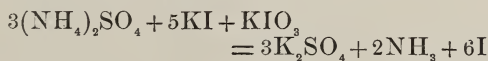
But, as has been said, to collect and correctly measure the iodine, the solution of potassium iodide in the receiver must be acidified with a little sulphuric acid.

* This Journal, xxii, 182, 1906.   ‡ Ibid.

The iodine set free corresponds to the various oxides, to ammonia and to sulphuric acid, therefore, in the following proportions:

$$
\begin{aligned}
Al_2O_3 &: 6I; \\
Fe_2O_3 &: 6I; \\
FeO &: 2I; \\
5ZnO &: 8I; \\
NH_3 &: I; \\
H_2SO_4 &: 2I;
\end{aligned}
$$

The precipitate produced in the hydrolysis contains after ignition the *total oxides*, Al_2O_3, Fe_2O_3, ZnO. Practically it is more convenient to determine the total oxides in a parallel process, carried on in an open beaker, from which the precipitate may be easily transferred, rather than to attempt to transfer and weigh the precipitate left in the distillation process.

Given the *total iodine* liberated in the distillation process, the weight of the *total oxides* obtained in the parallel boiling process, the *ferrous oxide* and *ferric oxide* by the permanganate titrations and the *zinc oxide* deduced from the corrected electrolytic determination, the *total alumina* and the *basic alumina* or *free acid* (as the case may be) are easily calculated.

Total oxides—(ferric oxide + ferrous oxide + zinc oxide) = *Total alumina.*

$$\left(\frac{6 \times 126 \cdot 97}{102 \cdot 2}\right)(7 \cdot 454) \times \text{Total alumina} =$$

iodine equivalent to total alumina.

$$\left(\frac{6 \times 126 \cdot 97}{159 \cdot 8}\right)(4 \cdot 767) \times \text{ferric oxide} =$$

iodine liberated by ferric sulphate.

$$\left(\frac{2 \times 126 \cdot 97}{71 \cdot 9}\right)(3 \cdot 532) \times \text{ferrous oxide} =$$

iodine liberated by ferrous sulphate.

$$\left(\frac{8 \times 126 \cdot 97}{5 \times 81 \cdot 4}\right)(2 \cdot 496) \times \text{zinc oxide} =$$

iodine liberated by zinc sulphate.

$$\left(\frac{126 \cdot 97}{17}\right)(7 \cdot 469) \times \text{ammonia} =$$

iodine liberated by ammonium sulphate.

Total iodine—(iodine corresponding to total alumina, ferric sulphate, ferrous sulphate, zinc sulphate, ammonium sulphate) = differential iodine.

Differential iodine (if positive) $\times \left(\dfrac{98 \cdot 08}{2 \times 126 \cdot 97}\right)(0 \cdot 386)$

= *free acid.*

Differential iodine (if negative.)

$$\times\left(\frac{102\cdot2}{6\times12\ \ 6\cdot9}\right)(0\cdot134) = \textit{basic alumina.}$$

The results of analyses of four specimens of alums are given in the following table :

TABLE.

Percentage composition.

| | Al$_2$O$_3$ | | | | | | Insoluble |
	Total.	Combined.	Basic.	FeO.*	ZnO.	NH$_3$.	material.
No. I							
(1)	14·48	13·49	0·99	0·43	3·70	none	0·61
(2)	14·28	13·46	0·82	0·44	3·70	none	0·61
No. II							
(1)	15·94	14·21	1·73	0·43	1·47	none	0·21
(2)	15·90	14·34	1·56	0·45	1·34	none	0·21
No. III							
(1)	15·59	14·81	0·78	0·34	0·73	none	0·71
(2)	15·97	14·80	1·17	0·36	0·82	none	0·71
D.							
(1)	16·59	15·24	1·35	0·24	0·11	none	0·61
(2)	16·37	15·18	1·19	0·24	0·19	none	0·61

The writer wishes to thank Prof. F. A. Gooch for suggestions of procedure during the investigation.

* A trace of iron in the ferric state was found present in each sample.

Art. XLII.—*The Separation of Arsenic from Copper as Ammonium-Magnesium Arseniate;* by F. A. Gooch and M. A. Phelps.

In a previous paper* from this laboratory it has been shown that arsenic in the higher condition of oxidation is completely removed from solution as the ammonium magnesium arseniate by adding the arsenic in solution with stirring to a sufficient excess of magnesia mixture kept ammoniacal; and, further, that traces of arsenic, even in presence of ammonium salts—which tend to dissolve the ammonium magnesium arseniate—may be precipitated by the use of a sufficient amount of magnesia mixture. The fact that ammonium magnesium arseniate is insoluble in presence of an abundance of magnesia mixture while many salts of copper are soluble in ammonia suggests that arsenic existing as an arseniate may be separated from copper in ammoniacal solution by magnesia mixture. The ammonium magnesium arseniate, as has been shown, may be filtered off upon a mat of fine asbestos under pressure, in a perforated platinum crucible, and ignited to the condition of magnesium pyroarseniate. Obviously, the action of the ammoniacal copper solution on cellulose renders it impossible to make such an estimation by the use of paper filters.

For the work given here, solutions of arsenic were made by dissolving potassium dihydrogen arseniate in water in definite amounts, and standardized by determining the pyroarseniate obtained in the manner described in the former paper, referred to above. Into an excess of magnesia mixture kept ammoniacal and contained in a platinum dish, a definite amount of the standardized potassium dihydrogen arseniate solution was added from a burette with stirring. Finally, a few drops of ammonia were added to make sure that the solution at the end was distinctly ammoniacal, while at the point of precipitation the ammonia was never in marked excess. As soon as the precipitate subsided it was filtered off on fine asbestos under pressure in a perforated platinum crucible; but the fine powdery, crystalline precipitate is so fine that the preparation of a firm mat of finest asbestos is a necessary precaution against loss in filtration. The precipitate remaining on the platinum dish was removed with a policeman and rinsed with portions of the filtrate into the crucible. The precipitate gathered in this way, after carefully draining by pressure, was rinsed with just enough distilled water made faintly ammoniacal to remove

* This Journal, ix, p. 55.

any traces of the magnesia mixture left on the precipitate. The residue in the crucible was dried at low temperature over a Bunsen flame, and, when the ammonia had been driven off, was ignited to the condition of the pyroarseniate, cooled in a desiccator, and weighed.

The magnesia mixture used in all this work was prepared according to Blair's directions.* That is—a solution one hundred and ten grams of the purest magnesium chloride of commerce containing water of crystallization was made in water and filtered. Into this solution was poured a solution of fifty-six grams of the commercially pure ammonium chloride in water further purified by treating it at boiling temperature with bromine water and then with ammonia in faint excess, and filtering. This solution, diluted to about two liters, was made ammoniacal by the addition of ten cubic centimeters of strong ammonium hydroxide. It was filtered after standing, and was filtered again each time as required for the experiments given below in the tables.

The solutions containing copper and arsenic from which the arsenic was separated, were made by treating the boiling solution of pure copper sulphate required for each experiment with ammonium hydroxide in such amount that all the copper was kept in solution, then filtering on asbestos in a perforated platinum crucible under pressure, pouring into a platinum dish and adding the arseniate.

In experiments (1) and (2) of Table I the solution of potassium dihydrogen arseniate was added from a burette to the ammoniacal solution of purified copper sulphate with the magnesia mixture held in a platinum dish ; and, after standing about two hours, the precipitate was filtered off on asbestos in a perforated platinum crucible under pressure, rinsed with the least amount of distilled water made faintly ammoniacal, 20–50$^{cm^3}$, dried carefully over a Bunsen flame, ignited after the ammonia was removed, cooled, and weighed. The results shown by (3), (4), (5), (6), (7), and (8) were obtained in the same way as in (1) and (2) excepting that the filtrations were made as soon as the precipitates subsided. The first filtrate was used to wash all traces of the precipitate into the crucible, and the precipitate was washed carefully, but not excessively, with distilled water made faintly ammoniacal, and then dried, ignited, and weighed. The results in (1), (2), and (3) show that it is possible to gather with accuracy any traces of arsenic present in solution. The presence of a compound of copper in precipitates considerable in amount was shown in some cases by dissolving the ignited pyroarseniate and getting the characteristic blue upon addition of ammonia to the solu-

* The Chemical Analysis of Iron, Blair, p. 59.

Table I.

No.	$CuSO_4$ grm.	H_2KAsO_4 cm^3.	MgMx cm^3.	$Mg_2As_2O_7$			Error in terms of arsenic. grm.
				Theory grm.	Found grm.	Error grm.	
(1)	2	0·2	25	0·0015	0·0015	0·0000 ±	0·0000 ±
(2)	2	0·2	25	0·0015	0·0015	0·0000 ±	0·0000 ±
(3)	2	0·2	25	0·0015	0·0015	0·0000 ±	0·0000 ±
(4)	2	1	25	0·0077	0·0086	0·0009 +	0·0004 +
(5)	2	5	25	0·0386	0·0415	0·0029 +	0·0014 +
(6)	2	10	50	0·0766	0·0798	0·0032 +	0·0015 +
(7)	2	50	50	0·3830	0·3922	0·0092 +	0·0044 +
(8)	2	50	100	0·3830	0·3910	0·0080 +	0·0037 +
(9)	2	50	50	0·3830	0·3957	0·0127 +	0·0061 +
(10)	2	50	25	0·3830	0·3952	0·0122 +	0·0059 +
(11)	2	50	50	0·3830	0·4120	0·0290 +	0·0140 +
(12)	2	50	50	0·3830	0·3960	0·0130 +	0·0063 +

tion. That the copper found here was not hydroxide or basic salt precipitated upon dilution from the ammoniacal solution is shown by the results of experiments (9) to (12), in which the precipitate gathered in the same manner as the previous ones was washed with mixtures of strong ammonia and water —1:8 in experiments (9), (10), and (12), and 1:5 in experiment (11). In experiments (11) and (12) the precipitate was rinsed by decantation with faintly ammoniacal water, then with ammonia and water (1:8) before transferring to the filter. The results make it probable that copper is held in combination in the residue as an arseniate and not as some other compound of copper precipitated from the ammonical solution by the water used in rinsing the precipitate.

In Table II are recorded results obtained by dissolving and reprecipitating the first precipitate. In these experiments a solution of potassium dihydrogen arseniate was run from a burette into the solution of copper sulphate and magnesia mixture in a platinum dish, the precipitate was transferred to a weighed crucible, and, after rinsing once with distilled water made faintly ammoniacal, was dissolved in hot hydrochloric acid, 1:4. For convenience in handling the solutions the filtration was made into a beaker inside an evacuated bell-jar rather than into the usual filter flask. After cooling and adding ammonia nearly to neutrality the solution was poured with stirring into an abundance of magnesia mixture kept constantly ammoniacal. The precipitate obtained in this way was gathered on the asbestos felt used for the first filtration, the first portion of the filtrate being employed in each case to remove the last portions of the ammonium magnesium arseniate from the platinum dish. After rinsing, all traces of reagents from the precipitate with distilled water made faintly

ammoniacal, 20–50$^{cm^3}$, it was dried over a low Bunsen flame until all ammonia was driven off, and then ignited. The weights of the ignited residues obtained after cooling in a

TABLE II.

No.	CuSO$_4$ grm.	H$_2$KAsO$_4$ cm^3.	MgMx cm^3.	Mg$_2$As$_2$O$_7$ Theory grm.	Mg$_2$As$_2$O$_7$ Found grm.	Error grm.	Error in terms of arsenic. grm.
(1)	2	0·2	25–25	0·0015	0·0012	0·0003 —	0·0001 —
(2)	2	0·2	25–25	0·0015	0·0009	0·0006 —	0·0003 —
(3)	2	1	25–25	0·0077	0·0072	0·0005 —	0·0002 —
(4)	2	1	25–25	0·0077	0·0079	0·0002 +	0·0001 +
(5)	2	5	25–25	0·0386	0·0389	0·0003 +	0·0001 +
(6)	2	5	25–25	0·0386	0·0383	0·0003 —	0·0001 —
(7)	2	10	25–25	0·0766	0·0754	0·0012 —	0·0006 —
(8)	2	10	25–25	0·0766	0·0754	0·0012 —	0·0006 —
(9)	2	25	25–25	0·1931	0·1927	0·0004 —	0·0002 —
(10)	2	25	100–100	0·1931	0·1919	0·0012 —	0·0006 —
(11)	2	50	50–50	0·3862	0·3867	0·0005 +	0·0002 +
(12)	2	50	25–25	0·3862	0·3864	0·0002 +	0·0001 +
(13)	2	100	50–50	0·7660	0·7724	0·0064 +	0·0031 +
(14)	2	100	50–50	0·7660	0·7694	0·0034 +	0·0016 +
(15)	2	100	100–50	0·7660	0·7723	0·0063 +	0·0030 +

desiccator, indicate that the ammonium magnesium arseniate is essentially free from copper in combination, except where the arsenic is present in amounts as large as three-tenths of a gram or more. For such amounts the second precipitate was dissolved in hydrochloric acid and reprecipitated by pouring into magnesia mixture after cooling and making nearly neutral. This treatment, as is shown in the results given in Table III, gives the arseniate free from copper, in ideal condition as the ammonium magnesium arseniate.

Where the amounts of arsenic were very small it was a matter of difficulty to recover the arsenic after solution in hydrochloric acid in such volumes as are necessary in every case where resolution is made—from 100–300$^{cm^3}$—although in some cases the solution was made distinctly ammoniacal before pouring into the magnesia mixture, stirred about five minutes to help bring the crystals out of solution and allowed to

TABLE III.

No.	CuSO$_4$ grm.	H$_2$KAsO$_4$ cm^3.	MgMx cm^3.	Mg$_2$As$_2$O$_7$ Theory grm.	Mg$_2$As$_2$O$_7$ Found grm.	Error grm.	Error in terms of arsenic. grm.
(1)	2	50	50– 50–50	0·3830	0·3822	0·0008 —	0·0004 —
(2)	2	100	50– 50–50	0·7660	0·7653	0·0007 —	0·0003 —
(3)	2	100	50– 50–50	0·7660	0·7656	0·0004 —	0·0002 —
(4)	2	100	100–100–100	0·7724	0·7726	0·0002 +	0·0001 +

stand over night before filtering. In such cases it was found that when the solution of arsenic and magnesia mixture with ammonia in distinct excess was frozen, by putting the platinum dish containing the mixture into a good freezing mixture of fine ice and salt for five minutes, the ammonium magnesium arseniate was precipitated out during the freezing and remained as a precipitate after the frozen mass was melted. In experiments (1) to (6) of Table IV the precipitates were obtained in this way. In every case the precipitate was filtered off on a firm mat of finest asbestos, ignited after careful drying, and weighed. In experiment (7), made in blank, no precipitation occurred. Experiments (5), (6), and (10) show that it is possible to recover satisfactorily the traces of arsenic even in presence of ammonium chloride in larger amount than would be necessary in the ordinary processes of analysis; and experiments (8), (9), and (10), show that double precipitation does not affect unfavorably the delicacy of the process.

The work as given above shows that arsenic in the higher condition of oxidation may be separated as ammonium magnesium arseniate from copper in ammoniacal solution. When the amounts of arsenic present are more than a few milligrams two precipitations are necessary. Up to two-tenths of a gram of arsenic two precipitations are sufficient. When the amount of arsenic exceeds two-tenths of a gram, three precipitations are requisite. If the arsenic is present in amounts as small as five milligrams, or less, when much stirring

TABLE IV.

No.	$CuSO_4$ grm.	H_2KAsO_4 cm^3	MgMx cm^3	NH_4Cl grm.	$Mg_2As_2O_7$			Error in terms of arsenic. gram.
					Theory grm.	Found grm.	Error grm.	
(1)	-	0·2	25	--	0·0015	0·0014	0·0001 —	0·0000 ±
(2)	-	0·2	25	--	0·0015	0·0017	0·0002 +	0·0001 +
(3)	-	1	25	--	0·0077	0·0078	0·0001 +	0·0000 ±
(4)	-	1	50	--	0·0077	0·0076	0·0001 —	0·0000 ±
(5)	-	0·2	25	10	0·0015	0·0013	0·0002 —	0·0001 —
(6)	-	1	25	10	0·0077	0·0070	0·0007 —	0·0004 —
(7)	2	--	25	--	- - - - -	- - - - -	- - - - -	- - - - - - -
(8)	2	0·2	25–25	--	0·0015	0·0015	0·0000 ±	0·0000 ±
(9)	2	0·2	25–25	--	0·0015	0·0015	0·0000 ±	0·0000 ±
(10)	2	0·2	25–25	10	0·0015	0·0012	0·0003 —	0·0001 —

is required to bring about crystallization, it is decidedly advantageous and even necessary in dilute solutions, especially if containing ammonium chloride, to freeze the mixture. The precipitate obtained by pouring into magnesia mixture the cooled solution of the arseniate in hydrochloric acid, in the manner described, is the ammonium magnesium arseniate of ideal constitution; and this by ignition after carefully drying until all ammonia is driven off yields magnesium pyroarseniate corresponding to the amount of arsenic in solution.

Art. XLIII.—*Contributions to the Geology of New Hampshire: No. II, Petrography of the Belknap Mountains;* by L. V. Pirsson and H. S. Washington.

Gilfordal-camptonose.

The rock mass forming the west lower slope of Locke's Hill has been described in respect to its geologic relations in the preceding paper on this region under the field term of diorite. While the mass shows some variation in structure and in mineral composition in places and especially so near the southeast border, there is a certain type which, because it strongly dominates and has certain strikingly peculiar features, impresses itself as the characteristic one of the area. The description of this rock type is as follows:

Megascopic.—Phanerocrystalline; medium to coarse grain; dark gray to black; composed chiefly of roughly equidimensional, anhedral, black hornblendes from $1-2^{cm}$ in diameter, so thickly crowded with short rough tables and anhedral masses of dull white feldspar from $2-3^{mm}$, which they poikilitically enclose, that there generally appears almost as much feldspar as hornblende; interspaces between the nearly juxtaposing hornblendes filled with granular masses of the same feldspars and black ferromagnesian minerals of similar size of grain $2-3^{mm}$. Contact facies similar but of finer grain, the large hornblendes from $3-6^{mm}$ in diameter; contains rare specks of pyrite. Fabric subporphyritic and poikilitic granular; fracture tough.

Microscopic.—Hornblende, augite and plagioclase essential; biotite, iron ore, titanite, pyrite, apatite accessory; chlorite, muscovite, epidote and göthite secondary; scapolite local, secondary.

Augite, short columnar prismoids, 010, 100 and 110, poorly developed; extinction angle greater than 40°; pleochroic c and b pale rose-red, a pale brownish-yellow; varies in depth of color, sometimes nearly colorless with pale greenish tone; contains inclusions of the brown hornblende mentioned below in parallel position as original intergrowths.

Hornblende in irregular masses, anhedral; includes all the other minerals, especially feldspar; strongly pleochroic; c umber-brown, b olive-brown and a pale brownish-yellow; absorption marked, c > b > a; angle of c on c about 18°; double refraction c–a about 0·020; it varies into a green variety which exists also in independent masses but is not so common and is then in small individual grains, c and b olive-green and a pale brownish-yellow. Cleavage good.

Plagioclase in short thick tables and laths: mostly anorthite but often zonal with varying mantles of labradorite; Carlsbad and albite twinning general; altering in spots, mainly in the contact facies, into scapolite, which fills the interstices between the other minerals. Feldspars embedded ophitically in hornblende, less commonly in biotite and augite.

Biotite varies locally in amount; in roughly developed tables up to 1^{mm}; ordinary brown variety and strongly pleochroic; slight variable openings of axial cross; of uniform coloration and not zonal; intergrown with augite and hornblende and may include any of the other minerals; altering in places into chlorite and epidote, or into muscovite.

Iron ore in anhedral to subhedral grains, sometimes including cores of pyrite; rarely altering into a deep reddish semitransparent substance assumed to be göthite; older than and enclosed in the other minerals.

Titanite in irregular grains, anhedral; sometimes aureoling iron ore; sometimes in masses filling angular interspaces between automorphic feldspars; sometimes independent in form.

Apatite not especially abundant; in the usual prismoid crystals enclosed in other minerals.

Scapolite occurs locally distributed and appears to be chiefly if not entirely confined to areas near the contact. It forms irregular masses filling the interspaces between other constituents, and its mode of occurrence and relations to the feldspars show clearly that it is of secondary origin and formed at their expense. From this it follows that it probably belongs to the meionite end of the series. It is easily identified by its very definite optical properties.

Chemical Composition.—The chemical composition of this rock is shown in No. I of the adjoining tables of analyses. For reasons previously stated, it was made upon a specimen not far from the border and representing rather more the border facies than the main type. As this contains more biotite, as shown in the descriptions of the mode, the water is largely constitutional, as hydroxyl in the biotite and hornblende, and is not to be regarded as a necessary sign of alteration.

The striking features of this analysis are the low silica and alkalies with the high alumina and bivalent oxides. It is clear that a magma of this character would form chiefly ferromagnesian minerals and labradorite. Especially notable is the large amount of iron.

For comparison the analyses of three other rocks (Nos. II, III and VII) which are composed of similar minerals, and which in the prevailing classification would be termed essexites, are given. It has features of agreement with them and also differ-

ANALYSES OF CAMPTONOSE AND RELATED ROCKS.

	I.	II.	III.	IV.	V.	VI.	VII.
SiO$_2$	43·94	46·99	43·65	42·73	41·63	·732	45·32
Al$_2$O$_3$	16·17	17·94	11·48	14·50	13·26	·159	18·99
Fe$_2$O$_3$	3·96	2·56	6·32	4·03	3·19	·025	3·78
FeO	10·06	7·56	8·00	7·28	9·92	·140	9·78
MgO	5·05	3·22	7·92	5·46	7·31	·126	4·68
CaO	9·59	7·85	14·00	8·46	8·86	·171	9·19
Na$_2$O	2·93	6·35	2·28	3·11	2·49	·047	3·78
K$_2$O	1·51	2·62	1·51	2·28	3·32	·016	2·12
H$_2$O110°+	1·42	0·65	1·00	3·08	1·35	----	0·31
H$_2$O110°−	0·13	----	----	0·36	----	----	0·09
CO$_2$	0·09	----	----	3·76	5·20	·002	----
TiO$_2$	4·13	2·92	1·09	4·30	3·95	·052	1·94
P$_2$O$_5$	0·69	·94	trace	·63	?	·005	----
S	----	----	----	·18	----	----	----
Cl	----	----	----	trace	----	----	----
Cr$_2$O$_3$	----	----	----	none	----	----	----
NiO	----	----	----	trace	----	----	----
MnO	tr	tr	----	·19	·27	----	----
BaO	none	none	----	trace	----	----	----
Total	99·67	99·60	100·16	100·65	100·75	----	99·98
O=S	----	----	----	·05			

100·60

I. Gilfordal-camptonose (essexite). West foot of Locke's Hill, Belknap Mts. New Hampshire. H. S. Washington analyst.

II. Hornblende grano-essexose (essexite). Salem Neck, Mass. H. S. Washington analyst (Jour. Geol. vii, p. 57, 1899).

III. Grano-limburgose. Brandberget, Gran, Norway ; (Brögger, Quar. Jour. Geol. Soc., vol. 50, p. 19, 1894). L. Schmelck anal.

IV. Hornblende phyro-camptonose. Summit of Mt. Gunstock, Belknap Mts. New Hampshire. H. S. Washington analyst.

V. Hornblende ourose (camptonite). Livermore Falls, Campton, New Hampshire. G. W. Hawes (this Jour. (3), vol. xvii, 147, 1879).

VI. Molecular ratios of No. 1.

VII. Hornblende grano-salemose (hornblende gabbro). Salem Neck, Mass. H. S. Washington (Jour. Geol. vii, p. 63, 1899).

ences; the rock of No. VII, described by one of us, is most nearly like it. Further discussion of this point is deferred until the classification is taken up. It is to be noted how closely it resembles in composition the camptonose dike rocks of this area as shown by a comparison with No. IV, and indeed it is essentially the same type of magma as that which furnishes the rocks classified in general as camptonites. This is seen from the analysis by Hawes of one from the type locality. Brogger*

*Basic Eruptive Rocks of Gran, Quar. Jour. Geol. Soc., 1, p. 26, 1894.

has already shown the close relationship between the rocks classed as camptonites and essexites, showing that the former could be derived from the latter by differentiation, and that since the volume of the complementary bostonite is relatively small, that of the essexite and camptonite are practically alike. If indeed in Gran the essexite magmas had been subjected to the same processes of cooling and crystallization, in undifferentiated condition, as those which produced the camptonites, it can scarcely be doubted that they would have produced essentially similar rocks which would also be termed camptonites.

Mode. — The mode or actual mineral combination was determined by Rosiwal's method. For the coarse-grained type of the main mass a large section measuring 30×40^{mm} of rock surface was used and a distance of 200 times the average grain was traversed. The border facies was also measured and the results obtained are given in the table.

	Vol. per cents.		Weight per cents.	
	Border.	Main.	Border.	Main.
Apatite	1·9	0·6	1·9	0·6
Titanite	0·3	2·2	0·3	2·2
Iron ore	4·5	7.7	7·6	12·5
Pyroxene	4·3	15·8	4·6	16·1
Biotite	10·7	3·3	10·4	3·1
Hornblende	27·6	26·3	30·6	27·9
Plagioclase	47·1	43·5	41·6	36·6
Scapolite	2·9	----	2·4	----
Epidote	0·6	----	0·6	----
Chlorite	----	0·6	----	0·6
Total	99·9	100·0	100·0	99·6

Classification in the Quantitative System.—The calculation of the norm of this rock from the analysis and the determination of its systematic position are given in the subjoined table.

Norm.

Or	8·90
Ab	22·01
An	26·69
Ne	1·42
Di	13·38
Ol	10·47
Mt	5·80
Il	7·90
Ap	1·68
Rest	1·64
Total	99·89

$$\frac{\text{Sal}}{\text{Fem}} = \frac{59·0}{39·2} = 1·5 = \text{Class 3, Salfemane}$$

$$\frac{\text{L}}{\text{F}} = \frac{1·4}{57·6} = 0·02 = \text{Order 5, Gallare}$$

$$\frac{K_2O' + Na_2O'}{CaO'} = \frac{63}{96} = 0·66, = \text{Rang 3, Camptonase}$$

$$\frac{K_2O'}{Na_2O'} = \frac{16}{47} = 0·34, = \text{Subrang 4, Camptonose}$$

In the mode the orthoclase and part of the olivine of the norm have united to form biotite, while the hornblende of the mode is made up from some of the normative olivine, diopside, magnetite and anorthite and probably it contains some or all of the nephelite as well. This is only another illustration of the complex nature of the hornblende molecule.

The mode is thus abnormative, containing a notable amount of hornblende and some biotite. The fabric, as has been shown, is granular and pseudoporphyritic or poikilitic. If one wished to characterize all of these features in the name it would become biotitic hornblende-grano-phyro-camptonose, but more simply it is hornblende-poikilo-camptonose. As, however, the fabric and other characters of the rock are so peculiar and striking, it has been thought best to erect this rock into a distinct type, on which the name of gilfordal camptonose is bestowed, the type adjective being derived from the village of Gilford near the type locality.

Classification in the older systems.—In these, if one considers merely the qualitative statement of the chief minerals of the rock, that it is composed mainly of plagioclase and hornblende, it would be termed a diorite; if we take into account also its basic chemical character, and the large amount of lime, iron and magnesia, it would be considered rather a hornblende gabbro; if there is also considered the nature of the hornblende, the presence of the pyroxene and biotite and the association of the rock with alkalic syenites and with camptonites and its close chemical and mineral correspondence with the latter, it would fall in Rosenbusch's family of essexites. It has, it is true, less alkalies than most of these rocks show, but it is also to be noted that under the heading of granular rocks, composed chiefly of basic plagioclase and brown barkevikitic hornblende, associated with alkalic rock complexes, types which differ quite widely among themselves in various chemical features have been grouped as essexites. This is seen, for example, in the table of analyses in Rosenbusch's Elemente der Gesteinslehre and our analysis agrees in each of its features with some of those there given.

Facies of the grano-camptonose (essexite) mass.

At the southwest foot of Locke's Hill the bench, which along the western side forms the top of the camptonose area, is cut off by a ravine, and at this point, as previously mentioned, both it and the pulaskose (syenite) are in contact with the gneisses. Above this on the bench are outcrops forming fine exposures of the salfemic rocks, and it may be seen here that locally the camptonose passes into phases of an even granular

dioritic-appearing rock in which the large poikilitic hornblendes are much restricted in amount or even entirely disappear. There is also considerable variation in grain. One specimen shows a granular rock with black and white minerals evenly mixed in very nearly equal amounts, the size of grain from 2–4^{mm}. The white mineral is feldspar, the black mostly hornblende, with some augite and here and there bronzy lustered biotites. In other places the rock is the same but of much finer grain. Under the microscope the same minerals are seen as in the gilfordal camptonose but in more variable amounts. Biotite is generally much more abundant; the brown hornblende in places yields to a green variety. Otherwise the minerals need no especial comment. Their relative proportions are variable and in one case the passage into a distinctly salic phase was noted, the rock containing an excess of feldspar, much of which is alkalic. Detailed study and analysis of the different facies at this place would undoubtedly show varieties bordering upon, or in, monzonase (monzonite, diorite and perhaps akerite of the older classifications), but these facies are of such restricted volume and confined to such a limited area, and play so small a rôle in the general petrography of the region, that it has seemed scarcely of value to undertake a complete chemical and petrographic investigation of them. They are so involved with what we consider the later irruptions of persalic magma described under the heading of breccia, that from the field exposures nothing more definite can be worked out than that they are distinct differentiation facies of the camptonose as stated above.

Hampshiral camptonose (camptonite).

Basaltic dikes of salfemic rocks are rather numerous in the area and a number of localities in which they have been found are mentioned in our previous paper. They are all composed of rocks made up of a brown barkevikitic hornblende and plagioclase which fall under camptonose or adjacent subrangs, or are camptonites in the older systems. One of these which affords the best preserved material occurs on the southwest side of Mt. Belknap, near the top, cutting a steep slope of syenite which is well exposed above the hillside pasture fields. The dike is about 3 feet wide with a pronounced columnar structure and is exposed for about 100 yards. A specimen of this was selected as a type for detailed study, measurement and analysis.

Megascopic.—Phanerocrystalline to aphanitic ; very dark stone-gray ; thinly sprinkled with minute white dots 0·25–1·00^{mm} in diameter (calcite fillings) ; the compact to fine-grained mass abundantly filled with slender dark glistening

needles 2–3^{mm} long (hornblende); tough, with a somewhat hackly fracture; on exposed surfaces altering to a leather brown crust dotted with black hornblende needles.

Microscopic.—Hornblende and plagioclase essential; iron ore and apatite accessory; calcite and chlorite secondary. The *hornblende* is present in two generations; the larger average about 1·50^{mm} in length by 0·40^{mm} in breadth, the smaller about 0·25 by 0·05. There are many gradations between them. Except in size they are alike in other respects, rather long columnar in development with 110 and 010 well developed, good terminals lacking. It is strongly pleochroic; $\mathfrak{c}$ and $\mathfrak{b}$ rich leather-brown, $\mathfrak{a}$ pale ocher yellow; absorption marked $\mathfrak{c} = \mathfrak{b} > \mathfrak{a}$. Angle of extinction *c* on $\mathfrak{c} = 18°$. The mineral includes a little iron ore and is very fresh and unaltered save in a few spots where it is changed to chlorite. The *plagioclase*, as the average of several determinations by Michel-Lévy's method shows, is a labradorite of about the composition Ab_7An_8. Its form is that of slender laths whose dimensions are similar to those of the small hornblendes mentioned above. Both Carlsbad and albite twinning occur. A few sporadic larger crystals of the same characters but in size like the larger hornblendes were observed. The smaller feldspars are often coated with films of an isotropic substance which also fills minute spaces. Its nature could not be ascertained, but presumably it is analcite and its association with calcite leads to the supposition that it is secondary.

The *iron ore* is in small grains ·05 to ·10^{mm} in diameter, peppered everywhere through the rock, sometimes agglomerated into larger lumps and often beading the edges of the hornblendes. *Apatite* occurs in minute needles of the character usual in such rocks.

Calcite is found liberally sprinkled through the mass in very minute pieces occupying little angular interspaces between the feldspars and other minerals; in these cases it does not appear as an ordinary alteration product since the adjoining minerals are fresh, but rather as an infiltrated material, if it is not indeed an original component. In a few places, however, it is agglomerated into masses which from their outlines and general appearance are evidently pseudomorphs of a former mineral, apparently augite, a few crystals of which about the size of the larger hornblendes were originally present. This seems to indicate that probably the calcite is to be regarded as secondary. These sporadic augites are the only minerals in the rock which have suffered any considerable alteration—the others being in good condition.

Mode.—The quantitative mineral composition as determined by the Rosiwal method is as follows:

	Vols.	Weights.
Apatite	1·9	1·8
Iron ores	6·4	10·8
Hornblende	31·7	34·9
Plagioclase	53·2	46·6
Calcite	6·7	5·8
Total	99·9	99·9

The amount of apatite is undoubtedly too low, for, as may be seen in the norm, the phosphoric acid demands about 2 per

ANALYSES OF CAMPTONOSE AND RELATED ROCKS.

	I	II	III	IV	V	VI	VII
SiO_2	42·73	41·63	41·94	48·22	46·59	44·22	·713
Al_2O_3	14·50	13·26	15·36	14·27	17·55	12·73	·142
Fe_2O_3	4·03	3·19	3·27	2·46	1·68	5·68	·025
FeO	7·28	9·92	9·89	9·00	10·46	5·18	·101
MgO	5·46	7·31	5·01	6·24	7·76	6·98	·137
CaO	8·46	8·86	9·47	8·45	10·64	11·57	·151
Na_2O	3·11	2·49	5·15	2·90	3·31	2·12	·050
K_2O	2·28	3·32	0·19	1·93	0·72	1·71	·023
$H_2O\ 110° +$	3·08	1·35	3·29	1·66	0·10	2·74	....
$H_2O\ 110° -$	0·36	....	....	0·28	0·07	....	....
CO_2	3·76	5·20	2·47	0·15	....	3·66	....
TiO_2	4·30	3·95	4·15	2·79	1·41	2·50	·054
P_2O_5	0·93	....	....	0·64	....	1·05	·006
S	0·18	....	....		....	....	
Cl	tr.	....	....	0·10	....	....	
CuO	none	....	....	tr.	....	....	
NiO	tr.	....	....	0·03	....	....	
MnO	0·19	0·27	0·25	0·20	....	0·45	
BaO	tr.	....	....	0·04	....	....	
	100·65			99·80			
$O=S$	·05	....	$O=Cl,F$	0·04	....	....	
Total	100·60	100·75	100·44	99·76	100·29	100·59	

I. Hampshiral-camptonose (camptonite). Mt. Belknap. H. S. Washington analyst.

II. Augite-ourose (diabase). Livermore Falls, Campton, N. H. G. W. Hawes analyst. (This Jour. (3), vol. xvii, p. 150, 1879.)

III. Hampshiral-livermorose (camptonite). Ibidem.

IV. Hampshiral-camptonose (camptonite). Mt. Ascutney, Vermont. Daly (Bull. 209 U. G. Geol. Surv. 1903, p. 87). W. F. Hillebrand analyst (includes Zro_2, ·03 ; F, ·05 ; FeS, ·36).

V. Hampshiral-auvergnose (camptonite). Salem Neck, Mass. Washington, (Jour. Geol. vii, p. 285, 1899.)

VI. Hampshiral-camptonose (camptonite). Kjöse Aklungen, Norway. Brögger (Erup. Gest. Krist. iii, p. 51, 1899). L. Schmelck analyst.

VII. Molecular ratios of No. I.

cent of the mineral to be present ; this is due to the fact that the needles of the mineral are excessively minute and cannot be measured accurately. In the same way, many tiny flecks of calcite also escaped, and this is probably also low. With the feldspar is included a small amount of isotropic base previously mentioned. All of these errors are small, however, and the result shows the rock made up of iron ore, hornblende and plagioclase in about the proportions given.

Chemical Composition.—This is shown in analysis No. I of the above table. In Nos. II–V are given for comparison analyses of rocks of similar mineral composition and occurrence which are either in camptonose or immediately adjoining subrangs. They are all classed as camptonites in the older systems. These are from the New England province and there is a strong resemblance between them in essential features. In No. III the total alkalies are about the same as in the others, but the soda very strongly predominates, throwing the rock over into the persodic subrang in the lendofelic order (III, 6.3.5), which is as yet unnamed, but for which we propose the name of livermorose, from the locality of Livermore Falls. Under the head of rocks which have been classed as camptonites in the qualitative systems, it will be found by a study of the analyses that types have been classed together which show quite wide divergences in chemical composition. When one recalls, however, that the type in such systems is based mineralogically upon the association of plagioclase with a relatively large amount of brown hornblende, this is not to be wondered at, for these brown hornblendes present as large a range of chemical variation as can usually be found under the heading of a single mineral name.

Classification.—In the quantitative system the norm of the rock and its position are as follows :

Norm

Or	..	13·34
Ab	..	20·44
Ne	..	3·12
An	..	18·90
Di	...	13·90
Ol	...	7·11
Mt	...	5·80
Il	....	8·21
Ap	..	2·02
Rest	..	7·57

$$\frac{\text{Sal}}{\text{Fem}} = \frac{55\cdot80}{37\cdot04} = 1\cdot5 \ (3), \ \text{Salfemane}$$

$$\frac{\text{L}}{\text{F}} = \frac{3\cdot12}{52\cdot68} = 0\cdot059 = (5), \ \text{Gallare}$$

$$\frac{K'_2O' + Na_2O'}{CaO'} = \frac{73}{63} = 1\cdot1 = (3), \ \text{Camptonase}$$

$$\frac{K_2O'}{Na_2O'} = \frac{24}{50} = 0\cdot48 = (4), \ \text{Camptonose}$$

Total, 100·41

The mode is abnormative and hornblende is the critical mineral. In texture the rock is trachytic though not of a typical character; in fabric it is megaporphyritic and hence it may be termed a hornblende-trachiphyro-camptonose. In the prevailing systems the rock is a typical, fine-grained camptonite.

To distinguish this alferphyric type of the camptonose and other closely related magmas, characterized largely by the abundance of highly automorphic, brown hornblende phenocrysts, and which rocks are called camptonites in the prevailing systems, we propose the adjective *hampshiral*, from the name of the state (New Hampshire) in which these rocks are common and where the first typical camptonite was found by Hawes. The general habit of these rocks may, therefore, be described as *hampshiroid*.

Variations from the hampshiral type.—Some of the black salfemic dikes are precisely similar to the type described above, but in other cases along with the hornblende there is developed a considerable amount of a pale brown augite of large extinction angle, well crystallized and appearing only in the phenocryst stage of development. When this appears the amount of plagioclase is lessened and a good deal of a cloudy, faintly doubly refracting base is present, which may perhaps be nephelite. It would seem as if lime had gone more largely into the augites and less was left for plagioclase. In one case where augite was quite abundant, no feldspar was seen. These variations in mineral development may be seen in closely contiguous dikes, as at Smith's Neck, and they are not believed to be correlated with any notable change in chemical composition. In a few cases there is also a variation in texture, the grain becoming so densely fine that under a high power the rock is made up of an exceedingly fine mesh of minute interlaced needles of hornblende and plagioclase. In general none of these last rocks have the hampshiroid habit with megaphenocrysts of hornblende like those of other well known localities.

West Dike.—One of the most interesting of these varieties is found in a dike on the lower west slope of Locke's Hill. The dike is about 20 feet in width and cuts the gilfordal camptonose (essexite) near its eastern contact as nearly as could be determined. It is in the northern part of the camptonose area, has an east and west trend, and is composed of a much cracked rock cut by many joint planes.

Megascopic. — Medium dull gray; much whitened and leached on the joint surfaces; occasional black hornblendes as phenocrysts $1-3^{cm}$ long and 0.5^{cm} broad showing 110 and 010; thickly dotted with small phenocrysts of feldspar of

stout tabular form 1–3^{mm} long, of a pink color and with
slender needles of hornblende also about 1–3^{mm} long, these
two with distinct fluidal arrangement. Groundmass compact
and of a medium, somewhat brownish-gray.

Microscopic.—The study of the section shows that the rock
is much altered. The groundmass consists of small feld-
spar granules tending to a short lath-shaped form, and although
considerably changed it can be seen that both alkalic and
plagioclase feldspars are present. At first glance the impres-
sion is that of a rock of syenitic aspect, that the rock is an
altered monzonose, a gauteite in current phraseology; but
further inspection reveals the fact that it is everywhere filled
with minute pseudomorphs of chlorite which, on grounds to be
presently mentioned, are thought to be pseudomorphs of
needles and microlites of hornblende. Were these latter pres-
ent, as they must have been originally, the rock would have a
distinct lamprophyric aspect and micro-hampshiroid habit.
This groundmass is dotted thickly with granules of calcite,
titanite and occasional ore grains. Scattered in it are infre-
quent phenocrysts of feldspar, which in spite of being more
or less filled with sericite shreds, show by the albite twinning
and extinction angles that they are of plagioclase.

The most interesting and important features of the rock are
the hornblende phenocrysts and the process of alteration
which they have suffered, one hitherto unmatched in our
experience. The unchanged mineral is a brown basaltic one,
with strong pleochroism in yellow tones and similar to that
already described in the gilfordal camptonose (essexite) and
in the dikes: c and 𝔟, dark yellowish brown; 𝔞, very pale
brown almost colorless, a pleochroism like many biotites.
Absorption strong, c = 𝔟 > 𝔞. Angle of c on *c* about 9°.
Cleavage very good. These are the properties of basaltic
hornblende. What remains of the small microlites in the
groundmass shows that they are similar.

These hornblendes are all more or less altered into pseudo-
morphs consisting of a pale green fibrous, almost isotropic
chlorite, grains of calcite and of titanite. The chlorite and
calcite as alteration products of hornblende present nothing
unusual, but, so far as we know, titanite as a secondary mineral
in this connection has not been described, and at first thought
it seems so unlikely an origin for it that the matter deserves
some consideration.

Titanite secondary from hornblende.

The titanite occurs in irregular grains and masses showing
no good crystal form, intermingled with the chlorite and cal-
cite in the pseudomorphs. Often it can be seen running into
the still unaltered hornblende in strips and wedges and

developed along cracks. The grains of titanite in such cases often have a nearly parallel orientation. Sometimes the outline of the pseudomorph is well defined by grains of titanite running along the boundary and more or less contiguous; the interior is mostly chlorite with scattered areas of the titanite. The amount of calcite present is usually relatively small and very often entirely wanting. The whole mode of occurrence of the titanite shows clearly that it is a secondary mineral; that it is quite similar to that of epidote in other cases of hornblende alteration. That the mineral is titanite, however, and not epidote is very clear, its refractive index and birefringence are far too high, and in sections perpendicular to the acute positive bisectrix it shows the characteristic optical figure—the small angle of the optic axes with both hyperbolas in the field with the strong dispersion of the optic axes which causes them to be bordered red and blue, with red greater than blue.

It might also be suggested that there was an original intergrowth of titanite and hornblende, but this is negatived by the fact that the unaltered fragments and crystals of hornblende are clear and free from inclusions; only where it is altered does the titanite appear.

In considering the cause of this manner of alteration, it should be remembered that basaltic hornblendes have been shown by Schneider[*] to have a pretty constant composition and to contain TiO_2 in amounts ranging from 4·26 to 5·40 per cent in the specimens analyzed by him, averaging about 5 per cent. Brögger,[†] in his table of the alkali-iron hornblendes, calls attention to the fact that these hornblendes rich in TiO_2 have extinction angles of 0–10° and pleochroism brown to light yellow, $c > b > a$, characters like those of the one under consideration.

It may be considered certain that this hornblende contains several per cent of TiO_2 and that in the breaking up of its molecule through processes of alteration this oxide has united with the lime and silica to form titanite. Five per cent of TiO_2 would yield over 12 per cent of titanite; the amount present appears considerably greater than this, and moreover it is not confined to the hornblende pseudomorphs but also occurs scattered through the groundmass in the same irregular grains. The larger grains of iron ore, when examined with a high power, are not solid mineral as is usually the case, but are filled with a network of holes, so that they are mere sponges. This suggests another source for the TiO_2, as that wandering out from the iron ore could have aided in a further increase of the titanite already forming from the hornblendes,

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[*] Zeitschr. für Kryst. xviii, 580, 1890.

[†] Grorudit-Tinguait Serie, Vid-Selsk. Skrifter, M-N-Kl., 1894, No. 4, p. 22.

which would supply the necessary lime and silica. The basaltic hornblendes contain about 12 per cent of lime, and if this were all used in producing titanite it would make 42 per cent in weight of the original hornblende. But as some of the lime has gone into calcite the amount of the mineral replacing hornblende is not so large as this, but is between this figure and that given above—probably 20–30 per cent and varying in different cases.

The two analyses of camptonose rocks previously given show about 4 per cent of TiO_2 in the rock, and as this has apparently all gone to form titanite, the total amount present is about 10 per cent in weight of the rock mass.

The appearance of the rock, and the white mica in the feldspars would seem to indicate that the alteration was due to hydrothermal metamorphism rather than to atmospheric weathering.

The occurrence of titanite as a secondary mineral seems not to have received the attention that it deserves. Every one is familar with its appearance in mantles around titanic ore grains in gabbroid rocks, and it is often mentioned in such circumstances as of secondary origin, but we are not acquainted with any description of its derivation from another mineral such as hornblende, though this may of course have been mentioned in the literature. In this connection it is interesting to recall the fact that it often appears in chlorite schists, amphibole chlorite schists and amphibolites whose chemical compositions are similar to those of magmas which yield salfemic and dofemic rocks.

Gunstock Gneiss.

As stated in the geological portion of this paper, the igneous rocks of the Belknap massif are in contact with micaceous gneisses along the western boundary. They constitute a distinct formation worthy of especial study, but as they are heavily covered with drift and exposures are none too frequent this would have taken more time than was possible to devote to this purpose and would have led us away from the main subject of this study. In our work along the western contact, however, we came upon these rocks in a number of places and specimens from several of them were taken for investigation. From two of these, one from the borders of the little ravine on the southwest foot of Locke's Hill and the other in the pasture fields at the foot of the steep slopes on the west side of Mt. Gunstock, sections were cut and studied and the results are given beyond. Since the lower valley of the Gunstock River is cut in this gneiss, we may provisionally, for purposes of reference, term it the Gunstock Gneiss.

Megascopic.—Color, dark stone-gray; of very fine grain; strongly foliated; even texture; highly micaceous and splitting readily along the plane of chief fracture; showing with lens an even mixture of white granules and flakes of mica.

Microscopic.—The minerals seen in the section are quartz, orthoclase, biotite, plagioclase, sillimanite, garnet, muscovite, apatite, iron ore and zircon in the order of their importance. The quartz is in irregular elongated granules, filled in places with dusty specks, shows occasional lines of fluidal cavities and rarely any evidence of undulatory extinction pointing to disturbance of the optical system by strain. The orthoclase has a similar form and in places is filled with shreds of sericitic muscovite; generally it is clear and unaltered and shows no twinning. The biotite is in small brown pleochroic flakes, well scattered but tending to lie with the base in the plane of schistosity, thus promoting the easy fracture. It sometimes contains iron ore with pleochroic halos. The plagioclase is similar to the orthoclase but distinguished by the albite twinning; it appears to be an oligoclase. It may be remarked here that the association of the sillimanite suggested the possible presence of cordierite, but careful search failed to reveal it by any of the usual diagnostic characters which it possesses. The sillimanite is in the usual characteristic bundles of needles, and it is not everywhere scattered through the rock but appears distinctly in layers; although these wedge out in places they soon recur again, running along at about the same horizon. The garnet, of an ordinary character, is in round grains of relatively considerable size associated with these sillimanite bands, which often curve around it. The apatite and zircon lie scattered in the quartz-feldspar layers; they are very small and a significant circumstance is the fact that they show no crystal outlines but are rounded ovoid bodies.

In the specimen taken near the contact at Locke's Hill the appearance of the biotite and the fabric of the rock suggested a distinct approach to the characteristic contact hornstone texture, but elsewhere this is not noticeable.

Origin of the Gunstock Gneiss.

The characters which have been mentioned above clearly point to a sedimentary origin for this gneiss. There is no sign of shearing or granulation and the minerals show no optical strain—it has therefore been recrystallized. The presence of the sillimanite-garnet bands points to fine clay layers of a somewhat marly nature interspersed among those forming the main mass of this very fine-grained arkose. The rounded forms of the apatite and zircon grains would point to their having been rolled in the fine sand; in the metamorphism

which recrystallized the rock they are minerals which would naturally be least affected and would retain their former shape. Had the rock been a sheared and recrystallized igneous one, we should expect them to have shown crystal outlines. The alternation in layers of different character points in the same direction. We think therefore that this gneiss was originally a very fine shaly arkose consisting of little-altered granitic debris with occasional very thin layers of a more marly clay-like nature. Often the chemical analysis of a rock helps greatly to decide its original character, but it is evident that the composition of a little altered arkose will be practically the same as that of the igneous rock from which it may have been formed, and in this case the solution of the problem, when it is metamorphosed, must be sought in other directions such as we have indicated above.

The Sequence of Magmas.

This has been previously alluded to on page 350 of the foregoing geological part. Now that the petrologic characters of the different types have been described, the reasons for the adoption of the succession of magmas there given can be discussed more fully. It depends upon the following facts, which have been brought out in these pages.

a. The pulaskose (syenite) passes into a fine-grained lassenose (adamellite aplite) marginal facies.

b. The pulaskose is cut by dikes of liparose (aplite), of camptonose (camptonite) and of akerose (spessartite). The relative ages of these dikes were not determined, as no place was found where they cut one another.

c. The grano-camptonose (essexite) shows contact facies as it approaches the pulaskose (syenite.)

d. The grano-camptonose (essexite) is cut by dikes of phyro-camptonose (camptonite) and of liparase (aplite).

e. The liparase (aplite) of *d* contains fragments of the camptonoses and akerose (essexite and spessartite) and of schists.

f. The breccia mass is like *e*, consisting of a liparase cement full of masses of the same rocks as in *e*.

From these facts we imagine then the sequence of events to have been as follows: First came the intrusion of the great body of pulaskose magma into the gneisses and schists. By processes of differentiation there formed a persalic or more quaric border of lassenose of variable width around this. Then followed a period of cooling and solidification. During this time extended processes of differentiation had been going on deep in the magma chamber, giving rise to products on the one hand more salic, on the other more femic. Then came a second period of magma upthrusting which forced the femic

magmas upward into the mass of pulaskose and into the surrounding area where they appeared as dikes, except in one place on the northwest boundary where the magma formed a small stock. In the dikes the texture assumed was dense and more or less porphyritic, forming trachiphyro-camptonoses and akeroses (camptonites and spessartite), but in the stock the crystallization was coarser, producing a granular texture and making grano-camptonose (essexite). This assumes that the rocks of the dikes and of the stock have a similar composition; that this is so, has already been shown with respect to the camptonoses. In regard to the akerose dikes it has been shown also that they correspond to one facies of the stock, which is somewhat variable in its composition.

The injection of the camptonose magma evidently was not everywhere a simultaneous one, for we find dikes of it in finer textured types cutting the camptonose stock, proving that this had already cooled and solidified to depths now exposed by erosion, when these later upthrusts of this magma took place. It is thus quite possible that the dikes of camptonose seen elsewhere are not all exactly of the same age but that their injection was successive, some corresponding in age with the intrusion of the stock and some later, like those dikes which cut it. On the general principles of differentiation as thus far developed, it would also seem probable that the akerose (spessartite) dike cutting the summit of Mt. Belknap was one of the earliest of this set, since it is less differentiated.

Following these came the period of the injection of the liparase (aplite), the persalic differentiate complementary to the camptonose. This has formed dikes in the pulaskose and in the camptonose stock. In the latter case it has brought up pieces of the camptonose in its various textural modifications and of the enveloping schists and gneiss involved within it, and in one place it forms an irregular mass, the breccia already described. At the time of its injection, cooling in and about the stock was becoming more pronounced and the magma was quite viscous. This is shown by the shattering and rupturing it produced on its upward way along the rock walls, the fragments thus broken off becoming kneaded through the mass, and also by the fact that these fragments were not melted, absorbed or changed, even when small and angular in shape. This was the final event in the formation of the igneous rocks.

The sequence thus worked out would be more certain if the actual contacts were everywhere visible, but as already stated they are in great part covered with drift. It however seems to correlate best all the facts seen in the field and determined by the laboratory studies. Moreover it has the advantage of simplicity in that it requires only three periods of injection

with corresponding changes in the composition of the magmas beginning with one of medium character, then changing to a more femic type and then back to a corresponding more salic one, and thus following the general history of differentiation observed in other districts. The only objection against this view which occurs to us is, that if the aplitic liparase injections are the latest phase along the contact between the camptonose and pulaskose rocks and contain blocks of the former, why do they not contain blocks of the latter? The answer to this is twofold—first, we are not sure that they do not, we did not observe them in the exposures studied; and second, we do not feel sure that we could identify them even if they were present, because in the field the liparose and the lassenose of the marginal facies both have the same aplitic habit and appear very much alike. They differ chemically and somewhat mineralogically as has been described, but in the rock masses these differences might not be appreciated and blocks of the one in the other would certainly be difficult and perhaps even impossible to recognize.

Moreover in this connection it should be pointed out that the dikes of liparase which penetrate the pulaskose were nowhere observed to contain fragments of the latter although of later intrusion into it, and it is in fact uncommon for aplitic dikes to contain such masses of the granitic rocks they penetrate, although they sometimes do. The further discussion of this point would carry us too far, but enough has been said to show that the objection advanced is not necessarily decisive against the sequence we have postulated and which we believe is best suited to explain the facts observed.

The Aplitic Marginal Facies

The aplitic, persalic marginal facies of the main massif of pulaskose is an interesting feature of the petrology of the area. Aplitic border facies of granites are probably not uncommon and have been described by a number of observers as listed by Rosenbusch.[*] In these cases, however, this appears to be mainly an endomorphic textural modification of the rock mass. In the present case it is not only a textural but much more a chemical modification, the border being richer in silica than the rest of the massif. At first thought it might seem as if the syenite had enriched itself in silica by solution of the enveloping rocks in some such way as Daly[†] has recently suggested for occurrences in Canada and elsewhere. A further consideration of the subject, however, does not seem to favor this view. It is true that the border facies contains here and there

[*] Mass. Gest., 3d ed., 1895-6, p. 65.
[†] This Journal, xx, 1905, p. 185.

fragments of the enclosing rocks, and that these appear at times, when very small, to be more or less absorbed, but generally even when minute they retain all their original sharpness of outline and angular form though completely metamorphosed. Moreover there is no evidence that the enclosing rocks are in general more siliceous than the syenite and in some cases they are distinctly less so. Where small fragments appear to have gone into solution the rock is not more but less siliceous, the small spot locally having more the character of a monzonase as already described in the inclusions in lassenose above Point Belknap.

Again, it should be considered that if such an action took place one would expect it to be general and everywhere present, while as previously shown the syenite on the southwest foot of Locke's Hill comes itself directly in contact with the schists. The consideration of the chemical character of the two rocks furnishes, however, the strongest argument against this view. In the syenite the percentages of the alkalies are $Na_2O = 4.89$, $K_2O = 5.90$, while in the granite border they are $Na_2O = 4.06$, $K_2O = 2.06$. It is clear from this that to reduce the alkalies of the former to those of the latter an enormous amount of some rock very rich in soda must have gone into solution. It could be easily demonstrated what the composition of such a rock would have to be by calculating from the two analyses, but this is unnecessary as the enclosing schists are clearly not of such a composition as could produce this change.

This explanation of the granite border being untenable, we are forced to fall back on causes endogenous to the fluid mass itself and to conclude that it is a case of magmatic differentiation. Cases where a massif of igneous rock has a differentiated border facies are becoming more numerous and several have been described where the border is more salic than the main portion.

Chemical Characters of the Belknap Magmas.

The data for studying the chemical characters of the magmas which furnished the rocks described in the preceding pages are found in the analyses presented in the annexed table.

Of these II and V have been calculated from the measured modes and, while not entitled to quite the weight of the others, may yet be regarded as representing fairly well the chemical compositions of the rocks in question.

The chemical range of the rocks is wide, especially as regards SiO_2, Al_2O_3, FeO and CaO, with Fe_2O_3, MgO, K_2O, TiO_2, and P_2O_5 showing less variation, while the amount of Na_2O is remarkably uniform. In general the variations of the several

constituents, referred to the percentage of silica or to the ratios of salic to femic minerals, are the usual ones, Fe_2O_3, FeO, MgO, CaO and TiO_2 increasing with decreasing silica, K_2O dropping sharply toward the femic end, while Na_2O also drops but to a much less extent.

Regarded from the point of view of the quantitative classification, the range of classes is from persalane to salfemane; the orders are only two, 4 and 5, the former being found only among the persalanes; the rangs represented are three, 1, 2 and 3, the first being most prominent in the persalanes and the last only found in the salfemanes; while there are only two subrangs, the sodipotassic and dosodic, the more salic and alkalic rocks belonging mostly to the first of these and the more femic and more calcic ones to the second.

ANALYSES OF THE BELKNAP ROCKS.

No.	I	II	III	IV	V	VI	VII	VIII	IX
SiO_2	75·65	68·16	69·76	60·75	59·91	52·95	43·94	42·73	60·33
Al_2O_3	12·89	15·27	18·22	19·55	15·82	14·96	16·17	14·50	17·69
Fe_2O_3	0·89	0·88	0·25	1·54	2·93	2·44	3·96	4·03	2·24
FeO	1·11	1·87	1·59	2·98	4·61	7·03	10·06	7·28	3·80
MgO	0·20	1·26	0·40	0·81	1·64	3·86	5·05	5·46	1·23
CaO	0·48	0·15	2·68	2·29	1·92	6·76	9·59	8·46	2·11
Na_2O	3·71	4·30	4·06	4·89	4·52	4·95	2·93	3·11	4·71
K_2O	5·50	7·06	2·06	5·90	6·61	1·64	1·51	2·28	6·26
H_2O+	0·15	0·37	0·50	0·08	0·43	0·55	1·42	3·08	0·26
H_2O-	0·08	---	0·15	0·24	---	0·09	0·13	0·36	---
CO_2	none	none	none	none	none	none	0·09	3·76	none
TiO_2	0·05	0·59	0·36	0·63	1·39	3·90	4·13	4·30	1·01
P_2O_5	---	0·09	---	0·13	0·22	0·76	0·69	0·93	0·18
S	---	---	---	---	---	0·05	---	0·18	---
Cl	---	---	---	---	---	---	---	tr	---
ZrO_2	---	---	---	---	---	0·02	---	---	---
NiO	--	---	---	---	---	---	---	tr	---
MnO	tr	---	tr	tr	---	tr	tr	0·19	
BaO	---	---	---	---	---	none	none	tr	---
	100·71	100·00	100·02	99·79	100·00	100·16	99·67	100·65	99·82
Subrang	I.4.1.3	I.4.1.3	I.4.2.4	I.5.2.3	II.5.1.3	II.5.2.4	III.5.3.4	III.5.3.4	I–II.5.2.3

I. Biotitic grano-liparose, (aplite). Dike, Mt. Belknap.

II. Hornblendic grano-liparose, (syenite). Locke's Hill.

III. Biotitic grano-lassenose, (adamellite-aplite). Piper Mountain.

IV. Hornblendic grano-pulaskose, (syenite). Mt. Belknap.

V. Hornblenditic grano-ilmenose, (syenite). Gunstock Peak.

VI. Hornblende akerose, (spessartite). Locke's Hill.

VII. Gilfordal camptonose, (essexite). Locke's Hill.

VIII. Hampshiral camptonose, (camptonite). Mt. Belknap.

IX. Hornblendic pulaskose-monzonose, (syenite). Average of IV and V.

It is to be noted, however, that some of the analyses are of rocks the volumes of which are very small relative to that of the whole igneous massif. This applies especially to the extremes, I and VIII, which are of the complementary dikes, whose total volume cannot be more than 5 per cent of the whole and is almost certainly considerably less than this. Similarly VI is of a rock of minor importance and of negligibly small relative mass. The area of the gilfordal camptonose (VII) of Locke's Hill is considerable, but its volume is undoubtedly not over another 5 per cent of the whole mass. That of the bordering aplitic lassenose facies (III) is undoubtedly considerably greater, though for reasons given previously it was impossible to estimate its extent with accuracy. The assumption that it forms about one-tenth of the complex will probably be not far from the truth.

As to the main mass of syenite we have seen that its composition is somewhat variable, different portions being represented by II, IV and V. Of these II is of a marginal facies and probably not fully representative of the whole. Analyses IV and V may therefore be held to represent the chemical composition of the bulk of the Belknap massif. These resemble each other in certain respects, especially in SiO_2, CaO, Na_2O and K_2O, but differ in the lower Al_2O_3 and higher Fe_2O_3, FeO and MgO of V, these resemblances and differences being clearly expressed by their respective places in the quantitative classification. Allowing equal weight to these two analyses, although V is calculated from a measured mode, we find that the composition of the syenite is that given in IX. The norm of this is as follows:

Sal			Fem		
Qz	1·56		Di	1·14	
Or	37·25		Hy	5·97	
Ab	39·82	86·97	Mt	3·25	12·68
An	8·34		Il	1·98	
			Ap	0·34	

The main syenite falls, therefore, in the dosalane class, but almost on the border of persalane and well within the limits of order 5, rang 2, and subrang 3, so that it is a pulaskose-monzonose, (I–II. 5.2.3).

We may attempt to estimate the composition of the magma as a whole, although the data are somewhat unsatisfactory and the results necessarily only approximately correct. For this purpose we may assume the relative volumes as estimated above, giving as much prominence as possible to the less abundant rocks. We shall thus estimate the volume of the syenite at eight-tenths of the whole, that of the border lassenose at one-tenth of the whole, that of the gilfordal camptonose at

one-twentieth, and that of the complementary dikes the same, those of liparose and of camptonose being in the proportion of 3 to 2. The analysis of the akerose (VI) may be neglected. Taking then 80 parts of IX, 10 of III, 5 of VII, 3 of I and 2 of VIII we obtain the following results :

SiO_2	60·94	Qz	4·50	
Al_2O_3	17·57	Or	32·80	
Fe_2O_3	2·13	Ab	38·25	86·67
FeO	3·91	An	11·12	
MgO	1·40	Di	0·92	
CaO	2·65	Hy	6·90	
Na_2O	4·52	Mt	3·02	13·31
K_2O	5·53	Il	2·13	
TiO_2	1·15	Ap	0·34	
P_2O_5	0·20			
	100·00		99·98	

These figures are practically identical with those furnished by the main syenite, though SiO_2 and CaO are a trifle higher and K_2O a little lower, and the classificatory position of the rock is the same, pulaskose-monzonose (I–II. 5.2.3.). That the divergence in composition of the average magma from that of the main syenite should be small follows from the fact that the combined weight of the modifying factors, that is the liparose, lassenose and camptonose, is only one-fourth that of the main mass. But the very close agreement shows that the several constituents in the more salic and the more femic magmas balance each other to a very great extent, and indicates that they are in the nature of complementary differentiates.

It is to be noted, however, that the main pulaskose-monzonose is higher in alumina, soda and potash than any of the smaller rock bodies,* while the figures for the other constituents lie between the extremes.

It is perhaps justifiable to infer from this the existence in the complex of a differentiate relatively higher in these constituents. Such a rock would be composed almost wholly of soda-orthoclase about Or_1Ab_1, with relatively insignificant amounts of quartz, plagioclase and alferric or femic minerals. We may possibly look for this in the syenitic cement of the breccia described above, which has not been examined chemically, but which we have shown to be markedly deficient in plagioclase and colored minerals, though the amount of quartz is considerable.

In conclusion a few words may be devoted to a comparison of the Belknap rocks with those of other igneous areas in New England and Canada. The best analogues are met with in the larger and more complex igneous district of Essex County,

* Except as regards soda in the akerose (VI).

Massachusetts, which has been described by one of us.* In this rocks of very similar chemical and mineralogical compositions occur. These include numerous types, of varying modes and textures, belonging to subrangs which are found at the Belknap Mountains, namely: liparose (granite, aplite, paisanite, keratophyre), lassenose (rhyolite), pulaskose (pulaskite, sölvsbergite), and camptonose (diabase), with essexose (essexite) closely like the phyro-camptonose of Belknap. These rocks of Essex County are, it is true, associated with miaskose (foyaite and tinguaite) and with umptekose (sölvsbergite,) but this heightens rather than detracts from the analogy, as miaskose and umptekose (nephelite-syenite), are found at Red Hill, across Lake Winnepesaukee from the Belknap Mountains. This last igneous mass will shortly be described by us, so that further consideration of this correlation may be deferred.

Still nearer to the Belknap Mountains are the rocks of Ascutney Mountain, which have been studied by Daly,† whose descriptions and analyses make clear the very close similarity between the two areas. The resemblance between the two is shown even in such details as the poikilitic development of the alferric minerals of some of the Ascutney gabbros and diorites, in this resembling the hornblendes of the gilfordal camptonose. Analogies may also be noted with the rocks of the Monteregian Hills, in the Province of Quebec, which have been described by Canadian petrographers.‡ The rocks of these last, however, are generally distinctly lower in silica and are more sodic, normative or modal nephelite being quite common.

It would seem that all of these occurrences, with perhaps others in Maine, New Hampshire, Vermont, and Massachusetts, belong to one petrographic province, or comagmatic region as it may be better termed, which may be called the Novanglian, from the many localities in New England. This is not the place for a discussion of this region, especially as our knowledge of some of the districts is as yet incomplete, but some of the chemical features may be briefly pointed out. These are the rarity of the dofemanes and perfemanes, the prevalence of quardofelic, perfelic, and lendofelic orders, of peralkalic and domalkalic rangs (alkalicalcic rangs occurring to some extent among the salfemanes), and of sodipotassic and dosodic subrangs. As features of minor importance may be mentioned the generally small amount of MgO, even in the salfemanes, the comparatively high FeO and TiO_2 (the amount of the latter being often very great in the salfemanes), and the almost complete absence of BaO.

New Haven, Conn., and Locust, N. J., June, 1906.

* Washington, Jour. Geol., vi, 787, 1898; vii, 53, 105, 284, 463, 1899.
† R. A. Daly, Bull. U. S. Geol. Surv., No. 209, 1903.
‡ J. A. Dresser, Am. Geol., xxviii, 203, 1901; F. D. Adams, Jour. Geol., xi, 239, 1903; J. A. Dresser, this Journal, xvii, 347, 1904.

Art. XLIV.—*On Yttrocrasite, a New Yttrium-Thorium-Uranium Titanate ;* by W. E. Hidden and C. H. Warren.

The crystal, from which the material for analysis was selected, was found about three years ago in Burnet County, Texas, by Mr. John J. Barringer, who discovered the famous gadolinite mine just across the Colorado River in Llano County, now known as Barringer Hill. The crystal was found among the debris thrown out from a small prospect pit, dug for gadolinite, and was the largest of several pieces observed in the loose pegmatite material. The locality is east of and nearly opposite Barringer Hill and distant from it about three miles. It is situated in Burnet County and in a region where coarse granite and pegmatite abound. This crystal when first found weighed about sixty grams, and was complete except at one end. It showed orthorhombic symmetry, but the faces were not smooth enough for satisfactory measuring. The type of form closely resembled the figure of yttrotantalite, on page 738 of Dana's System of Mineralogy. The three pinacoids, the unit prism, and one orthodome were apparent. The basal plane predominated.

The crystal had a thin dull brown coating of amorphous material which was evidently an hydrated alteration product, very similar to the yellowish brown coating observed on the polycrase (?) of North and South Carolina. The fresh underlying material is black in appearance, and has a bright pitchy to resinous luster, and closely resembles that of polycrase and euxenite, and like these has an uneven and small conchoidal fracture. Its hardness is between 5·5 and 6.

Under the microscope fragments of the mineral show, through their edges, a rich amber to light yellow color. Extremely thin pieces are almost colorless and transparent. In some portions near the surface minute black specks, suggestive of alteration products, or mechanical inclusions, were observed scattered through the material. The mineral when examined between crossed nicols is seen to consist of a mixture of isotropic and a feebly double refracting material. In several instances a distinctly spherulitic structure was observed with high powers, otherwise nothing of a definite nature could be made out regarding the optically active portion. The mineral is not now, therefore, of a strictly homogeneous structure. This fact taken into consideration with its content of water and carbon dioxide suggests that the mineral is a hydrated alteration of an originally anhydrous species. It may be mentioned here that a very similar heterogeneous structure has been also noticed as characteristic of specimens of polycrase (?) from North and South Carolina.

Before the blowpipe the mineral is infusible, assumes a dark grayish color and cracks open to a slight extent. In the closed tube it decrepitates slightly, gives off water and carbon dioxide at a temperature slightly below redness. The reactions with fluxes on platinum wire are not decisive. It is easily decomposed by hydrofluoric acid, leaving a light greenish residue of earth fluorides. If finely powdered it is soluble with slight effervescence when boiled in strong sulphuric acid, and yields a somewhat opalescent, pale yellowish green solution. If hydrochoric acid and zinc are added to this, a violet color is at first obtained, and this gradually changes to a blue-gray, and finally to a deep blue. (In this connection we would state that the South Carolina polycrase, when finally pulverized, makes a perfectly clear green solution when boiled with strong sulphuric acid, and leaves no residue.)

The material analyzed was that portion of the crystal which showed under the microscope practically none of the black specks above referred to.

The specific gravity was found to be 4·8043 at 17° Cent., the mean of two careful determinations on the chemical balance.

The results of the chemical analysis (Warren) were as follows :

Oxides.	Per cent.	Mol. wt.	Ratio.			
TiO_2	49·72	$\div$ 80·15	= ·620			
Nb_2O_5	present					
Ta_2O_5	trace					
WO_3	1·87	$\div$332·8	= ·008	·645	16·12	16
UO_3	0·64	$\div$288·0	= ·002			
SiO_2	trace					
CO_2	0·68	$\div$ 44·0	= ·015			
$(YtEr)_2O_3$	25·67	$\div$268·4	= ·096			
Ce_2O_3, etc.	2·92	$\div$331·0	= ·008	·113	2·82	3
Fe_2O_3	1·44	$\div$160·0	= ·009			
ThO_2	8·75	$\div$268·6	= ·033	·040	1·00	1
UO_2	1·98	$\div$271·6	= ·007			
PbO	0·48	$\div$222·9	= ·002			
MnO	0·13	$\div$ 71·0	= ·001	·036	0·90	1
CaO	1·83	$\div$ 56·0	= ·033			
MgO	trace					
H_2O	4·36	$\div$ 18·0	= ·242	·242	6·00	6
" hydrosc.	0·10					
Total	100·57					

The following points may be noted regarding the method of analysis : Water and carbon dioxide were determined directly by igniting the mineral in a platinum boat in a hard-glass com-

bustion tube reinforced with heavy platinum foil as recommended by Penfield and catching the products in sulphuric and potash bulbs respectively. Several blank determinations were run to test the apparatus previous to the actual determination. The combined weights of the water and carbon dioxide are slightly higher (0·15 per cent) than the loss on ignition of the boat and its contents, due probably to the oxidation of the UO_2. This close agreement indicates that there can be little if any helium or nitrogen present in the mineral and no evidence of their presence could be obtained. After ignition the mineral has a light buff color and goes into solution more difficultly than the unignited material.

A qualitative test for ferrous iron, made as recommended by Penfield,[*] proved its entire absence. The oxidation, therefore, of potassium permanganate by a cold sulphuric acid solution of the mineral was taken as an indication that part at least of the uranium present was in the form of the dioxide, and the figure given for this oxide in the analysis was obtained by titration with permanganate.

For the main portion of the analysis, the mineral was decomposed with hydrofluoric acid (the J. Lawrence Smith method). The greenish white residue of earth fluorides was filtered off, converted into sulphate (a little lead sulphate came out at this point) and twice precipitated with ammonium hydroxide to separate the earths, etc., from the lime. The earths were separated from the iron and uranium by precipitation with oxalic acid. Thorium and cerium earths were taken out as described by Hillebrand.[†] The cerium earths were separated from thorium by means of sodium thiosulphate and ammonium oxalate precipitations.[‡] The earths were all finally precipitated as oxalates, before ignition and weighing. Great care was taken to insure the complete recovery of earth oxalates from the filtrates. Some were almost invariably recovered, which again emphasizes the caution, in this regard, given in the article referred to above by Dr. Hillebrand. The yttrium earth oxides were of a light buff color and gave a pink nitrate solution. This tested spectroscopically showed the characteristic absorption spectra of erbium. The molecular weight was found to be 268·4 (R_2O_3).

The cerium oxides were brown in color and when dissolved in hydrochloric acid gave a yellow solution. Tested spectroscopically the didymium bands were obtained and a faint band in the position of the most characteristic erbium line, indicating a slight contamination. The molecular weight, determined as 331·0 (R_2O_3), is probably not exact owing to the small total weight

[*] Brush and Penfield's Determinative Mineralogy, p. 87.
[†] This Journal (4), xiii, p. 148, 1902.
[‡] See Metzger, Am. Chem. Jour., xxiv, 901, 1901.

of the oxides. Iron was separated from the uranium of this portion by passing hydrogen sulphide through the warm solution when nearly saturated with ammonium carbonate.*

The filtrate from the original hydrofluoric acid treatment was evaporated to fuming with sulphuric acid. After cooling and dilution with water, ammonium hydroxide and freshly prepared colorless ammonium sulphide were added and the precipitated hydroxides were digested on the water-bath. After filtration and solution the precipitation and digestion were repeated and the tungsten thus extracted was determined in the combined filtrates. Tin was tested for, but not found. Doubtless a little tungsten remains with the titanium, etc., but in the writer's experience the above method involves smaller errors than the one where a sodium-carbonate-sulphur fusion is made. After the second digestion with ammonium sulphide the precipitated hydroxides were allowed to stand with strong sulphurous acid, whereby the dark colored iron sulphide and some titanium and uranium passed into solution. The hydroxides were again dissolved in hydrofluoric acid, and later expelled with sulphuric acid, and the solution barely neutralized with ammonium hydroxide, after which an excess of ammonium carbonate was added, together with some fresh colorless ammonium sulphide. By this means the uranium was extracted together with a little titanium. By repeated reprecipitations in the presence of ammonium carbonate, the uranium was obtained free from all but a trace of iron and titanium. A little additional iron was recovered from the main precipitate by means of sulphurous acid. The small amount of titanium which goes with the iron is easily recovered by precipitation with sodium acetate in the presence of acetic and sulphurous acids.

The ignited oxides of titanium and niobium when fused with acid potassium sulphate and leached out with cold water, pass almost completely into solution (all but 0·0021 gr. from 0·3139 gr. in the sample treated). Qualitative tests according to the procedure recommended by Dr. A. A. Noyes† showed the presence of enough niobium to give the characteristic brown color to the solution after reduction by means of a zinc column, and to produce immediately an abundant white percipitate in the solution of mercuric chloride. This test is a delicate one and the reaction may be obtained with only a few milligrams of niobic acid. This taken in connection with the fact that but a small residue remains from the leaching of the bisulphate fusion, points to the presence of only a small

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* For suggesting this satisfactory form of the iron-uranium separation we are indebted to Dr. B. B. Boltwood of New Haven.

† A System of Qualitative Analysis, Technology Quarterly, vol. xvii, No. 3, 1904.

amount of niobium and tantalum. As will be pointed out in the accompanying note on the estimation of niobium and tantalum in the presence of titanium, it is entirely possible for several per cent of niobium and tantalum to be present and still leave practically no residue when fused with bisulphate and leached with water. At present there appears to be no way of accurately determining the small amount of niobium present. Tantalum was found to be present only as a trace.

Assuming that the amount of niobium is too small to affect the molecular ratio materially, we have on combining the acid and basic radicals, as shown in table above, the following approximate ratios:

$$\mathrm{H_2O} \quad : \quad \mathrm{R^{II}O} \quad : \quad \mathrm{R_2^{III}O_3} \quad : \quad \mathrm{R^{IV}O_2} \quad : \quad \mathrm{TiO_2} \text{ etc.}$$
$$6 \quad : \quad 1 \quad : \quad 3 \quad : \quad 1 \quad : \quad 16$$
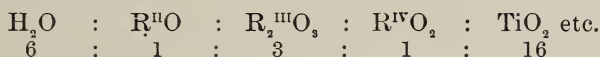
Where $\mathrm{R^{II}O}$ is chiefly lime, $\mathrm{R_2^{III}O_3}$ chiefly yttrium earths, $\mathrm{RO_2^{IV}}$ chiefly thorium. The mineral is therefore essentially a hydrous titanate of the yttrium earths and thorium. The above ratios may, of course, be no more than a coincidence but they are sufficiently sharp to argue in favor of the correctness of our assumptions. In view of the necessary incompleteness of the analysis and also of the small amount of exact knowledge which we possess regarding the true molecular relations existing between the so-called "rare-earths" and acid radicals, a further discussion here of the constitution of this mineral is hardly worth while. In fact it may be remarked that before a satisfactory understanding of the entire group of the so-called "titano-niobates" can be had, we must have, not only better analytical methods but also much clearer ideas of the capacity of these elements, and their compounds, to form isomorphous mixtures and solid solutions.

Radio-active properties.—Some fragments of the mineral were examined for radio-activity by Professor B. B. Boltwood of New Haven, to whom we wish to express our thanks for his kindness. The total activity of the mineral was found to correspond to 10 per cent of thorium and 2·08 per cent of uranium. The amount of uranium found by analysis was 2·29 per cent and of thoria 8·75 per cent, which are in very satisfactory agreement with Dr. Boltwood's figures.

The mineral is evidently a new species and the authors would suggest the name *Yttrocrasite* for it.

ART. XLV.—*Note on the Estimation of Niobium and Tantalum in the presence of Titanium ;* by C. H. WARREN.

THE obtaining of a strong reaction for niobium in the mineral described in the previous paper and the failure to obtain more than a fraction of a per cent of niobium by means of the acid potassium sulphate fusion and leaching in cold water, naturally led to an examination of the methods for estimating these elements quantitatively in the presence of each other.

So far as the writer can ascertain, the most common method followed is that involving a fusion with bisulphate of potash followed by leaching with cold water, these operations being repeated until all the titanium has passed into solution, while the niobic and tantalic oxides remain behind. In his System of Qualitative Analysis,* page 218, Dr. A. A. Noyes states that when treated in this manner fairly large quantities of niobium and tantalum pass into solution with titanium when much of the latter is present. With this statement in mind a few experiments were made to gain some further idea of the magnitude of the error involved in the method.

Pure TiO_2 was prepared from selected crystals of rutile by the usual chemical methods. Nb_2O_5 and Ta_2O_5 were prepared from the columbite of Branchville, Conn., after the method described by Osborne,† except that the precipitated oxides were digested for some time with ammonium sulphide to insure the removal of any tungsten or tin which might be present. The final products were subjected to the most careful qualitative examination and no impurity other than a trace of iron could be detected.

The attempts at separating these oxides, quantitatively, when mixed together were very unsatisfactory, and although few in number seem to thoroughly confirm Dr. Noyes' statement. Indeed, considerable quantities of niobium may be made to pass into solution with the titanium, as the figures given below show. In the first three experiments, the fusion and leachings were thrice repeated. In each case the fusion was mashed to a powder under cold water in an agate mortar and allowed to stand with from 250 to 300^{cc} of water for twenty-four hours. The titanium was precipitated from the combined filtrates with ammonium hydroxide, filtered, washed free from sulphates and ignited to a constant weight. The residues from the first two leachings gave a strong reaction for titanium with hydrogen peroxide, and a small amount of titanium always remained in the last residue.

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* Technology Quarterly, vol. xvii, No. 3, 1904.
† This Journal (3), xxx, 330, 1885.

Weight in grams :

Of Nb_2O_5—Ta_2O_5 (about 3:1) taken	Of TiO_2	Wgt. of oxides extracted	Excess
No. 1 ·2500	·2359	·3046	·0687
No. 2 ·2103	·2039	·2580	·0541
No. 3 ·3031	·2698	·2883*	·0185
No. 4 ·0178 (Nb_2O_5 only)	·3605	·0010 niobium undissolved	

From No. 4 it would appear that as much as 5 per cent of niobium may pass into solution with an excess of titanium and thus be practically lost in the course of analysis. Although further study of the most favorable conditions of fusion and solution might be of interest in themselves, the method appears to offer little chance of being modified so as to give more than roughly approximate results.

The method proposed by T. B. Osborne† was next examined. This depends on the titration of a solution containing the titanium and niobium in the lower state of oxidation with potassium permanganate, thus oxidizing these elements to the higher oxides, and the subsequent estimation of titanium colorimetrically, while any tantalum, which is not reduced to the lower oxide, present in the original sample, is found by difference. The method of procedure is briefly this : the mixture of the three acids, tantalic, niobic and titanic, is dissolved in hydrofluoric acid and the excess of acid expelled on the water bath. The fluorides thus obtained are dissolved in concentrated hydrochloric acid washed with the same acid into a 100^{cc} flash (total volume about 50^{cc}) and reduced for three-quarters of an hour with amalgamated zinc and a piece of platinum foil in an atmosphere of carbon dioxide at a temperature of 80° C. The reduced solution is cooled thoroughly, diluted with freshly boiled, cold water to about 350^{cc} and titrated with permanganate. To this solution ammonia is added in slight excess, the precipitate formed, just dissolved in sulphuric acid, and the volume made up to exactly 500^{cc}. The titanium is then estimated colorimetrically, with hydrogen peroxide in 50^{cc} portions of this solution.

For any except small amounts of titanium the colorimetric method is open to the serious objection that any error in estimating the amount of titanium in the aliquot portion (and that error can hardly fail to be considerable where a large amount of titanium is present) is multiplied by ten in estimating the total amount present. Mr. Osborne gives the result of only a single application of the method. The figures are as follows :

* Still gave a strong reaction for titanium.

† The Quantitative Estimation of Niobium, this Journal (3), xxx, pp. 328–337, 1885.

	Nb$_2$O$_5$	Ta$_2$O$_5$	TiO$_2$
Taken,	·3357 gr.	·2246 gr.	·0687 gr.
Found,	·3314 gr.	·2289 gr.	·0667 gr.

The agreement here is quite satisfactory but as the relative amount of titanic oxide is small, and as the writer had never had any experience with the method, it was decided to make a trial of the method before using it in an analysis. In experiments 1–4 of those given below Mr. Osborne's directions were followed closely. In Nos. 5 and 6 the time of reduction was increased and in No. 6 the volume of acid was doubled. One other experiment was tried and the temperature raised to nearly 100° C.: but as a separation of the metallic acids took place this one is not included. The results obtained by reduction and titration are as follows :

No.	Time of reduct'n	Temp.	Volume	Wgt. taken in grams Nb$_2$O$_5$	Ta$_2$O$_5$	TiO$_2$	Gram KMnO$_4$ required	Grams KMnO$_4$ used	Differences in grams
1	¾ hr.	80° C.	50^{cc}	·2163	·1649	·2453	·1988	·1450	—·0540
2	"	"	"	·2034	·1062	·2083	·1783	·1551	—·0232
3	"	"	"	·2067	·1090	·0708	·1254	·1138	—·0116
4	"	"	"	·2283	·1054	·2079	·1899	·1630	—·0269
5	1 "	"	"	·1889		·1933	·1565	·1317	—·0248
6	1 "	"	100^{cc}	·2140		·2033	·1814	·1620	—·0183

The large size and irregularity of the resulting errors led the writer to abandon further work on the method with the conclusion that it is wholly unsatisfactory as it stands. One source of error in the method is possibly the loss of some volatile, metallic fluoride during the removal of the hydrofluoric acid on the water bath. The addition of sulphuric acid with the hydrochloric in order to prevent such volatilization is inadvisable, since, as Mr. Osborne states, the reduction of the niobium is then far from constant, and it may be added, the tendency of the metallic acids to precipitate during reduction would be greater.

There appears to be, so far as the writer can discover, no method by which more than a rough approximation toward a quantitative separation of these elements can be effected notwithstanding the numerous analyses purporting to have accomplished a separation of sufficient accuracy to warrant considerable speculation as to the chemical constitution of the group of minerals containing these elements. The problem of their separation is an extremely interesting one mineralogically as well as chemically, since the constitution of so many highly interesting minerals depend on its successful solution. The increasing use of tantalum in lamps and perhaps in other ways, and its common occurrence with niobium and titanium make a satisfactory quantitative separation of these elements highly desirable, and it is to be hoped that it may soon be realized.

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Art. XLVI.—*Ceanothus Americanus* L. and *ovatus* Desf.; a morphological and anatomical study; by Theo. Holm. (With five figures in the text, drawn from nature by the author.)

Ceanothus Americanus L. is very frequent in the vicinity of Washington, D. C., and occurs in dry copses or in open fields; the other species *C. ovatus* Desf. is confined to the Potomac shore, where it inhabits the rocks at "Little Falls" associated with *Baptisia australis* R. Br., *Physostegia Virginiana* Benth., *Lythrum alatum* Pursh, *Scirpus lineatus* Michx., etc. They both are widely distributed through the Eastern and Central States extending northward to Canada, while nearly all of the other species of the genus are Californian.

The *Rhamnaceæ*, to which our genus belongs, comprises thirty-seven genera in accordance with Bentham and Hooker; the diagram of the flower has been described by Eichler,* and the general types of the inflorescence have been briefly mentioned by the same author (l. c.).

A few species of *Rhamnus* have been studied at the seedling-stage by Irmisch,† and of *Colletia* by Lubbock.‡ *Mycorhizæ* were detected in *Ceanothus Americanus* by W. J. Beal§ and the fungus identified by Geo. F. Atkinson as *Frankia Ceanothi.*‖

The internal structure seems to be better known and a very instructive discussion of the anatomical features of a number of genera and species is to be found in Solereder's work: Systematische Anatomie der Dicotyledonen.¶

However, among the *Rhamnaceæ* thus treated, *Ceanothus* has been merely briefly touched upon, and since the writer has had the opportunity of studying the two species that occur in the district of Columbia, the following notes may be presented as a small contribution to the knowledge of the genus.

The germination.—As stated above, Irmisch has described the seedlings of *Rhamnus cathartica* and *Rh. Frangula* (l. c.), and he calls attention to the fact that the cotyledons of the former are epigeic, but of the latter hypogeic. In *Rh. cathartica* the cotyledons are green, larger than the succeeding leaves during the first season, and borne upon a distinct hypocotyl. The leaves succeeding the cotyledons are arranged

* Blüthendiagramme. Pars 2, 1878, p. 371.
† Flora, 1855, p. 625.
‡ A contribution to our knowledge of seedlings. London, 1892, vol. i, p. 344.
§ Botan. Gazette, vol. xv, p. 232.
‖ Bull. Torrey Bot. Club, vol. xix, 1892, p. 171.
¶ Stuttgart, 1899, p. 247.
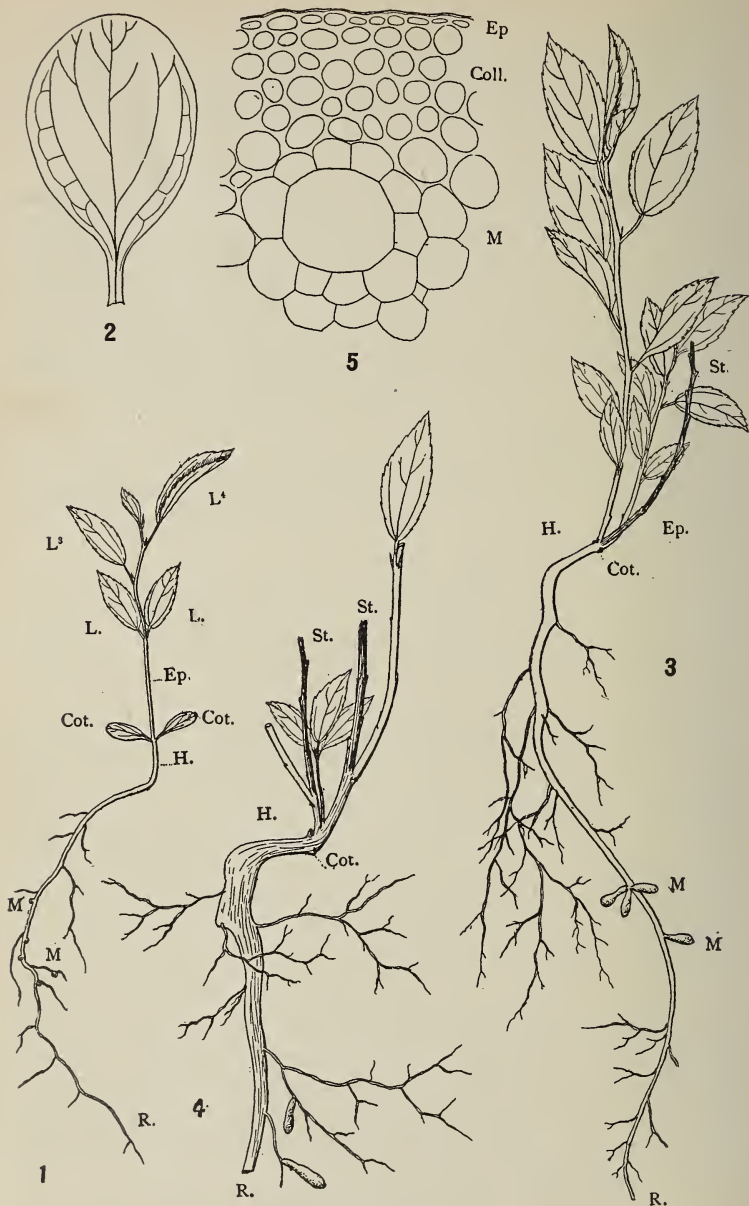
Ceanothus Americanus L.

Fig. 1. Seedling, natural size.   R = the primary root with mycorhizæ (M);
H = Hypocotyl; Ep. = Epicotyl; L—L = the two opposite leaves; L³ ānd
L⁴ = the succeeding, spirally arranged leaves.

Fig. 2. A cotyledon, magnified.

Fig. 3. A young plant in the second year, natural size.   St. = the dead
stem of previous year; the other letters as above.

Fig. 4. A plant in the third year, natural size.   Letters as above.

Fig. 5. Transverse section of petiole of mature leaf; Ep. = Epidermis;
Coll. = Collenchyma; M = a mucilage-cell, × 240.

spirally, and the first ones are often merely scale-like and rudimentary; buds were observed in the axils of the cotyledons. In *Rh. Frangula*, on the other hand, the cotyledons remain enclosed by the seed, and the hypocotyl is very short, but otherwise the development of leaves and buds is the same as in the former species. In *Rh. davuricus* and *Colletia cornuta*, described by Lubbock (l. c.), the cotyledons are epigeic.

The seedling of *Ceanothus Americanus* agrees with that of *Rhamnus cathartica* so far as concerns the epigeic cotyledons with buds and the presence of a distinct hypocotyl. Our figure 1 shows a seedling where the cotyledons (Cot.) are borne upon an erect hypocotyl (H); the epicotyl, the first internode (Ep.), is quite long, and the first two leaves, succeeding the cotyledons, show the same outline and venation as the typical leaf of this species, but are opposite (L and L), in contrast to the others, which are spirally arranged (L³—L⁴). Buds, though very minute, are developed in the axils of all the leaves including the cotyledons. The primary root (R) is long and slender with some of the lateral branches transformed into mycorhizæ (M), represented by small globular tubercles. Characteristic of the seedling is thus the presence of cotyledonary buds, the position of the first leaves (L) being opposite and, finally, the early appearance of the mycorhizæ.

The ramification of the shoot.—During the first season the seedling does not develop any further than the specimen, which we have figured, but the cotyledons fall off in the month of June, and at the end of the season the hypocotyl and sometimes, also, the epicotyl are the only parts remaining above ground, the other internodes having faded away entirely; at the same time the hypocotyl has bent itself downwards to the ground, though without any development of secondary roots. When the plant is one year old, we notice two opposite leaf-bearing shoots (fig. 3) either developed from the axils of the cotyledons or of the opposite leaves, succeeding these, while the main stem (St.) has died off, but remains as a blackish branch. It seems to be the most frequent case that the ramification of the shoot takes place by means of the cotyledonary buds, but as stated above, when these do not develop, the buds of the opposite leaves produce the branches. The hypocotyl is now horizontal (H) and the primary root has increased in length and thickness, besides that the mycorhizæ are much larger (M).

While examining a number of young plants at this stage, we noticed a peculiarity, which seems to be constant in our species. This peculiarity consists in the fact that the greater

portion of the primary root has become compressed, and very prominently so at the base.   By examining the internal structure we readily noticed that a very irregular growth had taken place.   The rays of hadrome had increased in thickness much more on the one side of the root than on the other, thus the vessels showed the arrangement somewhat similar to a fan. A similar case has been reported by Wigand,* who observed that while the primary root in *Ononis repens* and *spinosa* shows a normal and concentric growth during the first year (at the seedling stage), it exhibits a very conspicuous, excentric increase in the succeeding year.   This is due to the one-sided enlargement of the hadrome; besides that the medullary rays have not only been prolonged, but also very considerably broadened towards the periphery in exactly the same way as in our *Ceanothus.*   The so-called "Bretterwurzel" described by Haberlandt† shows the same structure, but this root-type has a special function which cannot be attributed to the roots of either *Ononis* or *Ceanothus,* since these are completely underground.   It is an anomaly, which seems to be rare among shrubs and herbs, and we are unable to offer any explanation as to its cause; we can only state that all the specimens examined of *C. Americanus* and *ovatus* showed this root-structure when more than a year old, and that it seems very improbable that it might be due to the nature of the soil, since the one of these species (*C. Americanus*) grows in clayish or somewhat sandy soil, while the other seems to thrive only among rocks with the roots tightly pressed in the narrow fissures.   It would be interesting to know whether the numerous Californian species behave in the same manner.

If we examine a plant in the third season (fig. 4), we notice the same principal structure as shown in our figure 3.   The hypocotyl (H) is still very distinct, and the scars from the cotyledons (Cot.) are plainly visible with two stem-bases from the preceding year (St.), while there is no trace of the primary stem above the cotyledons.   Young lateral shoots develop now from the basal leaves of the stems of the previous year; they are yet purely vegetative and die off to near the base during the fall.   In regard to the root, this has increased very considerably in length and thickness; the irregular structure is very pronounced, and the mycorhizæ are quite large, but do not yet show any signs of ramifying.

When the plant has reached the age of about five years it commences to flower; the ramification, however, is exactly the same as described above, and the flowers develop exclusively upon shoots of the same season.   One point deserves men-

* Einige Beispiele anomaler Bildung des Holzkörpers.   (Flora, 1856, p. 674.)

† Eine botanische Tropenreise.   Leipzig, 1893, p. 104.

tion, and that is the purely vegetative nature of the terminal bud in *C. Americanus* in contrast to *C. ovatus*, where the branches are terminated by an inflorescence. In *C. Americanus* it seems to be a constant character that the inflorescences are lateral; the terminal vegetative bud does not, however, seem to be of any importance to the plant, since the shoots die off to near the ground as observed in the younger specimens. In *C. ovatus* we observed no case where the apical inflorescence was not terminal, but it was frequently noticed, however, that the branches bore lateral inflorescences below the terminal; thus two or three inflorescences may be developed on the same shoot. We regret to say that the herbarium material which we have examined of the other species was not sufficient to demonstrate whether the apical vegetative or apical floral bud is the one that is most characteristic of the genus. Besides the lateral floral branches in *C. Americanus*, we noticed also that lateral vegetative shoots may be developed below these; in many cases the first two leaves of these vegetative shoots were observed to be opposite, similar to those of the seedling.

In regard to the inflorescence, the flowers are arranged in small helicoid cymes, destitute of fore-leaves.

If we compare now the seedling of *C. ovatus* with that of *C. Americanus*, described above, we find the same structure, the epigeic cotyledons, the distinct hypocotyl and the two opposite leaves preceding the spirally arranged. The primary root shows the same development, but we were unable to detect the mycorhizæ; these were evidently broken off since the roots were more or less damaged by being dug out of the stony soil. The growth of the shoots in mature specimens is identical with that of the former species with the exception of the inflorescence being terminal.

The internal structure of the vegetative organs of Ceanothus Americanus.

The root.—During the first season the root has already commenced to increase in thickness, but the epidermis is still preserved, and bears numerous hairs. No exodermis is differentiated, and the cortical parenchyma consists only of five compact strata. The endodermis is thin-walled and surrounds a pericambium and several groups of leptome separated from the hadromatic rays by layers of cambium. No hyphæ and no mucilage-cells were observed. In the second year the root has become somewhat compressed near the base; epidermis has been thrown off, and a secondary cortex of about six compact layers has been developed. The central cylinder shows the irregular increase in thickness as described above, due to the one-sided growth of the hadromatic rays. Near the apex of the same root the structure is normal with the various elements arranged strictly concentric. The mycorhizæ appear as

swellings on the lateral roots; they are unbranched and are much thicker than the normal ones. Their epidermis is simply papillose, and there is no exodermis. The cortex consists of five peripheral strata of normal structure, and of six internal, the cells of which are very large, stretched radially and filled with the fungus. The endodermis is like that of the main root and free from fungus. A pericambium surrounds five groups of leptome and a central, confluent mass of hadrome.

The primary root persists and represents a long, woody taproot in old specimens, reaching a thickness of about 1^{cm} or even a little more; such old roots are generally of a reddish brown color due to the cell-contents of the peripheral strata of the cortex. Another peculiarity possessed by the mature root is the presence of sclerotic cells, which occur in groups in the secondary cortex. Otherwise the mature root shows the same structure as observed in younger specimens, with a very pronounced, excentric growth of the hadrome and the medullary rays.

The leaves.—The cotyledons (fig. 2) have stomata on both faces of the blade; these are surrounded by several cells, from four to seven, none of which are parallel with the stoma. The stomata are most numerous on the dorsal face of the blade. The chlorenchyma is differentiated into a typical palisade-tissue and an open pneumatic tissue of roundish or oblong, loosely connected cells. An almost colorless parenchyma-sheath surrounds the very thin mestome-strands, which have no support of stereomatic or collenchymatic tissues.

The petioles of the cotyledons have no chlorenchyma, but a large tissue of colorless cells which surrounds two separate, broad mestome-strands. The cuticle is wrinkled and epidermis quite thick-walled. A layer of collenchyma separates epidermis from the colorless tissue, in which a few, two to three, mucilage-cells are located.

In a mature leaf from a flower-bearing shoot we meet with the same bifacial structure as observed in the cotyledons, but the stomata are here confined to the dorsal face. The cuticle is quite thick and prominently wrinkled; the outer cell-wall of epidermis is moderately thickened where it covers the veins, and hairs are quite numerous. They are of two kinds: uni- and pluri-cellular, thick-walled, with the apex pointed and more or less curved. The pluri-cellular hairs (of several cells in a single row) occur above and below the larger veins, and outside the pneumatic tissue. The chlorenchyma consists of two to three layers of palisades on the ventral face of the blade, and of four to five strata of open, pneumatic tissue on the dorsal.

A thin-walled, colorless parenchyma surrounds the larger veins; it consists of about three strata above, but of six below these, and is separated from epidermis by collenchyma.

Mucilage-cells occur in the colorless tissue; they are much wider than the surrounding parenchyma-cells, but only a little longer; they contain a clear, colorless mucilage and are very conspicuous in cross-sections. These mucilage-cells were in the *Rhamnaceæ* first described by Guignard and Colin,* while the occurrence of mucilage in epidermis of *Rhamnus* and other genera of this family, but not in *Ceanothus*, has been discussed by Blenk.†

The midvein and the two lateral nerves from the base of the leaf are quite thick on the dorsal face of the blade. They are supported by collenchyma, as described above, but have no stereome and no parenchyma-sheath; the leptome and hadrome is well developed, forming a broad, crescent-shaped strand in transverse section with many rows of vessels. The other veins are much thinner and are completely imbedded in the green chlorenchyma; in these the mestome is surrounded by a colorless parenchyma-sheath, but with no support of collenchyma; the cross-section of these minute veins is elliptic to almost orbicular.

The petiole of the mature leaf is hemicylindric in transverse section and hairy like the blade. There is no chlorenchyma, and the very broad, single mestome-strand is directly surrounded by a mass of colorless tissue in which the mucilage-cells are very conspicuous (fig. 5.) A sheath of thick-walled collenchyma of about five layers is noticeable beneath epidermis.

If we now examine the blades of the two opposite leaves of the seedling, which succeed the cotyledons, we observe a similar structure, though with the following exceptions. They are quite glabrous and epidermis is not thick-walled; moreover, the collenchyma is totally absent, besides that the colorless tissue with the mucilage-cells is much less developed. It might, also, be mentioned that the mediane and the two prominent, lateral veins are surrounded by colorless parenchyma-sheaths, which in the leaves of older specimens are restricted to the thinner mestome-strands.

The petiole shows the same tissues as observed in the mature leaf, but the collenchyma is much less developed, representing only a single layer beneath epidermis. Three wide mucilage-cells were observed in the colorless tissue.

The stem.—The hypocotyl of the seedling (H in fig. 1) is cylindrical and almost glabrous. The cuticle is smooth, but quite thick, and the outer cell-walls of epidermis are distinctly thickened; stomata and unicellular hairs were observed. There is a narrow zone of cortical parenchyma of which the innermost strata are partly collapsed and in which mucilage-

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* Sur la présence de réservoirs à gomme chez les Rhamnées. (Bull. de la soc. Bot. d. France, vol. xlv, Paris, 1888, p. 325.)

† Die durchsichtigen Punkte der Blätter in anatomischer und systematischer Beziehung. Inaug. diss., Regensburg, 1884, p. 68.

cells are located. A thin-walled endodermis surrounds the central cylinder of leptome, cambium and hadrome, with narrow medullary rays and a central, solid, starch-bearing pith. Inside the endodermis are furthermore four strands of thick-walled stereome bordering on the leptome and located in the same radius as the innermost four groups of vessels, which represent the proto-hadrome.

The same structure was observed in the epicotyl (Ep. in fig. 1), with the only exception that the stereome does not occur here as four separate strands, but as several, which form a more or less interrupted sheath around the leptome. The other internodes of the seedling possess a collenchymatic cortex (the peripheral two or three layers), and the endodermis is more distinctly differentiated, and contains deposits of starch. The stereome forms here an almost completely closed sheath, and druids of calcium-oxalate were noticed in the cortex. These various stem-portions of the seedling are, thus, able to increase in thickness, even if the hypocotyl and, sometimes also, the epicotyl, are the only parts that persist.

If we now examine the basal portion of a flower-bearing shoot, we notice a corresponding structure, but the various tissues show here a somewhat stronger development. The epidermis is more thick-walled, and the cortex more compact, with the mucilage-cells wider and longer; endodermis is thin-walled as in the young specimens, while the stereome is very thick-walled, forming an almost closed sheath around the central cylinder. The cambium is more distinct, and the hadrome consists of numerous rows of vessels with the medullary rays broader.

The internal structure of the vegetative organs of Ceanothus ovatus.—The root shows the same structure as that of *C. Americanus.* In regard to the mature leaves, these are almost glabrous, the hairs being confined to the larger veins on the dorsal face of the blade. The stomata, which are surrounded by four to six cells, are in this species distributed over both faces of the blade, most numerous, however, on the dorsal, and they are raised a little above the surrounding epidermis. The pneumatic tissue is more compact than observed in the former species but otherwise the structure is identical.

The petiole shows the same structure as that of *C. Americanus,* and in regard to the stem, the flower-bearing shoot, we observed no character of any essential importance, by which to distinguish this from the stem of the former species. When compared with each other these two species resemble each other very much from seedling to mature plant. But characteristic of *C. ovatus* is, however, the terminal inflorescences and the narrower leaves with stomata on both faces.

Brookland, D. C., July, 1906.

Art. XLVII.—*Photometric Measurements on a Person Possessing Monochromatic Vision;* by F. L. Tufts.

In an article on "Color Vision and the Flicker Photometer,"[*] the late Professor Ogden N. Rood reported some measurements made by means of the flicker photometer on a number of persons possessing normal color vision and also on three cases of red color-blindness. Through the kindness of Dr. W. S. Dennett of New York City, the writer was enabled, some three years ago, to extend these measurements to the case of a person possessing monochromatic vision. Owing to the limited amount of time which the subject, referred to in this article as J. T., could give to the work, the measurements were not so complete as the writer would have liked to make them. He has not previously published the results in hopes that circumstances might some time enable him to apply more extensive tests. This now seems very improbable, and the results of the work already done are given in the following pages.

The flicker photometer used was of the same type as the one already described by Professor Rood,[†] and the colored glasses were the same as the three used by him in his work on color vision.[‡]

The candle powers of two incandescent lamps referred to as A and B were compared by means of the flicker photometer, first directly and then when each of the three glasses respectively was placed between lamp A and the photometer wedge. Each of these comparisons was made by Dr. Dennett, J. T. and the writer, from ten to twenty readings being taken in each case. The numbers expressing the relative candle powers, given in the first three rows of Table I, were computed from

TABLE I.

| | | Candle power of | | |
Observer	A in terms of B	A through red glass in terms of B	A through green glass in terms of B	A through violet-blue glass in terms of B
W. S. Dennett	4·00	·520	·385	·052
F. L. Tufts	4·00	·480	·385	·048
J. T.	4·94	·101	·683	·235
J. T., using ordinary wedge photometer	5·00	·11	·72	·23

* This Journal, vol. viii, p. 258, Oct., 1899.
† Ibid., vol. viii, p. 194, Sept., 1899.
‡ Ibid., p. 258, Oct., 1899.

these readings.   From the numbers thus obtained the percentage of light from the incandescent lamp transmitted by each of the three glasses respectively was calculated for the different observers.   These results are given in the first three rows of the second table.

<div align="center">Table II.</div>

| Observer | Percentage of light from lamp A transmitted by — | | |
	Red glass	Green glass	Violet-blue glass
W. S. Dennett _____	13·0	9·62	1·30
F. L. Tufts _____	12 0	9·62	1·20
J. T. _____	2·04	13·8	4·75
J. T., using ordinary wedge photometer __	2·2	14·4	4·6
Standard eye _____	13·7	9·62	1·39

As a standard of color vision, the one already used by Professor Rood was chosen.   This he defined in substance as follows : The standard was the mean color vision of eleven persons possessing, according to ordinary tests, normal vision. This standard was indicated by 100 in the case of red, green and violet-blue.   One hundred was also taken as the maximum attainable by any person in each case, as the experiments did not deal with the general sensitiveness of the eye to light, but with its relative sensitiveness to light of different colors.   That is to say, in the case of the color curve of each person, the highest ordinate, whatever it may be, is set equal to 100, the others following where the observations indicate on this assumption.

Both Dr. Dennett and the writer had had their color vision expressed in terms of this standard, and the results, taken from Professor Rood's article,* are given in the first two rows of Table III.   From these figures the percentage of the light

<div align="center">Table III.</div>

	Red	Green	Violet-blue
W. S. Dennett _____	93·8	100	91·5
F. L. Tufts _____ ____	89·9	100	87·8
J. T. _____ __ ____	4·84	45·2	100·

from an incandescent lamp which the standard eye would see transmitted by the three glasses respectively, was computed both from Dr. Dennett's readings and from the readings of the writer.   The averages are given in the last row of Table II.

* This Journal, vol. viii, p. 258, Oct., 1899.

A comparison of the figures in the last row of Table II with those in the third row shows at once that the color curve for J. T. has the highest ordinate in the violet-blue. Designating this by 100, the ordinates in the red and green were computed and are given in the third row of Table III.

Measurements of the relative intensities of the white and colored lights were also made by J. T., using an ordinary wedge photometer in place of the flicker photometer. It was found that he could compare lights of different colors with the ordinary photometer with the same ease that the normal eye could make the comparison by the flicker photometer. The last row in Table I contains the results obtained by J. T. with the ordinary wedge photometer. The fourth row of Table II gives the percentages of the transmitted light calculated from these readings. Considering the small amount of practice the subject had had in photometric measurements, the agreement between these results and those he obtained with the flicker photometer is certainly very good.

Some measurements were also made on the extent of the visible spectrum and the position of maximum luminosity. The spectrum of an incandescent lamp seemed to J. T. to extend from 6350. Ångström units, in the red, to 4000 in the violet, while to the writer the same spectrum seemed to extend from 7700 to 3800. For J. T. the position of maximum luminosity seemed to be at wave length 5250, while for the writer it was at 5800.

Phœnix Physical Laboratory, Columbia University, Oct., 1906.

ART. XLVIII.—*On Eodevonaria, a new Sub-Genus of Chonetes;* by C. L. BREGER.

AMONG the Strophomenoid Brachiopoda, the presence of a crenulated or denticulated hinge line has always been considered as of at least generic importance. It was upon this consideration that the genus *Stropeodonta* was founded by Hall; and it is chiefly or very largely the presence of a denticulated hinge line which sharply demarcates as a special group apart from the normal Strophomena's the genera *Stropheodonta, Douvillina, Leptostrophia, Brachyprion* and *Strophonella.**

In the well-known Paleozoic genus *Chonetes,* the great mass of the species have a normal, non-crenulated hinge line; but, as is the case with the Strophomenoids, there occur a few closely associated and quite peculiar species in which the denticulated hinge line is a very prominent and characteristic peculiarity. It has been found than such a denticulated hinge line occurs in six species of *Chonetes.* All six species are so closely allied as to be distinguishable only with some little difficulty; and all six species occur at very nearly the same geologic horizon in the Lower Devonian, though scattered through Europe, South Africa, South America, and North America. These facts justify setting this group apart from the normal and typical species of *Chonetes,* and the name *Eodevonaria* is hereby proposed for this group. The name is suggested by the restriction of all the known species (as well as a few more which it is believed may possibly belong here) to the Eo-Devonian. The known species are

1. *Chonetes arcuatus* Hall
2. *C. dilatatus* F. Roemer's sp.
3. *C. melonicus* Billings
4. *C. acutiradiatus* Hall
5. *C. extensus* Kayser
6. *C. arcei* A. Ulrich

1. *Chonetes (Eodevonaria) arcuatus.* — The crenulated hinge line in this type was noted by Hall† in his description and illustrations of the species. Weller also noted the same features in New Jersey specimens of this species.‡ *Chonetes (Eodevonaria) arcuatus* occurs in the Upper Helderberg

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* For descriptions of these genera, see Paleontology New York, vol. viii, Pt. I.

† Hall, The Fossil Brachiopoda of the Upper Helderberg, Hamilton, Portage and Chemung group. Paleontology of New York, vol. iv, p. 119, Pl. XX, see figs. 7e, 7f, 1867.

‡ Weller, The Paleozoic Faunas of New Jersey. Paleontology of New Jersey, vol. iii, pp. 367, 373, Pl. LI, fig. 21, 1903.

group of Ohio, Indiana, New Jersey, New York and Maine. Some specimens in the U. S. Geological Survey collections from Little Brasna Lake, Somerest County, Maine, represent the same type of the species as occurs in New Jersey, and show very prominently the crenulated hinge line.

2. *Chonetes (Eodevonaria) dilatatus.*—This characteristic Lower Devonian fossil of the Continent occurs throughout the middle and upper Eo-Devonian, and a few specimens continue into the Middle Devonian. Its greatest development is reached in the Upper Coblentzian, and horizon near the top of the American Upper Helderberg (corniferous) group. The species has for a long time been known to have a crenulated hinge line. This feature was illustrated by Schnur,[*] and by Kayser,[†] and I believe also by the Sandbergers in their classic work on the fossils of the Rhenish series in Nassau (this volume is not just now at hand ; hence it is impossible to give the exact reference to the plate and figure).

3. *Chonetes (Eodevonaria) melonicus.*—The presence of crenulations on the hinge line of this species was noted, and emphasized by Billings. *Chonetes melonicus* was described[‡] from Little Gaspé, Quebec, Canada, in beds correlated with the Oriskany, but which may prove to be a trifle higher than the New York Oriskany. The species is certainly Lower Devonian.

4. *Chonetes (Eodevonaria) acutiradiata.*—This species was for a long time believed to have a smooth, non-crenulated hinge. Indeed, Billings differentiated his *C. melonicus* from this species by the crenulated hinge line of his Canadian form while in *C. acutiradiata* the hinge was presumed to be non-crenulated. In the Cornell University collections there occur several typical specimens of *C. acutiradiata* from the Corniferous limestone near Williamsville, Erie County, N. Y., all of which show plainly the crenulated hinge line.

5. *Chonetes (Eodevonaria) extensus* Kayser.—This large very broad *Chonetes* was described by Kayser[§] from Katzenelnbogen in the Rhenish middle Lower Devonian (Lower Coblentzian). The denticulated hinge line is quite plainly apparent in both his figures.

6. *Chonetes (Eodevonaria) arcei* Ulrich.—This species occurs at very nearly exactly the same geological horizon of the

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[*] Schnur, In Ubergangsgebirge der Eiffel vorkommende Brachiopoden. Palaeontographica, vol. iii, Pl. XLIII, figs. 1a, 1e, 1853.

[†] Kayser, Die Fauna des Hauptquartzits und der Zorger Schiefer des Unterharzes. Abhandl. d. Kgl. Preussischen geologischen Landesanstalt, Neue Folge, Heft I, Pl. XII, fig. 3, 1889.

[‡] Billings, Paleozoic Fossils, vol. ii, Part I, p. 15, fig. 6, 1874.

[§] Kayser, Fauna des Hauptquartzits, l. c., pp. 64, Pl. XXII. figs. 5, 6.

Lower Devonian in Bolivia,* in Argentina,† and in South Africa‡ in a fauna which is certainly that of some part of the Coblentzian and only very slightly if at all higher than the Gaspé fauna with Chonetes melonicus. The crenulated hinge line has been figured by Thomas.

All these species are medium to large-sized *Chonetes*, with gibbous to very gibbous pedicle valve and a concave brachial valve ; with a large number of medium fine radial striae ; and with the usual hollow spines along the posterior margin ;— all features of normal *Chonetes*. As in normal *Chonetes*, there is a wide cardinal area, quite prominent in the pedicle valve, less so in the brachial. The delthyrium is covered with a pseudodeltidium. Very narrow and short diverging lamellae support the teeth. The diductor muscles in the pedicle valve of *C. (Eodevonaria) arcuata* leave two broadly diverging isolated oval scars, while between them in the center may be seen the subcircular or elongate-oval scar left by the large adductor muscles. The latter scar is divided in two by a median septum. The median septum is present in the pedicle valve in all the species of *Eodevonaria*, as in all the *Chonetes*.

The precise nature of the denticulations on the hinge line in *Eodevonaria* cannot be stated just now. Whether these denticulations alternated with each other in the two valves to assist in articulation as in the Stropheodonta's ; whether the denticulations represent the bases of vertical tubes as in *Anoplia;* whether they are points of insertion or of division of a ligament or other membrane which probably covered the cardinal area in the brachiopods (compare the divided ligament in *Perna, Gervillia, Inoceramus,* and the other genera of *Pernidae* among the lamellibranchs); or whether they served some other purpose, will be known when better material than is now at hand becomes available.

* A Ulrich, Palaeozoische Versteinerungen aus Bolivien. Neues Jahrb. f. Mineralogie, etc., Beilageband VIII, p. 77, Pl. IV, figs, 35, 36, 1892.

† I. Thomas, Neue Beiträge zur Kenntnis der devonischen Fauna Argentiniens. Ztschr. d. Geol. Ges., vol. lvii, p. 258, Pl. XIII, fig. 26, 1905.

‡ F. Reed, Brachiopoda of the Bokkeveld Series. Annals of the South African Museum, vol. iv, Part III, p. 173, Pl. XXI, fig. 3, 1904. The South African specimens may not belong to Ulrich's species, nor possibly to the present subgenus.

ART. XLIX.—*Note on the Production of Radium by Acti-
nium;* by BERTRAM B. BOLTWOOD.

THE attempts on the part of several different investigators
to experimentally demonstrate the growth of radium in ura-
nium solutions, while they have given somewhat widely differ-
ing results, have nevertheless served to demonstrate conclu-
sively that the quantity of radium formed in a given time from
a known weight of uranium is very much smaller than would
be expected from the disintegration theory if radium is a direct
product of uranium. Thus Soddy[*] has stated that the amount
of radium formed in a commercial salt of uranium during a
period of eighteen months was only one five-hundredth of the
amount to be expected from the theory, while the writer[†] has
shown that in a purified salt of uranium the amount of radium
formed in 390 days can not be over one sixteen-hundredth of
the amount which the theory would require.

The constancy of the ratio between the quantities of uranium
and radium which are found in the natural minerals is, how-
ever, a convincing proof of the close relationship of these ele-
ments to one another. On the basis of the assumption that
radium is a disintegration product of uranium, it is necessary
to show that some intermediate product of a relatively slow
rate of change exists between them. In the search for such an
intermediate product the supposition that actinium was this
product has been gradually strengthened. A considerable
mass of experimental data which has been collected all points
to the conclusion that the quantity of actinium in a mineral is
directly proportional to the amount of uranium present and
that, accordingly, actinium is a product of uranium. The
following experiment was, therefore, undertaken to demon-
strate the position of actinium with respect to radium.

A kilogram of carnotite ore containing about twenty per
cent of uranium was treated with an excess of dilute hydro-
chloric acid and the insoluble portion was separated from the
solution. The sulphides precipitated by hydrogen sulphide
were then removed. To the solution thus obtained was added
about one-half gram of thorium nitrate followed by a solution
of several grams of oxalic acid. The slight precipitate which
formed after the mixture had stood for several days was com-
pletely removed, the oxalates were converted into nitrates, and
the nitrates in dilute solution were again submitted to the pre-

[*] Nature, lxxi, 294, 1904 ; Phil. Mag. (6), ix, 768, 1905.
[†] This Journal, xx, 239, 1905.

cipitation with oxalic acid. I have found from a number of other experiments that practically all of the actinium contained in a mineral can be separated in this manner.

The oxalates obtained from the second precipitation were converted into chlorides, and the dilute solution of the chlorides was sealed up in a glass bulb. About two months later, on the twenty-fifth of April last, the gases and emanation collected in the bulb were boiled out and, after standing for some time, were introduced into a standardized electroscope. The quantity of radium emanation present corresponded to the presence of 5.7×10^{-9} gram of radium in the actinium solution. The bulb was again sealed and allowed to stand undisturbed until November 4th, when the emanations and gases were again boiled out and tested. The amount of radium emanation then found corresponded to 14.2×10^{-9} gram of radium, indicating that during the interval of 193 days there had been formed in the solution a quantity of radium equal to 8.5×10^{-9} gram. This is equivalent to the production of about 1.6×10^{-8} gram of radium in one year. The amount of radium in equilibrium with 200 grams of uranium (the approximate amount of uranium in the mineral used) is 7.6×10^{-5} gram.* Assuming that the total amount of actinium present in the mineral was separated by the treatment described, the value of λ for radium can be calculated from the above numbers and is given as $2.1 \times 10^{-4} (\text{year})^{-1}$. The period required for the decay of the activity of radium to one-half its initial value is thus indicated as about 3300 years, and this is of the same order of magnitude as the most recent estimate made by Rutherford.†

Strong evidence has therefore been obtained in support of the assumption that actinium is the intermediate disintegration product between uranium and radium.

The entire series of operations from the start will be repeated with special precautions in order that a more accurate value for the various constants can be obtained.

New Haven, Conn., Nov. 5, 1906.

* Rutherford and Boltwood, this Journal, xxii, 1, 1906.
† 2600 years, Phil. Mag. (6), xii, 367, 1906.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *The Quantitative Separation of Beryllium and Aluminium.* —It is well understood that the methods in use for making the separation under consideration are somewhat inconvenient or unsatisfactory, so that a more simple method, and one which appears to give very accurate results, is worthy of attention. B. GLASSMANN carries out the analysis as follows: The hydrochloric or sulphuric acid solution of the metals is nearly neutralized with sodium carbonate, an excess of sodium thiosulphate solution is added, and the liquid is boiled until the odor of sulphur dioxide has disappeared. Then the liquid is heated on the water bath for half an hour. The precipitate, consisting of aluminium hydroxide mixed with sulphur, is washed and ignited. After the excess of thiosulphate in the filtrate has been decomposed with hydrochloric acid, the beryllium is precipitated as hydroxide, either with ammonia, or, as the author prefers, with a mixture of potassium iodide and iodate. In order to use the latter method sodium hydroxide solution is added to the liquid until a precipitate begins to form, and then the precipitate is dissolved in a few drops of dilute acid. Then an excess of a mixture of equal volumes of about 25 per cent potassium iodide solution and saturated potassium iodate solution is added. After about five minutes the separated iodine is decolorized by the addition of exactly the proper amount of 20 per cent sodium thiosulphate solution, and then a small amount of the iodide and iodate mixture is added in order to make sure, by the fact that it does not produce an instantaneous separation of iodine, that enough has been added. Then a few drops of sodium thiosulphate are added, and the liquid is heated on the water bath for half an hour. The precipitate is easily filtered, on which account the method is recommended, and also because the liquid, being absolutely neutral, does not act as much upon glass as do alkaline solutions.—*Berichte*, xxxix, 3366, 3368.   H. L. W.

2. *The Temperature at which Water Freezes in Sealed Tubes.* —MIERS and ISAAC have shown that in cooling a supersaturated solution in which a few crystals are growing while it is being stirred, the refractive index rises until at a certain temperature it attains a maximum value and then suddenly falls; at this moment also profuse crystallization takes place. They concluded that this is the temperature of spontaneous crystallization. These investigators have now made numerous experiments with water contained in sealed tubes which were violently and continuously shaken by hand, while being very slowly cooled in a bath of brine, until rapid crystallization of ice took place. Various

samples of water were used, and different kinds of glass were employed for the sealed tubes. All the tubes froze between $-2°$ C. and $-1·6°$ C. ; the mean of the experiments being $-1·86°$ C., and that for the purest water with a conductivity of $1·1 \times 10^{-6}$ being $-1·9°$ C. The authors conclude that $-1·9°$ is the temperature at which under atmospheric pressure water freezes spontaneously, i. e., in the absence of particles of ice, and they call attention to the remarkable fact that this is the temperature at which super-cooled water possesses a maximum refractive index according to the observations of Pulfrich. The effect of friction was also studied by introducing glass, garnet, galena, or lead into the tubes; this caused the water to freeze at $-0·4$ C.— *Chem. News*, xciv, 89. H. L. W.

3. *Preparation of Fused Molybdenum.*—Molten molybdenum was first prepared by Moissan by the use of the electric furnace. It has been made also by several experimenters by the "thermite" process, consisting in allowing the trioxide to react with finely divided metallic aluminium. The volatility of molybdenum trioxide, however, made this process unsatisfactory. BILTZ and GÄRTNER have modified the "thermite" process by using the non-volatile dioxide in place of the trioxide. To prepare the dioxide the trioxide is heated to moderate redness in a glass tube in a current of hydrogen gas. The "thermite" process then works well, the authors having obtained a yield of 93 per cent of the theoretical, and a product which contained over 98 per cent of the metal.—*Berichte*, xxxix, 3370. H. L. W.

4. *Potassium-lead Chlorides.*—By fusing mixtures of the two chlorides in varying proportions, determining the temperatures at which crystals were deposited by cooling, and investigating the products thus obtained, LORENZ and RUCKSTUHL have found that three double salts are produced from the fused mass. They are represented by the formulæ $2PbCl_2.KCl$, $PbCl_2.2KCl$, and $PbCl_2.4KCl$. It is interesting to notice that these three types of double lead salts—in one case only with water of crystallization—are known among the double halides of the alkali metals and lead which crystallize from aqueous solutions, and that still another type corresponding to the 1 : 1 ratio, for example, $CsCl.PbCl_2$, is also known.—*Zeitschr. anorgan. Chem.*, li, 71. H. L. W.

5. *Ammonia from the Recent Eruption of Vesuvius.*—STOKLASA has examined volcanic exhalations and many eruptive products of eruption of April, 1906, and has found ammonia always present in them. He draws the conclusion that the ammonia has its origin in the chemical actions which take place in the hot lava, possibly from the presence of silicon nitride or other nitrides. He considers the view of the mineralogists, that the sublimations of ammonia are caused by the combustion of vegetation, to be entirely incorrect.—*Berichte*, xxxix, 3530.

H. L. W.

6. *Beitraege zur Chemischen Physiologie und Pathologie,* herausgegeben von F. HOFMEISTER. VIII Band. 1906, Braunschweig (Fr. Vieweg und Sohn).—This volume is quite equal to

its predecessors in the diversity of topics which it presents. It is impossible to make special mention of more than a few of the papers. Particularly noteworthy are the valuable studies of Embden and his collaborators on the formation of acetone in the liver, indicating a large number of substances as possible precursors of this compound. Friedmann's renewed investigation of the structure of adrenalin leads to a choice of the formula

$$\begin{matrix} OH \\ OH \end{matrix} \left\langle \quad \right\rangle CH(OH)\cdot CH_2\cdot NH\cdot CH_3$$
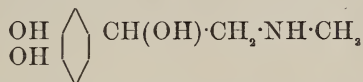
for this peculiar physiological compound, the formation of which Halle, in a separate paper, refers to an enzymatic reaction of the suprarenal tissue upon tyrosin. Among a series of contributions from the laboratory of Dr. von Fürth, reference may be made to his study of chitosan derivatives. It indicates that the "chitin" of molluscs and arthropods furnishes the same products. Two papers offer items of interest regarding nitrogenous metabolism : one by H. Vogt deals with the time relations in the catabolism of proteids of various groups ; the other, by Klercker, gives evidence that creatine and creatinine may experience quite different fates in the chemical reactions to which they become subject in nutrition. The volume also contains the usual number of papers on enzymes : rennin, diastase, gastric lipase, and the blood enzymes furnishing the themes for investigation. L. B. M.

7. *Change of Colloidal Nucleation in wet dust-free Air in the lapse of time ;* by C. BARUS (Communicated).—Observations extending over several months have now shown that the variation of the colloidal nucleation of dust free wet air in the lapse of time is independent (within the limits of accuracy of the fog chamber) of the barometric pressure and temperature of the atmosphere, of the ionization of the air or of the allied effect of natural external radiations; but that it varies to the remarkable extent of an increase of about 8000 nuclei per rise of temperature of one degree centigrade near 20 degrees. The reason for this unexpected result is yet to be found, but nothing has been suggested to explain it away.

Brown University, Providence, R. I.

8. *Leitfaden der praktischen Optik ;* von Dr. ALEXANDER GLEICHEN. Pp. viii + 221; 158 figures. Leipzig, 1906 (S. Hirzel).—This is an account of the more elementary parts of the theory of optical instruments, and is intended for the users of such instruments rather than for the optician or for the reader who is interested in the more complex details of geometrical optics. It is written in a clear and simple manner and no mathematics is used beyond the elements of geometry and algebra. Especial attention is given to the optics of the eye and of photographic apparatus, and the book will doubtless prove especially useful to oculists and photographers. H. A. B.

II. Geology.

1. *New Zealand Geological Survey.*—The first New Zealand Geological Survey was inaugurated in 1867 and up to 1905 had published a number of Bulletins dealing largely with economic problems. In February, 1905, Dr. James Mackintosh Bell was made director, the Survey was reorganized, and the following staff appointed : Mr. Alexander McKay, Geologist and Paleontologist; Mr. Percy Gates Morgan, General Geologist; Mr. Colin Fraser, Mining Geologist; Mr. Ernest John Webb, Assistant Geologist; Mr. Edward Clarke, Assistant Geologist ; Mr. Reginald Palmer Greville, Topographer ; Mr. Robert James Crawford, Draughtsman ; Mr. John Thompson, Secretary.

A scheme has been outlined for the preparation of a detailed topographical and geological map of New Zealand, together with reports on ten chief districts.

Bulletin No. 1 (New Series) is entitled "The Geology of the Hokitika Sheet, North Westland Quadrangle"; by James Mackintosh Bell and Colin Frazer. 101 pp., 13 maps, 42 plates. Ten formations are described in the present bulletin, ranging in age from "Early Mesozoic (?) and earlier" to Pleistocene and Recent. The Arahura series consists of a group of schists, grauwackes, argillites, and arkoses, parts of which have been assigned to different ages from Archean to Carboniferous by various authors. The Kanieri series consists largely of conglomerate and argillite. Both the Arahura and the Kanieri series are intersected by auriferous quartz reefs. The Tuhua formation consists of an extensive group of granites and syenites forming mountain bosses. The Pounamu formation is of particular petrographic interest. Static metamorphism and the alteration of sediments by the intrusion of the basic Pounamu rocks have produced such a variety of minerals as to give the formation the name of "mineral belt." The parent intrusive was dunite or olivinite, and the secondary rocks include many varieties of serpentine, talc, steatite, nephrite, tremolite-serpentine, muscovite-serpentine, etc. It is from this formation that the masses of nephrite are derived which appear in the glacial deposits as the famous "greenstone" bowlders.

The Koiterangi series is the remnant of former widespread sedimentary deposits which contain seams of coal. Dikes of camptonite, hornblende and pyroxene porphyrite, diabase, augite diorite, olivine basalt, cut all the bed-rock formations. Glacial débris is widely distributed over Westland, and is of great thickness. It is uncertain whether the period of maximum advance of the ice sheet was in Upper Pliocene or early Pleistocene time. "One thing is certain, and that is that the glaciation started in Miocene time and is still continuing."

The chief physiographic features are the Alpine Chain, recently uplifted but "submaturely dissected," the Wainihinihi

peneplain at an elevation of 4000 to 5000 feet and the Coastal Plain inaugurated by the Post Miocene Uplift. The river valleys are broad and U-shaped, and terminate in cirques. Many lakes occur, which for the most part occupy ancient valleys blocked by débris—as is indicated by soundings. Hot springs occur along fault lines.

The illustrations are excellent, especially the microphotographs of metamorphic rocks by Mr. McKay. It is to be hoped that an appropriation may be obtained to make a more detailed topographic map. H. E. G.

2. *Illinois State Geological Survey*, H. FOSTER BAIN, Director. Gov. C. S. Deneen, Profs. T. C. Chamberlin and E. J. James, Commissioners. Bulletin No. 1, the Geological Map of Illinois; by STUART WELLER. Pp. 26, with map. Urbana, 1906. Bulletin No. 2. The Petroleum Industry of Southeastern Illinois; by W. S. BLATCHLEY. Pp. 109, 6 plates, 3 figures.—A new and carefully prepared geological map is a fitting subject for the first bulletin of the Illinois State Survey. Thirty years have elapsed since the map prepared by A. H. Worthen was distributed with Volume IV of the State Geological Report. This early map has been used by Dr. Weller as a base and the additional material available from the more recent work of various geologists has now enabled him to present a map which, while necessarily open to further change and emendation, is a notable advance upon what has been available before. The map as issued measures 30×16 inches, in other words has been prepared on a liberal scale; it is also well executed and colored. Columnar sections are added for Northern, Central and Southern Illinois. The value of the map for economic purposes is much increased by the careful presentation of the exact location of coal mines.

The second Bulletin contains an account of the petroleum resources of the state. Until very recently the state had yielded very little either of oil or natural gas, although the search for them began as early as 1853. In 1905 and the early part of 1906, however, extensive investigations were carried on and with highly encouraging results, especially in the southeastern part of the state. In May, 1906, active production of crude oil and gas was going on over an area about 40 by 12 miles in extent between Westfield, Clark County, and Oblong, Crawford County. The oil wells all lie near—and mostly to the east of—the long line of deformation which extends across the state in a south-southeasterly direction from Stephenson to Lawrence County. The total production of crude oil from the Casey Field, in Clark County, for the eleven months ending with April, 1906, aggregated 400,000 barrels.

3. *Geological Survey of Ohio*. EDWARD ORTON, Jr., State Geologist. Fourth series, Bulletin No. 4, pp. 361, map and 53 figures. Bulletin No. 5, pp. 79, 2 plates, 8 figures.—These recently issued bulletins are devoted, No. 4 to the Limestone Resources and the Lime Industry of the State of Ohio, by E.

Orton, Jr. and S. V. Peppel ; No. 5 to the Manufacture of artificial Sandstone and Sand-lime Brick, by S. V. Peppel. The rocks of Ohio consist so largely of limestone, that it is not a matter of surprise to have it stated that these strata furnish the material which makes up almost a third of the present mineral resources of Ohio. The stratigraphical relations of the limestone have been discussed in detail in earlier publications, and the present one is devoted largely to a statement of the composition of the rock at different localities and of the uses to which it is put, for building material and particularly for making quicklime and hydraulic cements. An industry, new in this country, has also sprung up in the state, consisting in the manufacture of bricks from sand and quicklime; it promises to become an important factor in the state's resources. The bulletin (No. 5) devoted to this subject discusses the properties of sand-lime brick and the limiting conditions for the manufacture of a safe and durable product.

4. *Indiana: Department of Geology and Natural Resources. Thirteenth Annual Report.* W. S. BLATCHLEY, State Geologist. Pp. 1494, with 47 plates and 25 maps. Indianapolis, 1906.—The special subject of roads and road materials discussed in this report is one of the highest importance and requiring the best scientific advice, and yet not often treated so fully by a Geological Survey. This subject is discussed first in general by the State Geologist, and then in detail by his assistants in its applications to the different portions of the state. The value of the facts stated and of the results arrived at are obviously not limited to the state of Indiana. Statistics of the natural gas and petroleum industry for 1905 are also given and the concluding chapter by E. R. Cumings and J. W. Beede is devoted to the fauna of the Salem limestone.

5. *Geological Survey of New Jersey. Annual Report of the State Geologist,* HENRY B. KÜMMEL, *for the year 1905.* Pp. 338, with 30 plates, 21 figures, and 3 pocket maps. Trenton, 1905.—The subjects which are particularly discussed in this Report include the following : Changes on the New Jersey coast, by L. M. Haupt ; an account of the fossil plants, by E. W. Berry ; the composition of the crystalline limestones of Sussex and Warren Counties, by H. B. Kümmel; Lake Passaic as a storage reservoir, by C. C. Vermeule ; and on the peat deposits of northern New Jersey. The State Geologist furnishes an administrative report which opens the volume, and also an account of the mines and mineral production of the state.

6. *Geological Survey of Canada ;* ROBERT BELL, Director.—There have recently appeared Volumes XIV and XV of the Annual Report (new series). Volume XIV contains the summary report by the Director for the year 1901 ; also a series of special papers as follows : On the Klondike Gold Fields, by R. G. McConnell ; on the exploration of Ekwan River and Sutton Lakes and part of the West Coast to James Bay, by D. B. Dow-

ling ; on the Nickel and Copper Deposits of the Sudbury Mining District, Ontario, by A. E. Barlow ; on the Geology of a Portion of Eastern Ontario, by R. W. Ells; on the Pictou Coal Field, Nova Scotia, by Henry S. Poole ; on the Artesian and other Type Wells on the Island of Montreal, by Frank D. Adams and Osmond E. Leroy. These have already been issued independently and several have been noticed in this Journal. The volume also contains the Annual Report of the Section of Mines for 1901 by E. D. Ingall. Maps 751–792 in separate cover accompany the report.

Volume XV contains the Summary Report for the year 1902, pp. 472 ; also that for the year 1903, pp. 212. There is further a report on the Coal Fields of the Souris River, Eastern Assiniboia, by D. B. Dowling, and the Annual Report for 1902 of the Section of Mines by E. D. Ingall. As with the preceding volume, the several parts have been issued previously as completed. Maps 810–823 in a separate cover accompany the report.

There has also appeared a Catalogue of Publications of the Geological Survey of Canada. Pp. 129.

7. *A Bibliography of Clays and the Ceramic Arts ;* by JOHN CASPER BRANNER. Pp. 451, 8vo. 1906. Published by the American Ceramic Society.—Some ten years since, the author of the present volume published, as Bulletin No. 143 of the U. S. Geological Survey, the first edition of the Bibliography which, more than doubled in size, now appears in the present volume ; this first edition contained 2961 titles while the one now issued has 6027. To the work of thus expanding and completing the literature of this important subject, Professor Branner has devoted much time during the past ten years. The manuscript was presented by the author to the American Ceramic Society, and the volume is now issued by them and given to the public at a very moderate cost. The attitude of the Society towards the author's gift and the value of the work in general will be inferred from the following sentences taken from the publisher's preface : "The Society feels that the unselfish devotion and the utter absence of self-interest betrayed in this course is as beautiful as it is unusual. It is a fine example of the best traditions of scholarship and the true spirit of the scientist. . . . . We believe that this work, placing in concrete form before the young students of the rising generation the sources of the knowledge which they are seeking to acquire, is destined to profoundly affect the scholarship and progress of our time in this branch of human endeavor. . . ."

8. *Festschrift Harry Rosenbusch, gewidmet von seinen Schülern zum siebzigsten Geburtstag ; 24 Juni 1906.* Roy. 8°, 412 pp. Stuttgart, 1906.—Entirely aside from the many valuable contributions to mineralogic and petrographic science which this volume contains, it is a striking example of the progress which has been made in these fields of work and investigation since the master whose achievements it is intended to honor and commemorate began his labors. The science of petrology owes its present

position to-day more to Rosenbusch than to any other man, not perhaps so much to his investigations and published writings, though in these he has been excelled by none, as to his work and influence as a teacher. A large part, possibly a majority of those men, who as active workers during the past twenty-five years have been pushing forward into this field of science, have received more or less of their training in his laboratory and have been inspired by his zeal and enthusiasm. As a well-deserved tribute of honor and affection it will give not less pleasure to the recipient and to many who will use it, than it will be of value as a contribution to science.

In this brief notice it would be impossible to give an adequate review of the work, but the following brief summary of the table of contents will give an idea of its scope and the list of contributors : Prof. Grubenmann, of Zürich, on glaucophane rocks ; Prof. Hobbs on rocks of the Cortlandt series in Connecticut ; Prof. Wülfing, Danzig, on mineral pigments ; Prof. Hlawatsch, Vienna, on an amphibole from Portugal ; Dr. Hovey, New York City, on the geology of a district in Mexico ; Prof. Mügge, Königsberg, on the action of HFl on quartz ; Prof. Milch, Breslau, on differentiation in a granite magma ; Prof. Koch, Berlin, on diabases from the Hartz Mts. ; Dr. Daly, Ottawa, on a case of differentiation in a magma ; Dr. E. Becker, Heidelberg, on the Wartenberg in Baden ; Prof. Osann, Freiburg in Baden, on alkalic rocks from Spain ; Prof. Palache, Cambridge, Mass., on titanium minerals from Somerville, Mass. ; Dr. H. Preiswerk, Basel, on some dike rocks from Piedmont ; Prof. Steinman, Freiburg in Baden, on the origin of some copper ores in Bolivia ; Dr. Nicolau, Jassy, Bucharest, on aragonite ; Dr. L. Finckh, Berlin, on rhombic porphyry from Kilimandjaro ; Dr. W. Wahl, Helsingfors, on a diabase from Aland Island, Finland.

The volume is well printed and illustrated and is a handsome specimen of the bookmaker's art. L. V. P.

9. *Evidence Bearing on Tooth-cusp Development ;* by JAMES WILLIAMS GIDLEY. Proceedings of the Washington Academy of Sciences, Vol. VII, pp. 91–106, pls. IV–V.—In connection with the work of cataloguing the portion of the Marsh collection of Mesozoic mammals contained in the U. S. National Museum, Mr. Gidley has made some important discoveries bearing upon the question of tooth-cusp homologies in the mammalian molars.

The trituberular theory proposed by Professor Cope and developed by Professor Osborn accounts for the development of the molar cusps in a manner at variance with that shown by Scott to be true of the molariform premolars and contrary to the evidence of embryology as set forth by Woodward, Tacker, and others. *Centetes, Ericulus,* and *Chrysochloris,* wherein the embryological evidence seemed to agree with the theory of the trituberculists, are shown to have attained a secondary or pseudo-tritubercular form by the reduction of the true protocone and the fusion of the paracone and metacone into an apparent protocone.

As a result of a study of the Mammalia of the Atlantosaurus beds, including the two forms *Dryolestes* and *Triconodon*, upon which the trituberculists especially relied to prove the theory, Mr. Gidley has arrived at the following conclusions :

" (1) That the evidence obtained from the Mesozoic mammal teeth furnishes no support to the tritubercular theory in so far as it involves the position of the protocone and the derivation of the trigonodont tooth from the triconodont stage through the shifting of the lateral cones outward in the upper molars and inward in the lower molars.

" (2) That it supports entirely the embryological evidence that the primary cone is the main antero-external cusp, or *paracone*, having retained its position on the *outside* in most upper molars.

" (3) That it agrees in the main with Huxley's ' premolar-analogy ' theory ; as supported by Scott.

" (4) That the molars of the multituberculates, *Triconodon*, *Dryolestes*, and *Dicrocynodon*, were apparently derived independently from the simple reptilian cone ; hence the supposition follows that the trituberculate type represents but one of several ways in which the complex molars of different groups may have been derived.

" (5) That in the forms derived from the trituberculate type of molar the order of the succession of the cusps is not the same in all groups, and apparently homologous elements are sometimes developed from different sources. Hence it follows that *no theory involving an absolute uniformity of succession in the development of complex molars will hold true for all groups of mammals.*"

Gidley urges that, though founded upon mistaken homologies, Professor Osborn's convenient nomenclature be retained for the molariform teeth on the ground of clearness and brevity and because of its wide use in many publications.   R. S. L.

10. *The Origin of Birds ;* by W. P. PYCRAFT, A.L.S., F.Z.S. Knowledge and Scientific News, Vol. III, New Series, Sept., 1906, p. 531.—In this article Mr. Pycraft makes a very interesting fore-cast of the probable appearance of the ancestral bird or pro-avian. This he considers much more primitive than Archæopteryx from the Jura, for that genus is a genuine bird though with several reptilian characteristics.

The principal features of the pro-avian are thought to have been as follows : Of small size, probably arboreal, with the trunk relatively longer than in modern birds. Pycraft supposes that the creature had substituted leaping for climbing about the trees ; from this, leaping from tree to tree would naturally follow. This would in turn throw the most work upon the three inner digits of the grasping hand, which would as a consequence grow stronger and at the same time the outer fingers would suffer a corresponding diminution. Correlated with this would be the development of two folds of skin, one in front of and one behind the arm, and the flexion of the limb and development of its post-axial border

would also follow. The reduction of the digits of the hind foot to four and the lengthening and approximation of metatarsals 2–4 to form a "cannon" bone, Pycraft thinks were due to leaping. Feathers are derived from the reptilian scales, those upon the hinder border of the wing lengthening and becoming fimbriated along their edges and more and more efficient for carrying the body through space.

A figure of the pro-avian is presented which combines lizard-like characters with those of Archæopteryx. The principal objection to the restoration lies in the lack of sufficient alar expanse, either by membrane or by feathers, to support the animal in the air. It would seem as though a moderately well developed patagium, of which the pre- and post-patagia of existing birds are the mere remnant, must have preceded the development of feathers. This one might assume from the description, but not from the figure.

It is difficult for the reviewer to imagine the reduction of the bird's hand to be a grasping modification, or one which would aid the creature at all in its arboreal life ; but that it is directly correlated with the development of the feathered wing seems much more probable. Again, how is one to account for the great similarity of the hind-limb of the bird to that of the bipedal dinosaurs ? The Triassic dinosaurs with a few exceptions had this type of foot, yet they were preëminently terrestrial forms and the vast assemblage of their foot-prints in the Connecticut Valley shows not one instance of a leaping individual.   R. S. L.

III. Miscellaneous Scientific Intelligence.

1. *National Academy of Sciences.*—The autumn meeting of the National Academy was held in Boston on Nov. 20–22 in the new buildings of the Harvard Medical School. The meeting was one of unusual interest ; the attendance was large and as shown below a long list of papers was presented. A novel feature of the meeting was the Conversazione, or exhibit of specimens, apparatus, etc., held on Tuesday afternoon ; about fifty exhibits were included in the list. The titles of papers presented are as follows:

Alexander Graham Bell : A few notes concerning progress in experiments relating to aërodromics. On the construction of an aërodrome with historical introduction.

W. E. Story : A method for the enumeration of algebraic invariants.

A. G. Webster : Acoustic measurements.

W. T. Porter : Vasomotor relations.

A. A. Noyes and others : The conductivity, ionization and hydrolysis of salts in aqueous solution at high temperatures.

R. S. Woodward : Theory and application of the double suspension pendulum.

R. H. Chittenden : The minimal proteid requirement of high proteid animals.

G. N. Lewis : The free energy of oxidation processes.

G. W. Pierce : Wave-length measurements in wireless telegraphy.

E. H. Hall : Measurement of the Thomson thermoelectric effect in metals.

John Trowbridge : Analogy between electrical energy and nervous energy.

Joseph Barrell : Continental sedimentation with applications to geological climates and geography.

Theodore Lyman : Light of extremely short wave-length.

W. M. Davis : The eastern slope of the Mexican Plateau.

Ellsworth Huntington : Evidence of desiccation during historic times discovered in Chinese Turkestan in 1905–06.

W. H. Pickering : Planetary inversion and the tenth satellite of Saturn.

S. I. Bailey : The work of the Bruce telescope.

T. W. Richards, L. J. Henderson and H. L. Fevert : The heat of combustion of benzol.

T. W. Richards and George S. Forbes : The atomic weights of nitrogen and silver.

Robert T. Jackson : Structure of Richthofenia.

W. E. Castle : On the process of fixing characters in animal breeding.

E. L. Mark and J. A. Long : The maturation of the mammalian ovum.

E. L. Mark : The marine biological station at La Jolla, Cal.

G. H. Parker : Reactions of Amphioxus to light.

H. C. Jones : The absorption spectra of solutions in relation to the present hydrate theory.

S. F. Acree : On the salts of tautomeric compounds.

C. P. Bowditch : The Temples of the Cross, of the Foliated Cross, and of the Sun, at Palenque, Mexico.

G. C. Comstock : Extent and structure of the stellar system.

H. F. Osborn: Tyrannosaurus, an Upper Cretaceous Carnivorous Dinosaur. Section of American Tertiaries. Complete mounted skeleton of Fin-back Lizard Neosaurus of the Peruvian.

Otto Folin : Metabolism of Creatin and Creatinin.

C. S. Minot : Nature and cause of old age.

C. S. Peirce : Phaneroscopy, or natural history of signs, relations, categories, etc. A method of investigating this subject expounded and illustrated.

Bailey Willis : Heterogenous elements of the continent as factors in the history of North America.

S. C. Chandler : Present state of knowledge as to motions of the terrestrial pole.

C. S. Van Hise : The origin of the ores of the cobalt-silver district of Ontario.

C. D. Walcott : Geological and biological study of the Cambrian brachiopods.

J. M. Crafts : The catalysis of sulphuric acids.

W. B. Scott : The Miocene mammals of Patagonia.

G. F. Hale : Sun spot spectra, and their bearing on stellar evolution.

2. *The Human Mechanism ; its Physiology and Hygiene and the Sanitation of its Surroundings ;* by Theodore Hough and William T. Sedgwick. Pp. ix + 564, with 147 illustrations. New York and Boston, 1906 (Ginn & Company).—This textbook differs widely from the usual elementary treatise on physiology in that the anatomical portion of the subject is made as brief and elementary as possible in order to give greater emphasis to the strictly physiological and hygienic aspects of the body. The book is divided into two parts of nearly equal length: (I) physiology proper, including a brief and simple account of such anatomical structures as are absolutely necessary for a proper under-

standing of the organs involved, and (II) the hygiene of the human mechanism and the sanitation of its surroundings. The aims of the authors, as stated on p. 303, is to persuade every one who reads the book, not merely to study and know himself as a physical mechanism with the thoroughness with which he would study a valuable watch or an automobile, but to use that mechanism scientifically to the end that life may be longer, more useful, and more enjoyable. With this object in view, the second part of the book is devoted to personal hygiene, domestic hygiene and sanitation. The home is considered with respect to its supply of light, heat, air and water, and the removal of wastes, while the six concluding chapters on the public health and sanitation discuss public supplies of food, water, and gas, public sewerage, infectious and contagious diseases, vaccination and serums, public conveyances and public buildings, and the health of nations.

The book deserves much praise both for the attractive style in which the subject is presented and for the excellence of the many original illustrations. It will undoubtedly be of great service wherever it is used in encouraging the "establishment and maintenance of the highest possible working efficiency of the human mechanism."　　　　　　　　　　　　　　　　　　W. R. C.

3. *The Voyages and Explorations of Samuel de Champlain (1604–1616), narrated by himself.* Translated by ANNIE NETTLETON BOURNE. Together with the Voyage of 1603 reprinted from *Purchas His Pilgrimes.* Edited with introduction and notes by EDWARD GAYLORD BOURNE. In two volumes; vol. I, pp. xl, 254; vol. II, pp. 229. New York, 1906 (A. S. Barnes Company).—The voyages of Champlain were alike remarkable for the bravery and energy with which they were carried through, and for the importance of the geographical results attained. This excellent translation, which for the first time makes Champlain's most interesting writings readily accessible in English form, should find many readers not only among students of history but also among all those interested in the land which he did so much to make known. The introduction by Professor Bourne, with its able estimate of Champlain's character and work, adds largely to the value of the work. These two volumes form volumes sixteen and seventeen of "The Trail Makers Series" of early American expeditions, voyages and discoveries.

4. *U. S. Department of Agriculture. Field Operations of the Bureau of Soils, 1904* (Sixth Report); by MILTON WHITNEY, Chief, with Accompanying Papers by Assistants in charge of field parties. Pp. 1159, with one plate, 45 figures; also 53 maps in separate cover. Washington, 1905.

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