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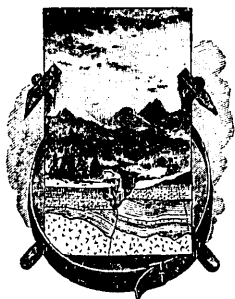
IN THE

DIVISION OF CHEMISTRY AND PHYSICS

MAINLY DURING THE

FISCAL YEAR 1886-'87

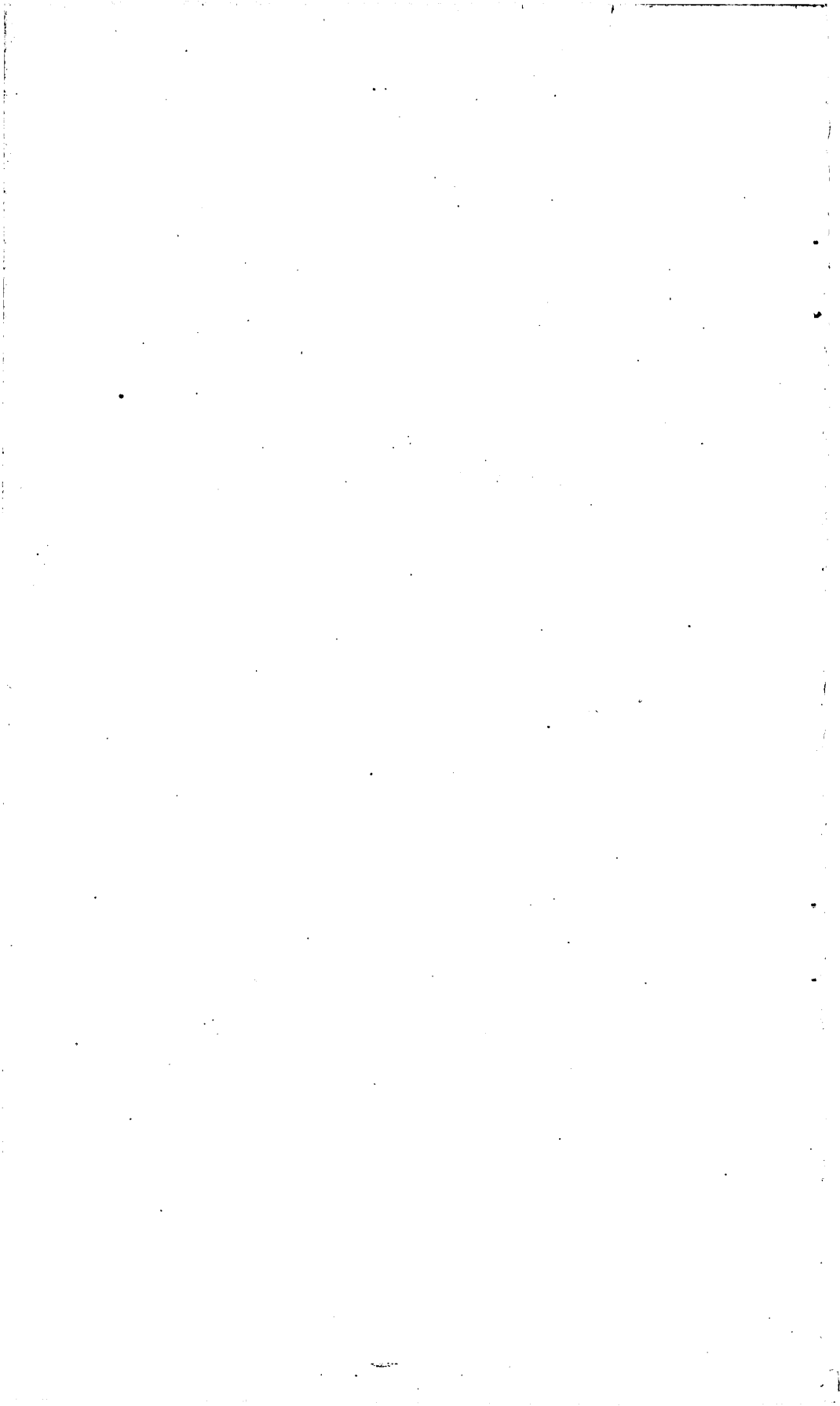
FRANK WIGGLESWORTH CLARKE, CHIEF CHEMIST



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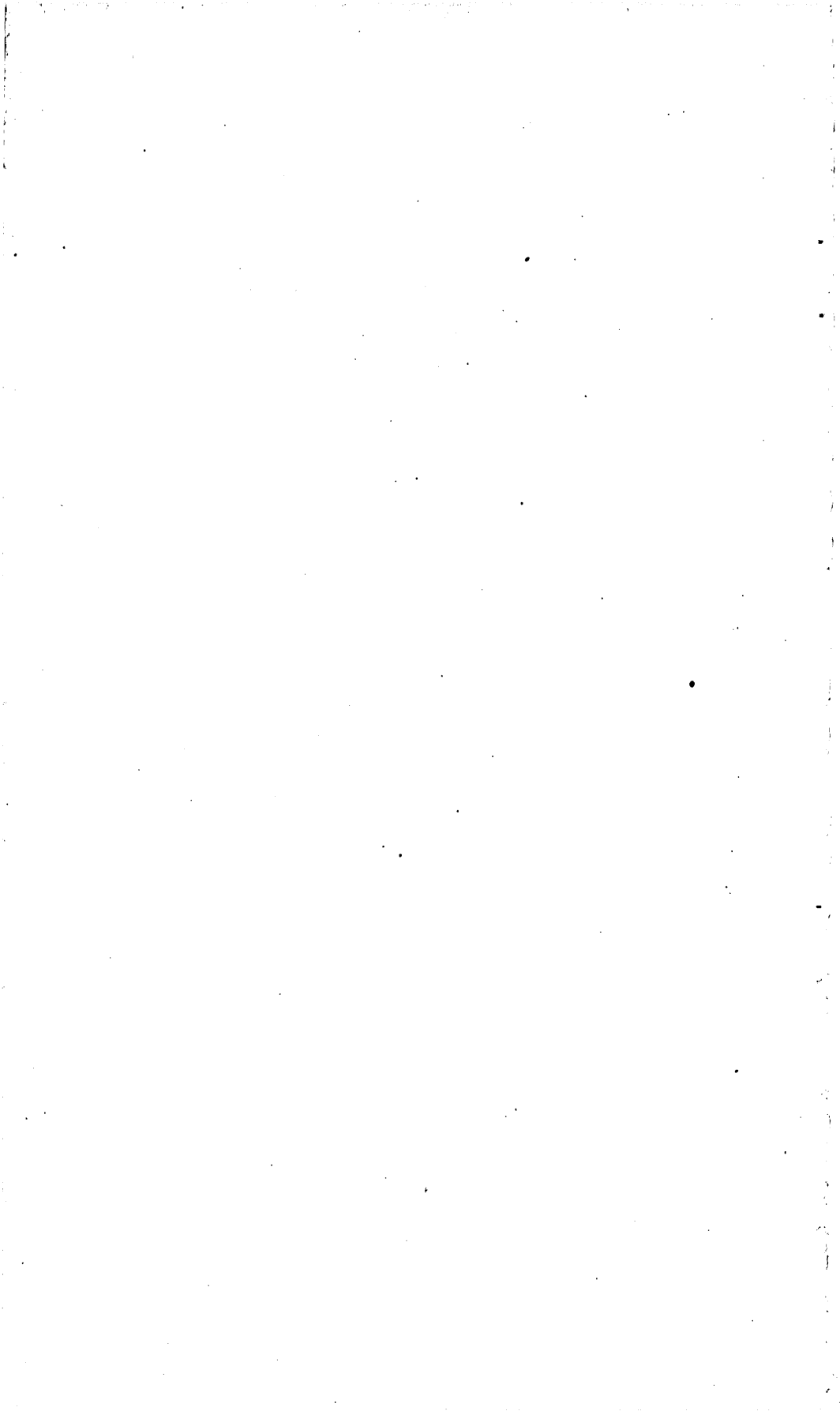
CONTENTS.

SCIENTIFIC PAPERS.

| | Page. |
|---|-------|
| Letter of transmittal..... | 9 |
| Studies in the mica groups. By F. W. Clarke..... | 12 |
| The analysis and composition of tourmaline. By R. B. Riggs..... | 19 |
| Notes on certain rare copper minerals from Utah. By W. F. Hillebrand and H. S. Washington..... | 38 |
| Mineralogical notes. By W. F. Hillebrand..... | 48 |
| Analyses of some natural borates and borosilicates. By J. Edward Whitfield.. | 56 |
| On the Johnson County, Ark., and Allen County, Ky., meteorites. By J. Ed- ward Whitfield..... | 63 |
| Scorodite from the Yellowstone Park. By J. Edward Whitfield..... | 65 |
| Flow of solids, or behavior of solids under high pressure. By William Hallock. | 67 |

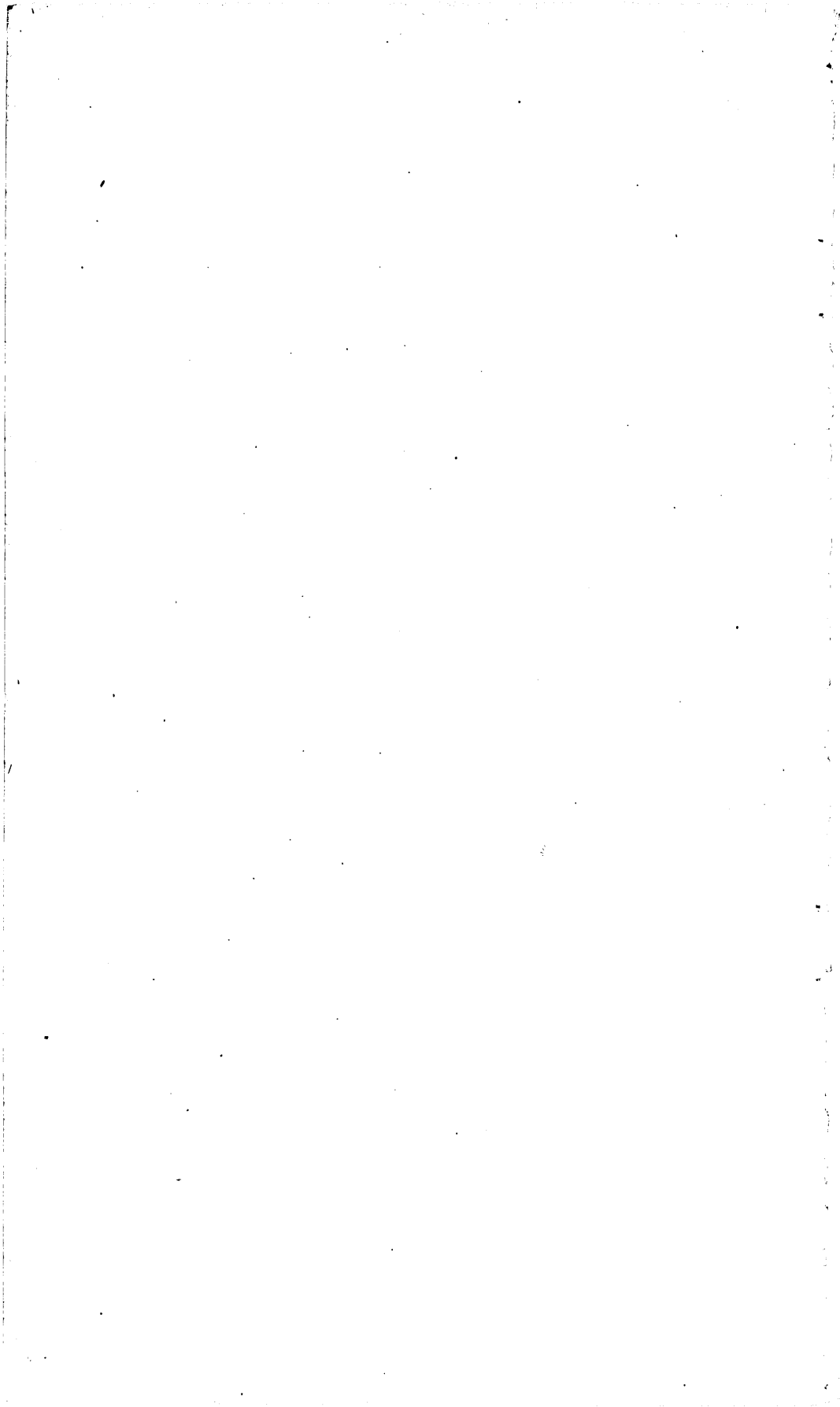
MISCELLANEOUS ANALYSES.

| | |
|--|----|
| Feldspar from the Hoosac Tunnel..... | 79 |
| Two feldspars from Greylock Mountain, Massachusetts..... | 79 |
| Three feldspars from Delaware..... | 79 |
| Triassic sandstone from Maryland..... | 80 |
| Limestone from the Auglaize River, Ohio..... | 80 |
| Twelve rocks from the Menomonee River..... | 81 |
| Rocks from Pigeon Point, Minnesota..... | 81 |
| Two rocks from Montana..... | 83 |
| Fifteen rocks from California..... | 84 |
| Ores of iron and manganese..... | 85 |
| Coals..... | 87 |
| Iron and steel..... | 87 |
| Nitre from Utah..... | 88 |
| Salt from Warsaw, N. Y..... | 89 |
| Two clays from Owen's Lake, California..... | 89 |
| Clay, sand, etc., from Martha's Vineyard..... | 89 |
| Water from Paris, Me..... | 91 |
| Waters from Savannah, Ga..... | 91 |
| Artesian wells in Georgia and Alabama..... | 91 |
| Water from Arkansas..... | 92 |
| Water from a spring near Fort Wingate, N. Mex..... | 92 |
| Water from Owen's Lake, California..... | 93 |



ILLUSTRATIONS.

| | Page. |
|--|-------|
| Plate I. Diagram of apparatus used in work on high pressure..... | 70 |
| FIG. 1. Crystalline form of olivenite | 39 |
| 2. Crystalline form of chalcophyllite | 43 |
| 3. Crystalline form of clinoclasite..... | 43 |
| 4. Crystalline form of clinoclasite..... | 43 |
| 5. Crystalline form of clinoclasite..... | 44 |
| 6. Crystalline form of brochantite..... | 46 |
| 7. Crystalline form of brochantite | 46 |
| 8. Crystalline form of brochantite | 46 |
| 9. Samarskite..... | 48 |
| 10. Cyrtolite | 52 |
| 11. Cyrtolite | 52 |
| 12. Crystalline form of colemanite | 57 |
| 13. Crystalline form of colemanite | 57 |
| 14. Diagram of apparatus used in work on high pressures..... | 70 |
| 15. Diagram of apparatus used in work on high pressures | 70 |
| 16. Diagram showing experiment | 71 |



LETTER OF TRANSMITTAL.

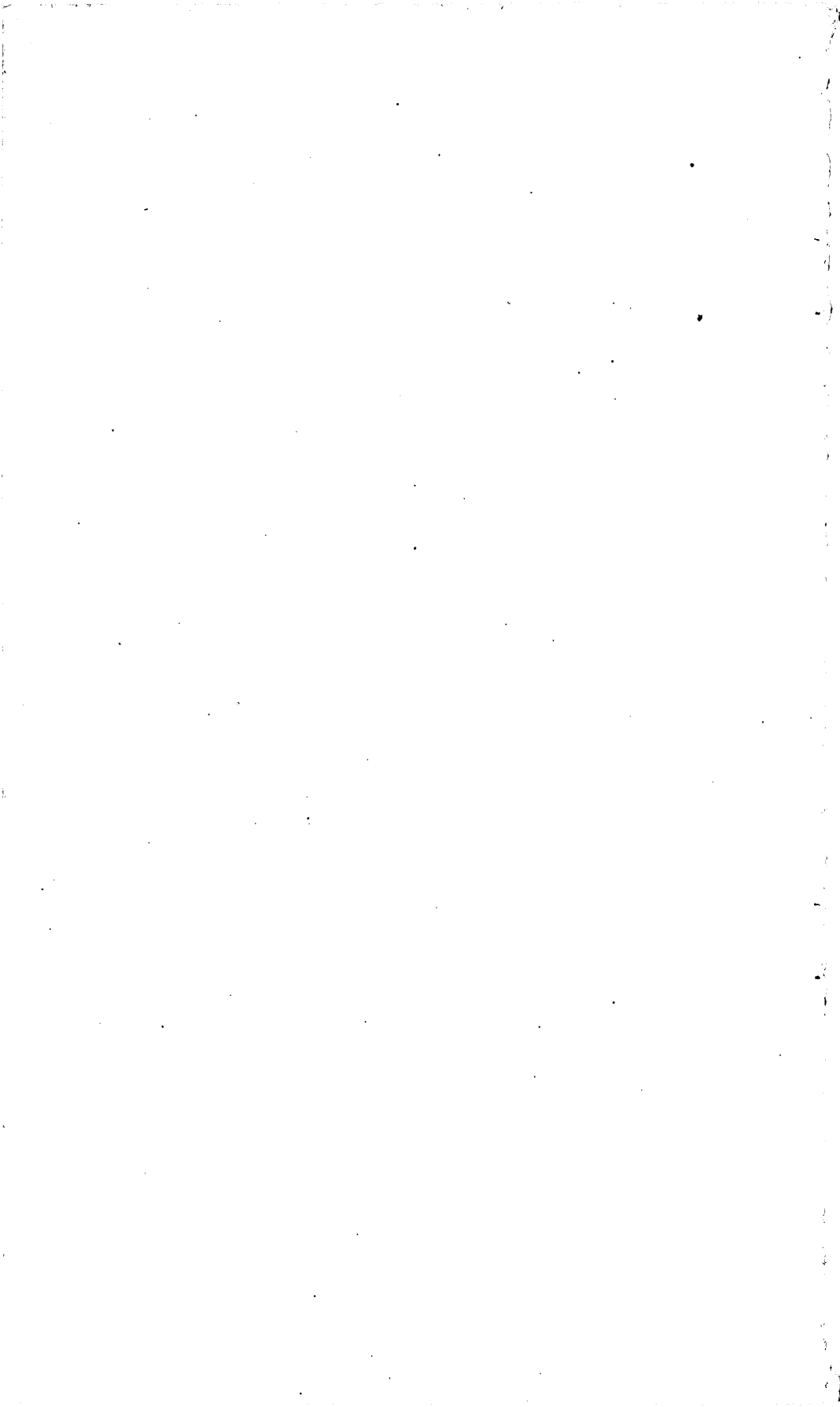
DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., January 1, 1888.

SIR: This bulletin, like its predecessors—Nos. 9, 27, and 42—represents some of the more important work done in the Division of Chemistry and Physics during one fiscal year. It does not by any means cover all the work completed in the laboratories, but only those portions which were considered far enough advanced for publication. Several other researches are very nearly finished, and will duly appear either as independent bulletins or in the next annual bulletin of the division.

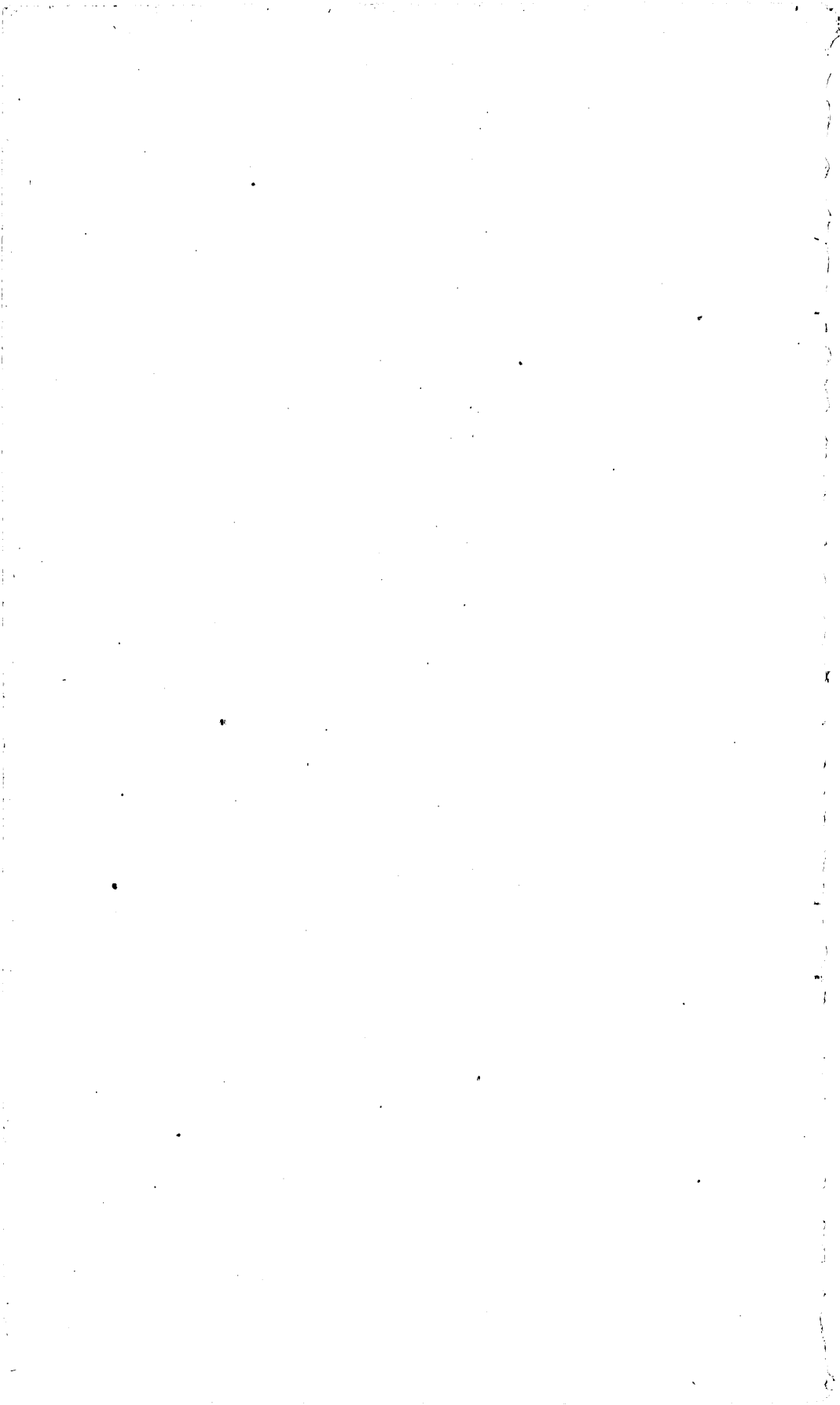
In one investigation we are indebted to Mr. H. S. Washington, of New Haven, for his kind co-operation. His name appears with Dr. Hillebrand's, as joint author of a paper herewith presented.

F. W. CLARKE,
Chief Chemist.

Hon. J. W. POWELL,
Director U. S. Geological Survey.



SCIENTIFIC PAPERS.



WORK DONE IN THE DIVISION OF CHEMISTRY AND PHYSICS IN 1886-'87. .

STUDIES IN THE MICA GROUP.

By F. W. CLARKE.

I. MUSCOVITE FROM ALEXANDER COUNTY, N. C.

This mica occurs in overlapping, crystalline plates, implanted edge-wise in pockets at the well-known locality for emerald and hiddenite at Stony Point. The plates are several centimeters in diameter, with sharply defined crystalline boundaries; and in the specimens before me they are associated with crystallized dolomite, pyrite, and rutile. All of these minerals are more or less dusted over with a dark-green chloritic coating, which, together with some ferruginous staining, gives the mica a somewhat bronzy appearance. An analysis made on carefully purified material gave the following results:

| | |
|--------------------------------------|--------|
| Ignition | 5.46 |
| SiO ₂ | 45.40 |
| TiO ₂ | 1.10 |
| Al ₂ O ₃ | 33.66 |
| Fe ₂ O ₃ | 2.36 |
| MgO | 1.86 |
| CaO | none |
| Li ₂ O | trace |
| Na ₂ O | 1.41 |
| K ₂ O | 8.33 |
| F | .69 |
| | <hr/> |
| | 100.27 |
| Less oxygen | .29 |
| | <hr/> |
| | 99.98 |

This, except for the presence of titanium, is the composition of an ordinary muscovite. Possibly the titanium may be due to minute inclusions of rutile, but none such were detected. It is more probably present as a replacement either of silica or of alumina.

One of the smaller plates of this mica was examined microscopically by Mr. J. S. Diller, who has kindly furnished the subjoined notes:

The group of muscovite scales shows well-defined crystallographic outlines, most prominent among which are the clinopinacoid and the unit prism, although a small clinodiagonal prism is also common. Parallel with the latter there are indistinct

cleavage lines, which in the basal plane make an angle of 31° with the edge between the basal plane and the clinopinacoid. The angle of the optic axes, measured in oil in a plane perpendicular to the plane of symmetry, is 35° .

The muscovite is partially coated by a greenish dust, which in its arrangement follows crystallographic lines, giving to the scales a streaked appearance. It appears most abundantly upon the prismatic edges, but to a considerable extent also upon the clinopinacoid, and in traces on the clinodiagonal. Thin laminae of dust occur between the foliae of the muscovite, to which they impart a yellowish tinge in reflected light. This dust appears to be weakly doubly refracting, but its structureless character and want of definite optical properties render its determination a matter of difficulty.

With some trouble I collected a little of this chloritic dust, 0.3165 gramme in all, and made a partial analysis of it, as follows:

| | |
|--------------------------------------|--------------------|
| Ignition | 20.50 |
| SiO ₂ | 31.16 |
| Al ₂ O ₃ | 8.06 |
| Fe ₂ O ₃ | 35.86 = 32.28 FeO. |
| MgO | 5.43 |
| | <hr/> |
| | 101.01 |

The iron is undoubtedly present chiefly, but not wholly, in the ferrous state; and the alumina is ascribable to traces of admixed mica. Still, with all its defects, the analysis clearly defines the mineral as a member of the obscure hisingerite group, which has rarely been noted in this country. Its association with pyrite is similar to some of its occurrences abroad, and here, as observed elsewhere, it may originate in the alteration of that species. I hope to give it a fuller examination sometime with a larger supply of material. For the specimens so far studied I am indebted to the kindness of Mr. Wm. Earl Hidden.

II. LEPIDOMELANE FROM BALTIMORE, MD.

This mineral, the characteristic black mica of the Jones Falls pegmatite, was sent me for analysis by Dr. G. H. Williams, of the Johns Hopkins University. The specimen submitted was in broad, brilliant foliations, black by reflected light, but dark smoky green by transmitted light. According to Dr. Williams it is very nearly uniaxial. In the following analysis the direct estimation of water and the determination of ferrous iron were made by Mr. R. B. Riggs:

| | |
|--------------------------------------|--------|
| H ₂ O | 4.48 |
| SiO ₂ | 35.78 |
| Al ₂ O ₃ | 16.39 |
| Fe ₂ O ₃ | 14.55 |
| FeO | 11.02 |
| MnO | 1.08 |
| CaO | none |
| MgO | 8.67 |
| K ₂ O | 7.76 |
| Na ₂ O | .56 |
| TiO ₂ | none |
| | <hr/> |
| | 100.29 |

Reckoning the water with the alkalis, the analysis gives approximately the formula $R'_6R''_3R'''_4Si_5O_{22}$. The mineral, therefore, is slightly too basic for an ordinary orthosilicate, and it seems to occupy an intermediate position, as do its ratios, between annite and the Litchfield lepidomelane.

III. LEPIDOMELANE FROM LITCHFIELD, ME.

In a previous paper upon the minerals of Litchfield¹ I gave an analysis of this mica, together with some data as to its occurrence. It is scattered abundantly through the elæolite syenite of the locality, in black brilliant plates or scales, which are transparent only in very thin laminae, and then transmit light of a dark green color. It is one of the least transparent micas I have ever seen. According to Mr. Diller, who kindly made a microscopic examination of the mineral, it is so nearly uniaxial, that a measurement of its optic axial angle is impracticable. Some specimens show evidence of two micas, one being blacker and more brittle than the other, so that a new analysis was made upon very carefully selected material. Only the more transparent and elastic foliæ were chosen, and the results are given below:

| | |
|--------------------------------------|--------|
| H ₂ O | 4.67 |
| SiO ₂ | 32.35 |
| Al ₂ O ₃ | 17.47 |
| Fe ₂ O ₃ | 24.22 |
| FeO | 13.11 |
| MnO | 1.02 |
| CaO | .89 |
| MgO | none |
| Na ₂ O | .70 |
| K ₂ O | 6.40 |
| TiO ₂ | none |
| | <hr/> |
| | 100.83 |

THE DETERMINATIONS FOR IRON IN THE FERROUS STATE AND FOR WATER.

The ferrous iron and water determinations were made by Mr. Riggs. Titanium was carefully sought for by two methods in three separate tests, but only a doubtful trace was discovered. The formula of the mica, reckoning water with the alkalis, is very nearly $R'_6R''_2R'''_6Si_5O_{24}$.

This mica, on account of its low percentage of silica and its basic nature, has peculiar interest. Among published analyses of micas I find only two which approach it in these particulars, namely the micas from Brevig and Miask, described by C. Rammelsberg.² These gave respectively 32.97 and 32.49 per cent. of silica, but they also contained, the first 2.42 and the second 4.03 of titanitic oxide. This constituent, as

¹ Bull. U. S. Geological Survey, No. 42, p. 35.

² Geol. Gesell. Zeitschr., vol. 31, 676-691.

has been stated, is lacking in the Litchfield mineral. Notably all three of these low silica micas are from localities of *elæolite* syenite, although Rammelsberg says nothing of the actual associations of the specimens discussed by him. The question at once arises, to be settled by future investigation, whether micas of this peculiar character are representative of *elæolitic* rocks, and whether there is any genetic relation between them and *eleolite*. I hope that observations upon this point may soon be multiplied.

Some months ago I published some analyses of the Rockport micas, which were made by Mr. Riggs in this laboratory.¹ One of these, the so-called *annite*, seems to have a serial relation with the analogous micas from Baltimore and Litchfield, which may be expressed in formulæ. These, stated in empirical form, are as follows:

| | |
|------------------|-----------------------------|
| Rockport | $R'_6R''_4R'''_2Si_5O_{20}$ |
| Baltimore | $R'_6R''_3R'''_4Si_5O_{22}$ |
| Litchfield | $R'_6R''_2R'''_6Si_5O_{24}$ |

Here we have R' and silicon constant, while a gain of R'''_2O_2 corresponds in each step to a loss of one atom of R'' . If now we assume that R'''_2O_2 represents really two of the recognized univalent groups $-Al=O$, we shall find that all three of the micas, reduce to the true orthosilicate type, containing the nucleus $R'''_2(SiO_4)_5$, which appears to be characteristic of many iron micas and of the *phlogopite* group. We thus have, uniting all the monoxide bases, the following general formulæ:

| | |
|------------------|---------------------------------|
| Rockport | $R'_{14}R'''_2(SiO_4)_5$ |
| Baltimore | $R'_{12}(AlO)_2R'''_2(SiO_4)_5$ |
| Litchfield | $R'_{10}(AlO)_4R'''_2(SiO_4)_5$ |

In short, the three micas are built upon the same fundamental plan, and exhibit a new and highly suggestive order of variation.

IV. IRON-BIOTITE FROM AUBURN, ME.

Among the minerals occurring at the well-known *lepidolite* locality at Auburn a brilliant black *biotite* is common. Some time since, in looking over a collection of the Auburn material in the possession of Mr. N. H. Perry, of South Paris, I observed that certain broad foliæ of this mica were bordered by a grayish distinct margin, about 5^{mm} wide, which was made up of micaceous scales. Inasmuch as the *lepidolite* of the locality forms similar borders upon the *muscovite*, I thought that this bordering might have interest, and Mr. Perry kindly placed his best specimen at my disposal. Analyses of both the *biotite* and the margin were made, but unfortunately the amount of the latter available was too small for complete investigation. In the study of the border, therefore, ferrous iron and water had to be neglected, and that analysis is

¹Bull. U. S. Geological Survey, No. 42, p. 22.

so far incomplete. The results are given below, with determinations of water and ferrous iron in the biotite made by Mr. Riggs:

| | Biotite. | Margin. |
|--------------------------------------|----------|---------|
| H ₂ O | 4.64 | undet. |
| SiO ₂ | 34.67 | 56.44 |
| Al ₂ O ₃ | 30.09 | 16.01 |
| Fe ₂ O ₃ | 2.42 | } 15.91 |
| FeO | 16.14 | |
| MnO | .85 | undet. |
| MgO | 1.98 | .97 |
| CaO | none | none. |
| Na ₂ O | 1.67 | 1.92 |
| K ₂ O | 7.55 | 6.15 |
| F | .28 | .71 |
| Less oxygen | 100.29 | |
| | .12 | |
| | 100.17 | |

Upon microscopic examination by Mr. Diller the mica was found to be "almost completely uniaxial, for when it was rotated between crossed nicols the displacement of the black cross was scarcely perceptible." He also found that the same mica, with a slight change of color from brown to greenish brown, continued into the border, where it was intimately mingled with grains and fibers of quartz. The latter admixture accounts in part for the high percentage of silica in the margin, although it seems probable that there may be also some degradation from the original orthosilicate toward a metasilicate type. At all events the specimens are in nowise analogous to those which show lepidolite borders upon muscovite.

In its ratios this Auburn mica is not simple. Approximately, reducing all monoxides to the univalent type, its formula may be written $R'_{11}(AlO)_3Al_2(SiO_4)_5$; with $R'_{11} = H_4K_2Fe_{2\frac{1}{2}}$. It seems to be a compound intermediate between the Litchfield and Baltimore micas, with R''' nearly all aluminum.

V. IRON-MICA FROM THE VICINITY OF PIKE'S PEAK.

This specimen, which was kindly given me by Mr. C. S. Bement, was a section from a large prismatic crystal in his collection. It was a bronzy black mica, resembling phlogopite externally, but remarkably altered at the center. The entire core of the crystal was made up of a soft, rotten material, evidently derived from the original mica, and surrounded by a broad black margin of the latter. Streaks of rusty alteration products reached into the margin in every direction, so that no

absolutely unchanged material could be obtained for analysis. According to Mr. Diller, the angle of the optic axes is too small for measurement.

Analyses were made of both margin and center, the former being as little altered, the latter as much altered, as could be selected.

Again I am indebted to Mr. Riggs for determinations of water and ferrous iron :

| | Margin. | Center. |
|--------------------------------------|---------|---------------|
| H ₂ O | 4.54 | Ignition 7.82 |
| SiO ₂ | 34.21 | 34.63 |
| Al ₂ O ₃ | 16.53 | 17.95 |
| Fe ₂ O ₃ | 20.15 | 31.25 |
| FeO | 14.17 | 3.01 |
| MnO | .91 | .34 |
| CaO | .48 | .81 |
| MgO | 1.34 | 1.08 |
| Na ₂ O | 1.43 | .89 |
| K ₂ O | 6.50 | 1.96 |
| F | .08 | .54 |
| | 100.34 | 100.28 |
| Less O | .03 | .23 |
| | 100.31 | 100.05 |

These figures show the order of alteration so well, that comment upon them is unnecessary. The original mica probably was very near Lewis's siderophyllite, but it is hardly worth while to discuss the ratios.

THE ANALYSIS AND COMPOSITION OF TOURMALINE.

BY R. B. RIGGS.

Apart from the work by Rammelsberg¹ very little has been done towards solving the question of the composition and constitution of tourmaline. Its apparent complexity and the difficulties attending the determination of certain constituents have doubtless turned many aside, possibly also the impression that with Rammelsberg's investigations the matter was settled. While Rammelsberg's work was comprehensive, and was possibly good for the times, his analyses are so seriously faulty in certain important respects as to justify a new investigation. Though the direct estimation of both water and boric acid would seem to be of the highest importance before any satisfactory conclusions could be reached with reference to the constitution of tourmaline, we find that, having failed in one single attempt to determine the water directly, he takes the loss on ignition, deducts therefrom an amount equal to the amount of silicon tetrafluoride, representing the fluorine found in the mineral, and calls the rest water. He takes it for granted that the fluorine is driven off quantitatively. While this supposition is questionable, it is not the main ground of objection. In the revision² of his earlier work Rammelsberg comes to the conclusion that the iron contained in tourmaline is all there in the ferrous condition, yet he wholly ignores the fact of its possible oxidation on ignition, especially an ignition such as would be necessary to expel the fluorine.

In a few cases boric acid was determined directly, but by a method (Stromeyer's) which has ever been counted as one of the most unsatisfactory. In the majority of analyses boric acid was estimated by difference. But if the results called water are incorrect and low, as they surely are, the boric acid ought to be correspondingly high, or the analysis must be faulty in other respects.

The direct estimation of water being possible, and a satisfactory method for determining boric acid having lately been devised by Dr. F. A. Gooch,³ new tourmaline analyses seemed desirable.

¹ Pogg. Ann., vol. 80, p. 449; vol. 81, 1 p.; vol. 139, pp. 379, 547.

² Pogg. Ann., vol. 139, p. 379.

³ Bull. U. S. Geological Survey, No. 42, pp. 64-72.

Through the kindness of many persons, abundant and varied material has been at my disposal.

METHODS OF ANALYSIS.

A few words on the methods of analysis may not be out of place here, that the character of the work may be the better judged.

Water.—The water was directly determined by igniting a mixture of the mineral and carbonate of soda in a Gooch tubulated crucible, the sodium carbonate being used to hold back any fluorine that might otherwise be driven off. The carbonate of soda was first fused, and then, in order to insure perfect dryness, the mixture of the mineral and this reagent was again dried in an air bath at 105° C. for two or three hours. This estimation, as well as all the other more important ones, was made in duplicate.

Boric acid.—When the tourmaline contained fluorine, the same material was used for determining both the boric acid and the fluorine, the filtrate from the mixed carbonate and fluoride precipitates being used for the estimation of the boric acid. The calcium borate (cf. line 7, page 16) which may be formed is so readily soluble in hot water that no difficulty is experienced in bringing it quantitatively into the filtrate. After evaporating this filtrate to a conveniently small volume, it is brought into the retort and acidified with nitric acid. The boric acid is then volatilized as methyl borate, according to the Gooch method, and weighed as borate of lime. It is scarcely necessary to say that throughout this treatment nitric acid should be used as the neutralizing reagent, and that, if care be taken in its use, in no case does the amount of salt which is to be brought into the retort become inconveniently great. Where no fluorine is present the soda fusion may be digested with water at once, the solution containing the sodium borate filtered off, neutralized, and treated as above indicated. One might save himself even this filtration but for the fact that in using the whole fusion a quantity of bases would thus be brought into the retort, which, even at the low heat required by the distillation, would give up their nitric acid, thereby rendering the determination in its after stages more difficult, and possibly less exact.

Fluorine.—The fluorine was estimated by the Berzelian method. Though it is far from a good method, care and experience enable one to obtain fairly trustworthy determinations. The tendency is towards too high results, because of the difficulty of freeing the calcium fluoride from last traces of alumina and silica, and a better method will probably show even less fluorine to be present in tourmaline than the insignificant quantity now found.

Ferrous oxide.—Tourmalines, particularly the lithia and iron varieties, are decomposed by acids with extreme difficulty. This fact, together with the fact that the iron in tourmaline (possibly from some

inherent organic reason, such as the high and unstable degree of oxidation of the boric acid) oxidizes with unusual ease, has made the determination of the condition of this constituent most troublesome. On account of its refractory nature, usually not more than 0.2 gramme of the finely ground mineral was taken for this determination. Several methods of decomposition were tried without any satisfactory results other than to lead to the conviction that the presence of ferrous iron in large amounts was doubtful until the digestion of the mineral with hydrofluoric acid in a sealed platinum crucible over the direct flame was resorted to, with fairly conclusive results.

(1) The mineral was digested with hydrofluoric and sulphuric acids in a sealed platinum crucible immersed in boiling water from one to seven days, a treatment which decomposes most minerals in the course of a few hours. In a few cases complete decomposition seemed to have been effected; in the greater number, however, it was at the best very incomplete. In no case was more than 1 per cent. of ferrous oxide found, though between thirty and forty experiments were made, and some of the tourmalines analyzed contain as high as 11 per cent. of iron. These determinations were made in a deep heavy platinum crucible of about 60^{cc} capacity. This crucible has a flaring mouth, into which fits a platinum head securely held in place by a gallews screw clamp. Though the joints are ground, a rubber washer is inserted between the cap and the lips of the crucible to insure a tight fit. Before sealing the crucible a little carbonate of ammonia is thrown in to expel the air. During the period of digestion the crucible is kept completely immersed in water, so that it is difficult to comprehend how the outside air can play any part in the oxidation of the iron. I am accordingly tempted to think that we have here to deal with a very slow reduction of the highly oxidized condition of the boric acid, at the expense of which there is a corresponding oxidation of the iron. That this change goes on slowly, if at all, is evident from the possibility of effecting a decomposition unaccompanied by it.

(2) From 0.2 to 0.5 grammes of the mineral were heated with sulphuric acid—4 parts acid to 1 of water—in sealed glass tubes, from one to four days, at temperatures varying from 150° C. to 250° C. Although the tubes were frequently taken out of the bath and shaken, decomposition in none of the fifteen attempts was more than partial. As even the best acid contains organic matter, sometimes in considerable quantities, a high heat, i. e., above 200° C., is likely to be attended by a reduction of the acid, thus vitiating the results.

(3) The mineral was also fused with bisulphate and bifuoride of potassium, respectively, in an atmosphere of carbon dioxide. Though decomposition was usually effected in a couple of hours, the iron was invariably all oxidized. A reduction of the sulphuric acid may be the cause of the results when bisulphate of potassium was used. No such explanation avails in the case of the bifuoride fusion.

(4) Convinced, by the summations of some of the analyses and by comparing the loss on ignition with the corresponding direct water determinations, that the iron in tourmaline must be there, in large part at least, in the ferrous condition, I finally heated the mineral with hydrofluoric and sulphuric acids in the closed platinum crucible over the direct flame, thus digesting at a moderately high temperature and a correspondingly high pressure, and at the same time securing a constant agitation of the powdered mineral. In these determinations a thin lead washer replaced the rubber. Half an hour with these conditions usually sufficed to effect complete decomposition. The crucible was cooled in an atmosphere of carbon dioxide and the iron was determined in the usual way with a potassium permanganate solution. Fair results were obtained, such as to indicate that the iron in tourmaline is there chiefly in the ferrous condition; the conclusion which Rammelsberg reached as the result of Mitscherlich's experiments¹, confirmed by a few determinations of his own.

Alkalies.—Several vain attempts were made to decompose the tourmaline with hydrofluoric and sulphuric acids. As showing the refractory nature of the mineral, the following is a case in point: One gramme of the pale green Auburn variety, after being ignited, was evaporated to dryness with about 20^{cc} of hydrofluoric acid five times and left an insoluble residue of 0.473 gramme. The Lawrence Smith method was finally adopted, and with highly satisfactory results. The only precautions necessary are that the mineral be finely powdered, and that the mixture with ammonium chloride and calcium carbonate be intimate, which latter condition is only to be secured by grinding the several ingredients together. When these conditions are all that they should be, there is no trouble in bringing about complete decomposition in the course of an hour's gentle ignition. After the alkalies have been leached out with water, the residue should of course be treated with acid to test the completeness of the disintegration. In the case of the tourmalines, with their low silica percentages, the solution is usually complete if the decomposition has been perfect. After the alkalies have been freed from the other bases by the usual well-known methods, although the greater part of the boric acid will have been driven off by the repeated evaporations, more or less of it remains. This residual amount is removed by two or three evaporations with methyl alcohol. The separation of lithia from the other alkalies was made by the Gooch method,² by boiling the mixed chlorides in amyl alcohol, and further separations were effected in the usual way.

Silica.—On the strength of the belief that tourmaline sometimes contains fluorine in considerable amounts, the silica was at first estimated by precipitating it with carbonate of ammonia. Where the bases thrown down by this reagent are so in excess of the silica as they are in tourmaline, its precipitation is fairly easy and quantitative.

¹ Jour. Prakt. Chemie, vol. 86, p. 1.

² Bull. U. S. Geol. Survey, No. 42.

Nevertheless, where this method was used, of duplicate determinations the higher is taken in the summation. Save where the silica is greatly in excess of the bases thrown down by ammonium carbonate, the addition of zinc compounds, as is commonly recommended, is wholly unnecessary. In fact, even in dealing with such minerals as the lepidolites, which contain about 50 per cent. of silica and only 30 per cent. of alumina, the addition of zinc compounds gives no better results than are obtained by simple evaporation with carbonate of ammonia, the evaporation being repeated several times.

As soon as it became evident that the amount of fluorine, if present at all, was so small that its influence in carrying off silica could be neglected, the ordinary method of separation was employed. In all cases silica was corrected by evaporation with hydrofluoric acid.

Alumina.—The only point worthy of mention in this connection is the necessity of testing the alumina for the silica which it frequently contains. This is usually done by fusing the ignited product with potassium bisulphate. Where it amounts to as much as it does in tourmaline, generally exceeding four-tenths gramme, a carbonate of soda fusion works more satisfactorily; it can be continued longer and at a higher temperature. This fusion is readily converted into a sulphate fusion, and the desired separation is thus accomplished. Several fusions are sometimes necessary to bring the bases into solution. As regards other determinations nothing in particular need be said.

ANALYSES.

Analyses have been made of material from the following localities: Auburn, Rumford, and Paris, Me.; Calhao, province of Minas Geraes, Brazil; De Kalb, Gouverneur, and Pierrepont, N. Y.; Hamburgh, N. J.; Orford, N. H.; Monroe and Haddam, Conn.; Stony Point, N. C.; and Nantic Gulf, Baffin Land, well representing the variations in physical properties and chemical composition which characterize the different varieties of tourmaline.

For the sake of compactness the results of these analyses have been grouped. The tourmalines from Maine and those from Brazil are thrown together according to localities, though, barring the iron varieties, they should be classed together on the basis of their composition, on which basis those from other localities are roughly grouped.

Maine.—These tourmalines occur in veins of albitic granite, the chief constituents of which are quartz, albite, and muscovite, with lepidolite and beryl as important accessories. At Rumford spodumene is abundant.

Auburn.—A. Colorless to very pale green crystals, some of which were tinged faintly pink and blue, infusible. Sp. gr., 3.07. B. Light green, fragile crystals, infusible. C. Dark green, massive tourmaline;

fuses with difficulty. D. Massive black tourmaline, easily fusible. Sp. gr., 3.19.

| A. | | B. | | C. | | D. | |
|--|-------------|--------|-------------|--------|-------------|--------|-------------|
| I. | II. | I. | II. | I. | II. | I. | II. |
| SiO ₂ ... 38.14 | 38.00 | 37.85 | 37.80 | 36.26 | 36.18 | 34.99 | 34.87 |
| Al ₂ O ₃ ... 39.60 | 41.37-41.48 | 37.73 | 42.37-42.54 | 36.68 | 44.65-44.73 | 33.96 | 49.76-49.79 |
| Fe ₂ O ₃ ... .30 | | .42 | | .15 | | none | |
| FeO ... 1.38 | | 3.88 | | 7.07 | | 14.23 | |
| TiO ₂ ... none | | none | | none | | none | |
| P ₂ O ₅ ... trace | | trace | | trace | | trace | |
| MnO ... 1.38 | | .51 | | .72 | | .06 | |
| CaO ... .43 | | .49 | | .17 | | .15 | |
| MgO ... trace | | .04 | | .16 | | 1.01 | |
| Li ₂ O ... 1.34 | | 1.34 | | 1.05 | | trace | |
| Na ₂ O ... 2.36 | | 2.16 | | 2.88 | | 2.01 | |
| K ₂ O ... .27 | | .62 | | .44 | | .34 | |
| H ₂ O ... 4.16 | 4.06- 4.26 | 4.18 | 4.16- 4.20 | 4.05 | 4.00- 4.11 | 3.62 | 3.56- 3.68 |
| B ₂ O ₃ ... 10.25 | 10.15-10.34 | 10.55 | | 9.94 | 9.83-10.04 | 9.63 | 9.44- 9.82 |
| F ... .62 | .72 | .62 | .72 | .71 | .80 | none | |
| 100.23 | | 100.39 | | 100.28 | | 100.00 | |
| Less O .26 | | .26 | | .30 | | | |
| 90.97 | | 100.13 | | 99.98 | | | |

The material for the above analyses was received from Mr. N. H. Perry, of South Paris, Me.

Rumford, Black Mountain.—A. Massive, rose-colored, infusible. G., 2.997.

B. Massive, dark green; fuses with difficulty.

Paris, Mount Mica.—Massive, black, powder blue-black, easily fusible.

| A. | | B. | | Paris. | |
|--|-------------|-------|-------------|--------|-------------|
| I. | II. | I. | II. | I. | II. |
| SiO ₂ 38.07 | 38.02 | 36.53 | 36.42 | 35.03 | 34.99-35.06 |
| Al ₂ O ₃ 42.24 | 42.44-42.64 | 38.10 | none | 34.44 | 3.63- 3.75 |
| Fe ₂ O ₃ none | | none | | 1.13 | |
| FeO ..... .26 | | 6.43 | | 12.10 | |
| P ₂ O ₅ none | | trace | | trace | |
| MnO ..... .35 | | .32 | | .08 | |
| CaO ..... .56 | | .34 | | .24 | |
| MgO ..... .07 | | none | | 1.81 | |
| Li ₂ O 1.59 | | .95 | | .07 | |
| Na ₂ O 2.18 | | 2.86 | | 2.03 | |
| K ₂ O ..... .44 | | .38 | | .25 | |
| H ₂ O 4.26 | 4.25- 4.28 | 3.52 | 3.44- 3.60 | 3.69 | 3.63- 3.75 |
| B ₂ O ₃ 9.99 | 9.85-10.13 | 10.22 | 10.03-10.41 | 9.02 | 8.92- 9.12 |
| F ..... .28 | | .16 | | none | |
| 100.29 | | 99.81 | | 99.89 | |
| Less oxygen ..... .12 | | .07 | | | |
| 100.17 | | 99.74 | | | |

For the Rumford material I am indebted to Mr. E. M. Bailey, of Andover, Me. The Paris tourmalines was kindly furnished me out of the National Museum collection.

In connection with the Maine tourmalines the following interesting alteration products were studied:

- A. An alteration from the light green Auburn (B) variety.
- B. Flesh-colored alteration product from the Rumford locality.
- C. An alteration from the Hebron rubellite.

| | A. | B. | C. |
|--------------------------------------|-------|--------|--------|
| SiO ₂ ..... | ..... | 53.03 | 43.90 |
| Al ₂ O ₃ ..... | ..... | 31.67 | 38.71 |
| Fe ₂ O ₃ ..... | ..... | .51 | .58 |
| FeO ..... | ..... | ..... | .25 |
| MnO ..... | ..... | trace | .04 |
| CaO ..... | ..... | trace | .41 |
| MgO ..... | ..... | trace | .05 |
| Li ₂ O | 2.86 | .26 | ..... |
| Na ₂ O | 2.16 | .54 | 1.05 |
| K ₂ O | 9.64 | 9.44 | 10.92 |
| H ₂ O ..... | ..... | 4.80 | 4.25 |
| B ₂ O ₃ | trace | trace | trace |
| F ..... | ..... | trace? | none |
| | | 100.25 | 100.16 |

While the light green Auburn tourmalines were mostly translucent crystals, a few were found which, having become partially opaque, had assumed a micaceous structure. With scant material only the above partial analysis was possible. The results indicate a change in the direction of lepidolite.

The Rumford alteration was examined microscopically by Mr. J. S. Diller, who observed as follows:

Under the microscope it is seen to be composed of two minerals most thoroughly intermingled in nearly equal proportions. One of these minerals is micaceous in structure, with strong double refraction like damourite, which it closely resembles in general appearance. The other mineral is clear, colorless, and apparently monoclinic, with a rather low index of refraction and moderately intense double refraction.

While the Hebron rubellite alteration retains its crystalline form, its material is altered into a softer mineral of an opaque, talcose appearance. The analysis shows the change to be towards damourite,¹ and not towards lepidolite as has been supposed.

Brazil.—*Calhao, province of Minas Geraes.* The association of these tourmalines I was unable to find out. From their composition, however, it is probable that it does not differ greatly from that of the Maine varieties. The specimens analyzed were supplied by Mr. G. F. Kunz.

A. The pink, almost colorless, center of crystals having a green border, infusible. Sp. gr., 3.028.

B. Pale green, like the border of A, infusible.

C. Olive green, fusible in very thin splinters.

¹ F. W. Clarke, U. S. Geological Survey, Bulletin No. 42, p. 15.

D. Black, in splinters a smoky blue green, fuses easily. Sp. gr., 3.20.

| | A. | | B. | | C. | | D. | |
|--------------------------------------|--------|-------------|--------|-------------|-------|-----------|-------|-----------|
| | I. | II. | I. | II. | I. | II. | I. | II. |
| SiO ₂ | 37.19 | 37.12 | 37.39 | 37.31 | 36.91 | | 34.63 | 34.50 |
| Al ₂ O ₃ | 42.43 | | 39.65 | | 38.13 | | 32.70 | |
| Fe ₂ O ₃ | none | 42.94-43.08 | .15 | 42.30-42.38 | .31 | | .31 | |
| FeO..... | .52 | | 2.29 | | 3.19 | | 13.69 | |
| P ₂ O ₅ | none | | trace | | .11 | | none | |
| MnO..... | .79 | | 1.47 | | 2.22 | | .12 | |
| CaO..... | .57 | | .49 | | .38 | | .33 | |
| MgO..... | none | | none | | .04 | | 2.13 | |
| Li ₂ O..... | 1.73 | | 1.71 | | 1.61 | | .08 | |
| Na ₂ O..... | 2.24 | | 2.42 | | 2.70 | | 2.11 | |
| K ₂ O..... | .23 | | .25 | | .28 | | .24 | |
| H ₂ O..... | 3.90 | 3.86- 3.93 | 3.63 | 3.60- 3.66 | 3.64 | | 3.49 | 3.42-3.56 |
| B ₂ O ₃ | 10.06 | 9.96-10.16 | 10.29 | 10.10-10.49 | 9.87 | 9.85-9.88 | 9.63 | 9.55-9.70 |
| F..... | trace? | | .32 | .41 | .14 | .17 | .06 | .10 |
| | 99.66 | | 100.06 | | 99.53 | | 99.52 | |
| Less oxygen..... | | | .13 | | .06 | | .02 | |
| | | | 99.93 | | 99.47 | | 99.50 | |

De Kalb, St. Lawrence County, N. Y.—Colorless to light brown translucent crystals in calcite, with quartz and titanite inclusions, easily fusible. Sp. gr., 3.085.

Gouverneur, St. Lawrence County, N. Y.—Brown, associated with calcite, easily fusible.

Hamburgh, N. J.—Large, cinnamon brown crystals, associated with calcite, quartz, and colorless mica, with many small, shiny, black scales of titanite, easily fusible.

| | De Kalb. | | Gouverneur. | | Hamburgh. | |
|--------------------------------------|----------|-------------|-------------|-------------|-----------|-----------|
| | I. | II. | I. | II. | I. | II. |
| SiO ₂ | 36.98 | | 37.39 | 37.33-37.45 | 35.25 | |
| Al ₂ O ₃ | 28.87 | | 27.79 | | 28.49 | |
| Fe ₂ O ₃ | | | .10 | | none | |
| FeO..... | .52 | | .64 | | .86 | |
| TiO ₂ | .12 | | 1.19 | | .65 | |
| P ₂ O ₅ | undet. | | none | | trace | |
| MnO..... | none | | none | | none | |
| CaO..... | 3.70 | | 2.78 | | 5.09 | |
| MgO..... | 14.53 | | 14.09 | | 14.58 | |
| SrO..... | trace | | trace | | trace | |
| BaO..... | none | | none | | none | |
| Li ₂ O..... | trace | | trace | | trace | |
| Na ₂ O..... | 1.39 | | 1.72 | | .94 | |
| K ₂ O..... | .18 | | .16 | | .18 | |
| H ₂ O..... | 3.56 | 3.55- 3.57 | 3.83 | 3.77- 3.89 | 3.10 | 3.02-3.18 |
| B ₂ O ₃ | 10.58 | 10.46-10.70 | 10.73 | 10.63-10.83 | 10.45 | |
| F..... | .50 | | trace? | | .78 | |
| | 100.83 | | 100.42 | | 100.37 | |
| Less oxygen..... | .21 | | | | .33 | |
| | 100.62 | | | | 100.04 | |

For the De Kalb and Hamburg tourmaline I am indebted to Mr. G. F. Kunz. The Gouverneur material was from the National Museum collection.

From the large amount of titanite oxide found in the Gouverneur specimen it was feared that it might be there as an impurity. On examining a section microscopically Mr. Diller found it, on the contrary, to be quite free from inclusions of any kind. Specimens from other Gouverneur localities, viz, from the town of Gouverneur itself and from Reese's farm, 7 miles north of the town, were also found to contain the oxide in large amounts.

Orford, N. H.—Dark brown crystals, in chloritic schist, easily fusible.

Monroe, Conn.—Dark brown crystals, in chloritic schist, easily fusible.

| | Orford. | | Monroe. | |
|--------------------------------------|---------|------------|---------|-----------|
| | I. | II. | I. | II. |
| SiO ₂ | 36.66 | | 36.41 | |
| Al ₂ O ₃ | 32.54 | | 31.27 | |
| Fe ₂ O ₃ | none | | none | |
| FeO | 2.50 | | 3.80 | |
| TiO ₂ | .23 | | 1.61 | |
| P ₂ O ₅ | none | | trace | |
| MnO | trace | | trace | |
| CaO | 1.35 | | .98 | |
| MgO | 10.35 | | 9.47 | |
| SrO | trace | | trace | |
| BaO | none | | none | |
| Li ₂ O | trace | | none | |
| Na ₂ O | 2.42 | | 2.68 | |
| K ₂ O | .22 | | .21 | |
| H ₂ O | 3.78 | 3.77- 3.79 | 3.79 | 3.76-3.82 |
| B ₂ O ₃ | 10.07 | 9.86-10.28 | 9.65 | 9.57-9.73 |
| F | trace? | | none | |
| | 100.42 | | 99.87 | |

The Orford material was received from Prof. C. H. Hitchcock. The Monroe specimens came from the National Museum collection. The schistose gangue, in which the tourmalines from Orford and Monroe are imbedded, is of particular interest, and was studied microscopically as well as chemically, in the hope that it might throw light on the genetic relations of magnesian tourmaline. The microscopic work, which was of special importance, was kindly undertaken by Mr. J. S. Diller.

Chemical analysis.

| Constituents. | Orford. | Monroe. |
|--------------------------------------|---------|---------|
| SiO ₂ | 27. 18 | 43. 30 |
| Al ₂ O ₃ | 33. 10 | 27. 44 |
| CaO | . 19 | 1. 96 |
| MgO | 28. 09 | 19. 22 |
| Na ₂ O | undet. | 1. 47 |
| K ₂ O | undet. | . 60 |
| Ignition | 11. 75 | 7. 45 |
| | 100. 31 | 101. 44 |

While Mr. Diller found the Orford matrix to be essentially chlorite, in agreement with the results of chemical analysis, the gangue rock of the Monroe tourmaline turned out to be particularly interesting.

Of this Mr. Diller says:

This light gray glittering rock is composed chiefly of biotite, chlorite, and a light-colored mineral which may possibly be zoisite. The biotite is very dark and apparently uniaxial and negative with all the other physical properties of the species. The chlorite is much paler than the biotite and of a greenish color. It is distinctly biaxial, with a small optic angle and positive. The relation of the chlorite to the biotite is readily seen in the thin sections, where it evidently is derived from the latter by a process of alteration. An interesting feature is that in the immediate vicinity of the imbedded tourmaline the biotite is all changed to chlorite, and is arranged with its folia approximately perpendicular to the crystallographic planes of the tourmaline, against which it impinges. The chlorite completely envelops the tourmaline, and the other portions of the hand specimen are made up chiefly of biotite and the zoisitic mineral with a small proportion of chlorite. This variation in the mineralogical composition of the hand specimens readily explains the discrepancy that at first appeared to exist between the results of chemical analysis and my observations.

That the analysis represents a portion of the rock rich in chlorite and poor in biotite, the high magnesia and low alkalis plainly show. The relation existing between the biotite, the chlorite, and the tourmaline in this Monroe matrix is of importance, indicating, as suggested, the transition to be from the mica through the chlorite to the tourmaline.

Pierrepont, St. Lawrence County, N. Y.—Perfect black crystals, highly modified, associated with calcite; fuses easily. Sp. gr., 3.08.

Nantic Gulf, Cumberland, Baffin Land.—Large black crystal, easily fusible. Sp. gr., 3.095.

Stony Point, Alexander County, N. C.—Perfect, medium-sized, black crystals, from the hiddenite mine, with implanted crystals of quartz. The associated minerals are chiefly quartz, muscovite, apatite, rutile, beryl, and spodumene; fuses easily. Sp. gr., 3.13.

Haddam, Conn.—Black crystals in quartz and feldspar, powder blue black, easily fusible.

| Pierrepont. | | Nantic Gulf. | | Stony Point. | | Haddam. | |
|-----------------------------------|-------------------|-------------------|-----|-----------------|-----|-----------------|-----|
| I. | II. | I. | II. | I. | II. | I. | II. |
| SiO ₂ ... | 35.61 | 35.34 | | 35.56 | | 34.95 | |
| Al ₂ O ₃ .. | 25.29 | 30.49 | | 33.38 | | 31.11 | |
| Fe ₂ O ₃ .. | .44 | none | | none | | .50 | |
| FeO ... | 8.19 | 8.22 | | 8.49 | | 11.87 | |
| TiO ₂ ... | .55 | .40 | | .55 | | .57 | |
| P ₂ O ₅ ... | trace | none | | ? | | trace | |
| MnO .. | trace | trace | | .04 | | .09 | |
| CaO ... | 3.31 | 2.32 | | .53 | | .81 | |
| MgO .. | 11.07 | 7.76 | | 5.44 | | 4.45 | |
| SrO ... | none | trace | | none | | none | |
| BaO ... | ? | ? | | none | | none | |
| Li ₂ O ... | trace | trace | | trace | | trace | |
| Na ₂ O .. | 1.51 | 1.76 | | 2.16 | | 2.22 | |
| K ₂ O ... | .20 | .15 | | .24 | | .24 | |
| H ₂ O ... | 3.34 3.30- 3.37 | 3.60 3.53- 3.67 | | 3.63 3.57- 3.69 | | 3.62 3.58- 3.66 | |
| B ₂ O ₃ ... | 10.15 10.00-10.31 | 10.45 10.30-10.60 | | 10.40 | | 9.92 9.74-10.10 | |
| F | .27 | none | | none | | none | |
| | 99.93 | 100.49 | | 100.42 | | 100.35 | |
| Less O. | .11 | | | | | | |
| | 99.82 | | | | | | |

Mr. W. E. Hidden very kindly furnished the Stony Point material. For the other specimens I am a debtor to the National Museum collection. The gravity determinations of the Pierrepont, Stony Point, and Nantic Gulf tourmalines were kindly made by Dr. William Halleck.

From the above analyses it is at once apparent that we have three types to deal with, lithia, iron, and magnesian tourmalines, respectively, with an indefinite number of intermediate products.

For comparison's sake I have tabulated these results, arranging them so as best to show how these types graduate from one into the other, beginning with the lithia tourmaline and passing thence through the iron varieties to those of the purest magnesian type. To render it a complete table of tourmaline analyses, so far as such analyses are worth considering, the results of Rammelsberg's extensive work are added, given in the order and grouping found in his revision of the subject.¹ Also an analysis of an interesting chrome-tourmaline from the Ural, by A. Cossa and A. Arzruni;² the only one of a small number of scattering analyses which seemed to have any value from an analytic standpoint.

¹ Ramm. Handb. d. Min. Chem., 1875, 538-544; Pogg., lxxx, 449, lxxxi, 1.

² Zeit. Kryst. und Min., vol. 7, 1.

Analyses by R. B. Riggs.

| Localities. | B ₂ O ₃ | SiO ₂ | Al ₂ O ₃ | Fe ₂ O ₃ | FeO | TiO ₂ | P ₂ O ₅ | MnO | CaO | MgO | Li ₂ O | Na ₂ O | K ₂ O | H ₂ O | F | Total. | Ign. |
|-------------------|-------------------------------|------------------|--------------------------------|--------------------------------|-------|------------------|-------------------------------|-------|------|-------|-------------------|-------------------|------------------|------------------|-------|--------|-------|
| Rumford (A) | 9.99 | 38.07 | 42.24 | ..... | .26 | none | none | .35 | .56 | .07 | 1.59 | 2.18 | .44 | 4.26 | .28 | 100.17 | 4.35 |
| Brazil (A) | 10.06 | 37.19 | 42.43 | none | .52 | (?) | none | .79 | .57 | none | 1.73 | 2.24 | .23 | 3.90 | trace | 99.66 | 4.10 |
| Auburn (A) | 10.25 | 38.14 | 39.00 | .30 | 1.38 | none | trace | 1.38 | .43 | none | 1.34 | 2.36 | .27 | 4.16 | .62 | 99.97 | 4.09 |
| Brazil (B) | 10.29 | 37.39 | 39.65 | .15 | 2.29 | (?) | trace | 1.47 | .49 | none | 1.71 | 2.42 | .25 | 3.63 | .31 | 99.93 | ..... |
| Auburn (B) | 10.55 | 37.85 | 37.73 | .42 | 3.88 | none | trace | .51 | .49 | .04 | 1.34 | 2.16 | .62 | 4.18 | .62 | 100.13 | ..... |
| Brazil (C) | 9.87 | 36.91 | 38.13 | .31 | 3.19 | (?) | .11 | 2.22 | .38 | .04 | 1.61 | 2.70 | .28 | 3.64 | .14 | 99.47 | 3.62 |
| Rumford (B) | 9.22 | 36.53 | 38.10 | none | 6.43 | (?) | trace | .32 | .34 | none | .95 | 2.86 | .38 | 3.49 | .16 | 99.71 | 3.31 |
| Auburn (C) | 9.94 | 36.26 | 36.68 | .15 | 7.07 | none | trace | .72 | .17 | .16 | 1.05 | 2.88 | .44 | 4.05 | .71 | 99.98 | ..... |
| Paris | 9.02 | 35.03 | 34.44 | 1.13 | 12.10 | (?) | trace | .08 | .24 | 1.81 | .07 | 2.03 | .25 | 3.69 | none | 99.89 | 2.30 |
| Auburn (D) | 9.63 | 34.99 | 33.96 | none | 14.23 | none | trace | .06 | .15 | 1.01 | trace | 2.01 | .24 | 3.62 | none | 100.00 | 2.17 |
| Brazil (D) | 9.63 | 34.63 | 32.70 | .31 | 13.69 | (?) | none | .12 | .33 | 2.13 | .08 | 2.11 | .24 | 3.49 | .06 | 99.50 | 2.19 |
| Haddam | 9.92 | 34.95 | 31.11 | .50 | 11.87 | .57 | trace | .09 | .81 | 4.45 | trace | 2.22 | .24 | 2.62 | none | 100.35 | 2.41 |
| Nantic Gulf | 10.40 | 35.56 | 33.38 | none | 8.49 | .55 | (?) | .04 | .53 | 5.44 | trace | 2.16 | .24 | 3.63 | none | 100.42 | 2.88 |
| Stony Point | 10.45 | 35.34 | 30.49 | none | 8.22 | .40 | none | trace | 2.32 | 7.76 | trace | 1.76 | .15 | 3.60 | none | 100.49 | 2.86 |
| Pierpont | 10.15 | 35.61 | 25.29 | .44 | 8.19 | .55 | trace | trace | 3.31 | 11.07 | trace | 1.51 | .20 | 3.34 | .27 | 99.82 | 2.69 |
| Monroe | 9.65 | 36.41 | 31.27 | none | 3.80 | 1.61 | trace | trace | .98 | 9.37 | none | 2.68 | .21 | 3.79 | none | 99.87 | 3.59 |
| Orford | 10.07 | 36.66 | 32.84 | none | 2.50 | .23 | trace | trace | 1.35 | 10.35 | trace | 2.42 | .22 | 3.78 | trace | 100.42 | ..... |
| Gouverneur | 10.73 | 37.39 | 27.79 | .10 | .64 | 1.19 | none | none | 2.78 | 14.09 | trace | 1.72 | .16 | 3.33 | trace | 100.42 | ..... |
| DeKalb | 10.58 | 36.88 | 28.37 | none | .52 | .12 | (?) | none | 3.70 | 14.53 | trace | 1.39 | .18 | 3.56 | .50 | 100.62 | ..... |
| Hamburgh | 10.45 | 35.25 | 28.49 | none | .86 | .65 | trace | none | 5.09 | 14.58 | trace | .94 | .18 | 3.10 | .78 | 100.04 | ..... |

Analyses by Rammelsberg.

| Localities. | B ₂ O ₃ | SiO ₂ | Al ₂ O ₃ | Fe ₂ O ₃ | FeO | TiO ₂ | P ₂ O ₅ | MnO | CaO | MgO | Li ₂ O | Na ₂ O | K ₂ O | H ₂ O | F | Total. | Ign |
|-----------------------|-------------------------------|------------------|--------------------------------|--------------------------------|-------|------------------|-------------------------------|-------|-------|-------|-------------------|-------------------|------------------|------------------|-------|--------|-------|
| 1. Gouverneur..... | (2.35) | 38.85 | 31.32 | ..... | 1.14 | ..... | ..... | ..... | 1.60 | 14.89 | ..... | 1.28 | .26 | 2.31 | ..... | 100.00 | 3.19 |
| 2. W. Kappel..... | 11.15 | 38.09 | 32.90 | ..... | .66 | ..... | ..... | ..... | 1.25 | 11.79 | ..... | 2.37 | .47 | 2.05 | .64 | 101.37 | 2.93 |
| 3. Eibenstock..... | (9.14) | 37.75 | 30.86 | ..... | 4.36 | ..... | ..... | ..... | .88 | 11.62 | ..... | 2.27 | .30 | 2.82 | ..... | 100.00 | 3.50 |
| 4. Zillertal..... | (9.52) | 38.51 | 32.65 | ..... | 2.80 | ..... | .36 | ..... | .16 | 10.46 | ..... | 2.13 | .37 | 3.04 | .36 | 100.36 | 3.54 |
| 5. Orford..... | 9.66 | 38.33 | 33.15 | ..... | 2.88 | ..... | ..... | ..... | .77 | 10.89 | ..... | 1.32 | ..... | 2.81 | ..... | 100.21 | 3.49 |
| 6. Texas..... | (8.57) | 38.45 | 34.56 | ..... | 2.98 | ..... | .09 | ..... | .71 | 9.11 | ..... | 2.00 | .73 | 2.80 | ..... | 100.00 | 3.30 |
| 7. Monroe..... | (8.95) | 39.01 | 31.18 | ..... | 4.07 | ..... | ..... | ..... | 1.81 | 9.90 | ..... | 1.82 | .44 | 2.82 | ..... | 100.00 | 3.32 |
| 8. Godthaab..... | (7.82) | 37.70 | 34.26 | ..... | 4.42 | ..... | ..... | ..... | 1.25 | 9.51 | ..... | 2.00 | .43 | 2.61 | ..... | 100.00 | 3.11 |
| 9. Havedal..... | (9.29) | 37.11 | 31.26 | ..... | 7.58 | ..... | ..... | ..... | .80 | 9.43 | ..... | 1.78 | .32 | 2.43 | ..... | 100.00 | ..... |
| 10. Goth rd..... | (10.32) | 38.00 | 31.41 | ..... | 7.23 | ..... | ..... | ..... | 1.31 | 7.27 | ..... | 1.43 | .28 | 2.75 | ..... | 100.00 | 3.25 |
| 11. Haddam..... | (9.02) | 37.50 | 30.87 | ..... | 8.54 | ..... | ..... | ..... | 1.33 | 8.60 | ..... | 1.60 | .73 | 1.81 | ..... | 100.00 | 3.44 |
| 12. Ramfossen..... | (9.73) | 37.22 | 30.00 | ..... | 11.16 | ..... | .58 | ..... | .65 | 7.94 | ..... | 1.13 | .53 | 1.64 | .55 | 100.55 | ..... |
| 13. Elba, black..... | (9.03) | 38.20 | 30.02 | ..... | 9.93 | ..... | ..... | ..... | .74 | 6.77 | ..... | 2.19 | .25 | 2.29 | .15 | 100.15 | ..... |
| 14. Unity..... | (9.04) | 36.29 | 30.44 | ..... | 13.23 | ..... | ..... | ..... | 1.02 | 6.32 | ..... | 1.94 | ..... | 1.72 | ..... | 100.00 | 2.22 |
| 15. Krummhu..... | (9.82) | 36.43 | 34.12 | ..... | 11.58 | ..... | ..... | ..... | .44 | 3.84 | ..... | 1.36 | .30 | 2.11 | ..... | 100.00 | 2.66 |
| 16. DeKalb..... | (9.70) | 37.07 | 31.86 | ..... | 12.55 | ..... | .51 | ..... | ..... | 3.49 | ..... | 2.04 | .30 | 2.48 | .31 | 100.31 | ..... |
| 17. Langenbielau..... | (11.02) | 37.24 | 31.63 | ..... | 11.64 | ..... | ..... | ..... | .62 | 3.65 | ..... | 1.93 | .82 | 1.45 | ..... | 100.00 | ..... |
| 18. Bovey Tracy..... | (10.72) | 37.94 | 30.22 | ..... | 13.82 | ..... | .40 | ..... | .50 | 2.62 | ..... | 1.39 | .65 | 1.74 | .45 | 100.45 | 2.09 |
| 19. Krummbach..... | (10.27) | 36.25 | 32.21 | ..... | 12.82 | ..... | ..... | 1.50 | .40 | 2.32 | ..... | 1.43 | .46 | 2.34 | .64 | 100.64 | ..... |
| 20. Alabaschka..... | (12.79) | 36.19 | 30.41 | ..... | 15.59 | ..... | .54 | ..... | ..... | 1.88 | ..... | 1.02 | .47 | 1.11 | .76 | 100.76 | ..... |
| 21. Andreasberg..... | (11.11) | 36.06 | 30.34 | ..... | 17.40 | ..... | ..... | .11 | .72 | .78 | ..... | 1.36 | .58 | 1.54 | .85 | 100.85 | ..... |
| 22. Saas..... | 11.64 | 36.11 | 35.46 | ..... | 13.17 | ..... | ..... | .28 | ..... | 1.52 | ..... | .98 | .09 | 1.26 | .41 | 100.92 | ..... |
| 23. Sarapulsk..... | (11.62) | 38.30 | 31.53 | ..... | 10.30 | ..... | ..... | 2.68 | ..... | 1.06 | trace. | 2.37 | .33 | 1.81 | .80 | 100.80 | 3.28 |
| 24. Goshen..... | 10.65 | 36.22 | 33.35 | ..... | 11.95 | ..... | ..... | 1.25 | ..... | .63 | .84 | 1.75 | .40 | 2.21 | .82 | 100.82 | ..... |
| 25. Elba..... | (9.37) | 37.14 | 34.15 | ..... | 10.52 | ..... | ..... | 1.87 | ..... | 1.68 | .32 | 2.30 | .75 | 1.90 | .47 | 100.47 | ..... |
| 1. Elba, green..... | (9.99) | 37.74 | 41.89 | ..... | 1.38 | ..... | ..... | 2.51 | ..... | .41 | .74 | 2.40 | .31 | 2.60 | .50 | 100.50 | ..... |
| 2. Schaitansk..... | (9.29) | 38.26 | 43.97 | ..... | ..... | ..... | ..... | 1.53 | .62 | 1.60 | .48 | 1.53 | .21 | 2.49 | .70 | 100.70 | 3.45 |
| 3. Paris..... | 9.97 | 38.19 | 42.63 | ..... | ..... | ..... | ..... | 1.94 | .45 | .39 | 1.17 | 2.60 | .68 | 2.00 | 1.18 | 101.20 | 3.61 |
| 4. Itozema..... | (8.93) | 41.16 | 41.83 | ..... | ..... | ..... | ..... | .95 | ..... | .61 | .41 | 1.37 | .217 | 2.57 | 1.19 | 101.19 | 3.76 |
| 5. Elba, red..... | 9.52 | 38.85 | 44.05 | ..... | ..... | ..... | ..... | .92 | ..... | .20 | 1.22 | 2.00 | 1.30 | 2.41 | .70 | 101.17 | 3.37 |

Analyses by Rammelsberg—Continued.

| Localities. | B ₂ O ₃ | SiO ₂ | Al ₂ O ₃ | Fe ₂ O ₃ | FeO | TiO ₂ | P ₂ O ₅ | MnO | CaO | MgO | Li ₂ O | Na ₂ O | K ₂ O | H ₂ O | F | Total. | Ign |
|----------------------|-------------------------------|------------------|--------------------------------|--------------------------------|------|------------------|-------------------------------|------|-------|------|-------------------|-------------------|------------------|------------------|-------|--------|-------|
| 1. Brazil..... | (10.09) | 38.06 | 37.81 | ..... | 5.83 | ..... | ..... | 1.13 | ..... | .92 | 1.30 | 2.21 | .42 | 2.23 | .70 | 100.70 | ..... |
| 2. Chesterfield..... | 9.73 | 38.46 | 36.80 | ..... | 6.38 | ..... | ..... | .78 | ..... | 1.88 | .72 | 2.47 | .47 | 2.31 | .55 | 100.55 | ..... |
| 3. Paris..... | ..... | 38.47 | 40.93 | ..... | 2.77 | ..... | ..... | 1.55 | .88 | 1.21 | 1.47 | 2.36 | .36 | ..... | ..... | ..... | ..... |

Analysis by Cossa and Arzruni.

| Localities. | B ₂ O ₃ | SiO ₂ | Al ₂ O ₃ | Fe ₂ O ₃ | FeO | TiO ₂ | P ₂ O ₅ | MnO | CaO | MgO | Li ₂ O | Na ₂ O | K ₂ O | H ₂ O | F | Total. | Ign |
|-------------|-------------------------------|------------------|--------------------------------|--------------------------------|------|---|-------------------------------|--------|-----|-----|-------------------|-------------------|------------------|------------------|-----|--------|------|
| Ural..... | 9.51 | 36.79 | 30.56 | ..... | 2.91 | Cr ₂ O ₃ 10.86 | ..... | trace. | .72 | .47 | ..... | 1.36 | trace. | 2.25 | .65 | 100.08 | 3.07 |

Rammelsberg concludes that all tourmalines can be referred to mixtures of the following silicate types: $R'_6\text{SiO}_5$, $R''_3\text{SiO}_5$, and $R'''_2\text{SiO}_5$, in which $R' = \text{H, K, Na, and Li}$; $R'' = \text{Mg, Fe, Ca, and Mn}$, and $R''' = \text{Al and B}$, making boric acid the equivalent of alumina. He groups them in two classes:

I. Magnesian-iron tourmaline, represented by the rather complicated formula

$$m \left\{ \frac{R'_6\text{SiO}_5}{3 R'''_2\text{SiO}_5} \right\} + n \left\{ \frac{R''_3\text{SiO}_5}{3 R'''_2\text{SiO}_5} \right\} \text{ where } R''' = \text{B} : 2 \text{ Al}$$

and

II. Lithia tourmaline, represented by

$$m \left\{ \frac{R'_6\text{SiO}_5}{8 R'''_2\text{SiO}_5} \right\} + n \left\{ \frac{R''_3\text{SiO}_5}{8 R'''_2\text{SiO}_5} \right\} \text{ where } R''' = \text{B} : 3 \text{ Al},$$

with the following special formulæ: $R'_2R''_2\text{Al}_4\text{B}_2\text{Si}_4\text{O}_{20}$ for the more purely magnesian varieties; $R'_{10}R''_4\text{Al}_{12}\text{B}_6\text{Si}_{12}\text{O}_{60}$ for the purer iron varieties, and for the lithia tourmaline $R'_6\text{Al}_{12}\text{B}_4\text{Si}_9\text{O}_{45}$, and other complications for those lithia varieties containing iron. The results may warrant these deductions; of that we have nothing to say. The important question concerns the chemical constitution of tourmaline. Attention has already been called to the weak points in Rammelsberg's analyses; but for the sake of emphasis I refer again to his method of determining the water percentages and what depends on it. He assumes that the fluorine is driven off quantitatively on ignition, carrying with it silicon as the tetra fluoride. This assumption is questionable. A half hour's blasting would seem to be sufficient to drive off the water, but it was repeatedly observed that where the tourmaline contained fluorine, further blasting, after the water was presumably all off, was invariably accompanied by a small loss of but a few hundredths per cent. This after loss is probably fluorine in some of its compounds with silica, as experiments made it clear that boric acid is not expelled by any amount of blasting. While making this correction for fluorine the oxidation of the iron is wholly ignored. With this in mind I have given loss on ignition in connection both with my own analyses and with those by Rammelsberg. Comparing this loss with the direct determinations of water, at the same time noting the amounts of iron contained in the respective tourmaline, one is forced to conclude that the oxidation of the iron plays an important rôle here in diminishing the loss on ignition by the amount required to convert it into ferric oxide. If we were to make the more justifiable correction for the oxidation of the iron, setting aside the fluorine correction, we would have more concordant results to deal with—results, moreover, which agree closely with the direct determinations of water—but if the percentages representing water are low, those of boric acid, when it is estimated by

difference, ought to be correspondingly high, and so they are in a few cases. In the greater number of analyses, however, they are unaccountably low, unless we suppose, as I am inclined to do, that the silica determinations run high, representing, in some cases, besides the actual silica, more than 1 per cent. of impurities. If all this be true, in working out his ratios Rammelsberg found in water and boric acid two variables instead of the two constants that they probably are.

It is scarcely necessary to say that certain constituents found in tourmalines are not essential, but have been thrust upon them by their associates. The idea that a tourmaline must contain fluorine was long ago exploded. Indeed, it had its birth not in facts but in Rammelsberg's assumption that tourmaline contained no water and that the loss on ignition was due wholly to fluorine.

Studying those constituents, which are the essentials, in the light of their molecular or atomic ratios, we find some very interesting relations. The ratios of certain elements are constants in all varieties of tourmaline. $\text{Si} : \text{B} : \text{H} : \text{O} = 1 : \frac{1}{2} : \frac{2}{3} : 5.2$. All the other constituents are variable within rather indefinite limits, and considered individually are confusing. If, however, the bases, including hydrogen, be reduced to a common univalent basis and be consolidated, the results fall into line with the above ratios. This reduction may be made in either one of two ways and with almost equally good results. It will be noticed that the oxygen ratio is invariably in excess of the amount necessary to the silicon and boron, even though we assume both the SiO_4 (as we certainly must) and BO_2 groups. This small residual is to be disposed of. It can be done by assuming the presence of either the $\text{Al}=\text{O}$ or the $\text{O}=\text{H}$ group. Both hypotheses have been made use of in the following table. $\text{R}^{(1)}$ is the univalent equivalent of the bases with the oxygen excess incorporated in an $\text{Al}=\text{O}$ group; $\text{R}^{(2)}$ the univalent equivalent of the bases on the basis of an assumed $\text{O}-\text{H}$ group. The table is given in full that the extent of the variations, from what seem to be simple ratios, may in no wise be concealed, as often happens, in giving averages. The hydrogen ratio, though already included in R , is given by itself, being one of the constants. For much the same reason the alkali ratios are also given, although with them the values vary according to the type of the tourmaline. This at least would appear to be true for the iron and lithia varieties.

| | Si | B | $\text{R}^{(1)}$ | $\text{R}^{(2)}$ | O | H | Alk |
|-----------------|----|-----|------------------|------------------|------|-----|-----|
| Rumford A | 1 | .46 | 4.48 | 5.01 | 5.18 | .74 | .28 |
| Brazil A | 1 | .47 | 4.45 | 5.12 | 5.26 | .70 | .31 |
| Auburn A | 1 | .46 | 4.43 | 4.83 | 5.10 | .72 | .28 |
| Brazil B | 1 | .47 | 4.50 | 4.92 | 5.17 | .66 | .31 |
| Anburn B | 1 | .48 | 4.48 | 4.80 | 5.11 | .71 | .30 |
| Brazil C | 1 | .45 | 4.42 | 4.93 | 5.15 | .66 | .32 |
| Rumford B | 1 | .48 | 4.44 | 4.95 | 5.20 | .64 | .30 |
| Auburn C | 1 | .46 | 4.50 | 4.99 | 5.20 | .74 | .28 |

| | Si | B | R ⁽¹⁾ | R ⁽²⁾ | O | H | Alk |
|-------------------|----|---------------|------------------|------------------|----------------|---------------|-----|
| Paris..... | 1 | .45 | 4.47 | 5.09 | 5.21 | .70 | .12 |
| Anburn D | 1 | .48 | 4.50 | 5.01 | 5.21 | .70 | .12 |
| Brazil D | 1 | .48 | 4.50 | 5.02 | 5.21 | .68 | .13 |
| Haddam. | 1 | .50 | 4.51 | 5.00 | 5.24 | .69 | .12 |
| Nantie Gulf | 1 | .51 | 4.52 | 5.00 | 5.25 | .68 | .12 |
| Stony Point | 1 | .51 | 4.19 | 5.01 | 5.41 | .68 | .10 |
| Pierrepoint..... | 1 | .51 | 4.52 | 4.77 | 5.13 | .63 | .09 |
| Monroe..... | 1 | .46 | 4.43 | 4.89 | 5.12 | .69 | .15 |
| Orford | 1 | .48 | 4.48 | 4.99 | 5.20 | .68 | .13 |
| Gouverneur | 1 | .50 | 4.51 | 4.73 | 5.10 | .68 | .10 |
| Hamburgh | 1 | .51 | 4.50 | 5.08 | 5.30 | .59 | .06 |
| De Kalb..... | 1 | .50 | 4.51 | 5.08 | 5.29 | .66 | .08 |
| | 1 | .48 | 4.47 | 4.96 | 5.20 | .67 | |
| | 1 | $\frac{1}{2}$ | $\frac{2}{5}$ | 5 | $5\frac{1}{5}$ | $\frac{2}{3}$ | |

Except in two or three cases the ratios of Si : B : R⁽¹⁾ : O approximate closely $1 : \frac{1}{2} : \frac{2}{5} : 5$, the oxygen, in excess of the amount exactly represented by the ratio (5), having been absorbed in an Al=O group. These ratios give as a general tourmaline formula the simple borosilicate $R_9BO_2SiO_4$. The R_9 includes the constant H= R_3 , (Li, Na, K) varying between the limits R_3 and R_3^2 , (Ca, Mg), varying from R_0 to R_3 , Fe varying from R_0 to R_3 , and (Al, Al=O) varying from R_4 to R_7 . On the other hand the ratio Si : B : R⁽²⁾ : O are about as $1 : \frac{1}{2} : 10 : 5.20$, which would give the equally simple general formula $R_{10}BO_2SiO_4$, when R_{10} includes the above constant and variables, excepting that OH replaces the Al=O group, and Al accordingly varies between the limits R_5 and R_8 . If we expand, in order to bring out the hydroxyl ratio, we have $12SiO_4, 6BO_2, R_{32}H_5(OH)_3=Si : B : R : O=1 : \frac{1}{2} : 5 : 5.25$. Between these two views there are no means at hand of deciding. Could we find that the water is not all driven off at the same temperature, or something of the kind, that knowledge would favor the latter assumption.

Experiments to this end are desirable; but whichever postulate we make, the following special formulæ may be taken as representing typical compounds of the three varieties:

I. Lithia tourmaline— $12 SiO_2, 3 B_2O_3, 4 H_2O, 8 Al_2O_3, 2 (NaLi)_2O$.

II. Iron tourmaline— $12 SiO_2, 3 B_2O_3, 4 H_2O, 7 Al_2O_3, 4 FeO, Na_2O$.

III. Magnesian tourmaline— $12 SiO_2, 3 B_2O_3, 4 H_2O, 5 Al_2O_3, \frac{2}{3} MgO, \frac{2}{3} Na_2O$.

| Calculated. | I. | II. | III. |
|--------------------------------------|--------|--------|--------|
| B ₂ O ₃ | 11.00 | 10.18 | 10.90 |
| SiO ₂ | 37.70 | 34.89 | 37.38 |
| Al ₂ O ₃ | 42.75 | 34.59 | 26.49 |
| FeO | | 13.95 | ..... |
| MgO ..... |  | ..... | 19.31 |
| Li ₂ O | 1.57 | ..... | ..... |
| Na ₂ O | 3.21 | 2.90 | 2.18 |
| H ₂ O | 3.77 | 3.49 | 3.74 |
| | 100.00 | 100.00 | 100.00 |

On comparing the theoretical composition of the above types with the results of analysis, they will be found to agree as closely as could be expected, at least in the values of the constants. The boric acid found invariably falls short of the theory. This is to be expected. The analyses do not represent ideal compounds, absolutely free from impurities, and the case would be very exceptional in which the impurity tended to raise and not to lower the percentage of boric acid.

In some of the above formulas the group BO_2 has been assumed because the oxygen ratio demanded it. As has already been suggested, the ease with which the iron oxidizes, and the mysterious manner in which this change takes place, under conditions where we would suppose it impossible, perhaps point toward a higher degree of oxidation than the more common B_2O_3 . As the result of a slow molecular rearrangement, the one is oxidized at the expense of the other. Such a change is, I believe, not without its analogies. Certain borates, where the assumption of an even higher oxide is thought necessary, on being heated, give borates of a lower order.

Notes.—The question of color is one of some consequence, particularly when the varying colors of the lithia tourmalines are concerned. For, while the color of the iron and magnesian varieties depends on the amount of iron present, and ranges from the colorless De Kalb through all the shades of brown to the Pierrepont black, the lithia tourmalines, containing more or less manganese, give us the red, green, and blue, as well as colorless varieties; the shades of color not depending on the absolute amount of manganese present, but rather on the ratios existing between that element and iron. When the ratios of $\text{Mn} : \text{Fe} = 1 : 1$ we have the colorless, pinkish, or very pale green tourmaline. An excess of manganese produces the red varieties. If, on the other hand, the iron be in excess, the result is the various shades of green and blue. When a section of tourmaline shows a red center bordered by green, the two colors are usually separated by a narrow belt of nearly colorless material, in which the iron and the manganese are presumably in equilibrium.

As regards fusibility; the lithia tourmalines which are free from both iron and magnesia are infusible. The presence of either or both of these elements brings with it a degree of fusibility increasing with their increase, till we find that the purest tourmalines, both iron and magnesian, fuse with great ease.

The titanite associated with the Hamburgh and De Kalb tourmalines attracted special attention because of its form. Having been examined chemically it was kindly studied microscopically by Mr. J. S. Diller, who observed as follows:

The small iron black scales with a rather brilliant metallic luster are cleavable into very thin foliæ, the thinnest of which, under the microscope, are perfectly opaque. In reflected light these lamellæ show three systems of cleavage planes, traces of which,

upon the plane of foliation, intersect at an angle of 60° . The cleavage planes make a large angle with the plane of foliation, and it is evident that this mineral is rhombohedral in crystallization. It is infusible on very thin edges, and does not become magnetic when heated. By this means it is distinguished from hematite and ilmenite. From its physical properties alone I should conclude that it is a member of the ilmenite series rich in oxide of titanium. As analysis shows it to be essentially titanic oxide, it becomes of special interest. In the first place it is the extreme member of the ilmenite series, and in the second place it is a new form of titanic oxide, which is thus shown to be tetramorphic.

NOTES ON CERTAIN RARE COPPER MINERALS FROM UTAH.¹

BY W. F. HILLEBRAND AND H. S. WASHINGTON.

Some time since analyses and partial descriptions of several rare copper minerals from the American Eagle Mine, Tintic district, Utah, were published² by one of us. These minerals had been found by Mr. Richard Pearce in ore shipments from that mine to the Boston and Colorado Smelting Works, near Denver, Colo. Later, in shipments from the neighboring Mammoth Mine, in the same district, Mr. Pearce discovered a second series of minerals of similar character, most of the species, however, being distinct from those of the former occurrence. In recent papers³ he has given the results of his examinations and enumerated the following species: Enargite, olivenite, conichalcite, clinoclasite, brochantite, pharmacosiderite, tyrolite (?), erinite, chalcophyllite, malachite, azurite, and one or two others of doubtful identity, of most of which "enargite is the mother mineral."

In order that this interesting series, in part new to America, might receive fuller study than he was able to devote to it, Mr. Pearce, with the assistance of Mr. Whitman Cross, selected a set of specimens for examination in the laboratory of the Geological Survey at Washington. The chemical work of this paper was there carried out by one of us,⁴ while the crystallographical and optical study was undertaken by the other,⁵ at New Haven, under the guidance of Prof. E. S. Dana. The results of our work, both chemical and physical, failed to meet some of the hopes induced by a first view of the material at disposal, although this was the best that could be found. They are of sufficient interest, however, to make public, especially in view of the meager state of our knowledge regarding a majority of the species herein mentioned.

¹ Read before the Colorado Scientific Society January 2, 1888, and published in the *Am. Journ. Sci.*, 3d series, vol. 35, 1888, p. 298.

² *Proc. Colorado Sci. Soc.*, vol 1, p. 112, and *Bull. U. S. Geol. Survey*, No. 20, p. 83.

³ *Proc. Colorado Sci. Soc.*, vol. 2, pp. 134, 150.

⁴ W. F. Hillebrand.

⁵ H. S. Washington.

OLIVENITE.

This mineral occurred well crystallized. Its habit is tabular, parallel to a (100), and the crystals are, as usual, very simple, as shown in the figure. The planes b (010) and v (101) as a rule are either absent or very small. Measurements were made for the purpose of obtaining a more exact axial ratio than we have at present, the old values of Phillips dating back to 1823.

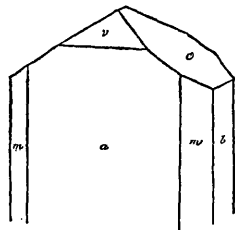


FIG. 1.—Crystalline form of olivenite.

Upon examination and measurement with a Fues horizontal goniometer, it was found that $e \wedge \acute{e}$ (011 \wedge 0 $\bar{1}$ 1) was the only angle sufficiently accurate for the purpose, a and m being a little rough and uneven. The angle mentioned furnished a good value for c , but to obtain the value for \acute{a} use had to be made of a specimen of olivenite from the American Eagle Mine.¹ This olivenite was acicular in habit, the prism m (110) predominating. From these crystals good measurements were obtained of $m \wedge m'''$ (110 \wedge 1 $\bar{1}$ 0), and a satisfactory axial ratio was deduced. The measured angles are as follows:

$$e \wedge \acute{e}, \quad 011 \wedge 0\bar{1}1 = 67^\circ 51'$$

$$m \wedge m''', \quad 110 \wedge 1\bar{1}0 = 86^\circ 26'$$

From these angles we obtain the following axial ratio:

$$\acute{a} : \bar{b} : c = 0.93961 : 1 : 0.672606$$

The measurements above differ considerably from the fundamental angles of Phillips, which are

$$e \wedge \acute{e}, \quad 011 \wedge 0\bar{1}1 = 69^\circ 10'$$

and

$$m \wedge m''', \quad 110 \wedge 1\bar{1}0 = 87^\circ 30',$$

giving the axial ratio

$$\acute{a} : \bar{b} : c = 0.9573 : 1 : 0.6894.$$

Measurements were made with the view of determining whether the species is really orthorhombic or not. The following are the angles obtained:

$$a \wedge e, \quad 100 \wedge 011 = 89^\circ 4', \quad \acute{a} \wedge e, \quad \bar{1}00 \wedge 011 = 89^\circ 59'$$

$$a \wedge \acute{e}, \quad 100 \wedge 0\bar{1}1 = 89^\circ 9', \quad \acute{a} \wedge \acute{e}, \quad \bar{1}00 \wedge 0\bar{1}1 = 90^\circ 1'$$

It is seen that the front angles are in each case a trifle less than the rear angles; but not much reliance can be placed on these results, owing to the poor surface of both a (100) and \acute{a} ($\bar{1}$ 00).

¹ No. 5684 in the Yale collection.

Under the microscope the tabular crystals showed parallel extinction and a slight pleochroism, the vibrations $\parallel c$ being pale olive green, while those $\parallel \bar{b}$ were of a brownish yellow, with the absorption $b > c$.

The mineral was not analyzed, because of the small quantity available, and because its identity was otherwise clearly established.

ERINITE.

Erinite occurs as a dark green crystalline lining of cavities, associated with and generally upon enargite, azurite, barite, or clinoclase. Crystals of olivenite are frequently scattered over its surface, which shows often a somewhat satiny sheen due to minute crystal facets. Hardness 4.5, sp. gr. undetermined. Because of its intimate association with azurite and olivenite it was very difficult to obtain pure material for analysis. Sample I contained 3.90 per cent. of insoluble matter, not included in the analysis. Sample II was composed of a small lot of vitreous crusts, the only ones of the kind observed, which had been collected before shipment of the specimens, and were thought to be erinite by Mr. Pearce, whose partial analyses of material similar to sample I are added for comparison under III.

| | I. Hillebrand. | II. | III. Pearce. | |
|--------------------------------------|--------------------|-------|-----------------|-------|
| | | | a. | b. |
| CuO..... | 57.67 ¹ | 57.51 | 56.56 | 57.43 |
| ZnO..... | 1.06 | 0.59 | | |
| CaO..... | 0.32 | 0.51 | 0.43 | |
| MgO..... | trace | trace | | |
| As ₂ O ₅ | 33.53 | 31.91 | 32.07 | 32.54 |
| P ₂ O ₅ | 0.10 | | | |
| H ₂ O..... | 7.22 | 9.15 | 6.86 | 7.67 |
| Fe ₂ O ₃ | 0.14 | 0.20 | 0.85 | |
| SO ₃ | | | trace. | |
| | 100.04 | 99.87 | 96.77 | 97.64 |

Analyses I and II, and presumably those of Pearce, show the composition of air-dried powder. Sample I lost 0.67 per cent. H₂O over sulphuric acid and a total of 0.78 per cent. at 100° C. At 280° C. the total loss was 1.14 per cent., leaving 6.08 per cent. firmly combined. Sample II lost 2.06 per cent. over sulphuric acid and a total of 3.22 per cent. at 280° C., leaving 5.93 per cent. firmly combined. The molecular ratios, including all the water, are:

| | CuO (CaO,ZnO). | As ₂ O ₅ (P ₂ O ₅). | H ₂ O. |
|-----------------|----------------|--|-------------------|
| I..... | 5.08 | : 1.00 | : 2.74 |
| II..... | 5.34 | : 1.00 | : 3.66 |
| III (mean)..... | 5.13 | : 1.00 | : 2.87 |

If the weakly combined water be excluded from both I and II, the ratio is brought considerably nearer to that derived from Turner's ap-

¹ Mean of 57.61 and 57.74.

proximative analysis,¹ i. e., 5 : 1 : 2. It is uncertain whether Turner's sample was air-dried or heated to 100° C.

TYROLITE (?).

Regarding the identity of this species some doubt exists, as the analytical results obtained do not agree with those given by von Kobell² and Church.³ In general appearance it seems to resemble tyrolite. It occurs in thin scales on quartz, but more often in radiating scaly masses, somewhat like the pyrophyllite from Graves Mountain, Georgia. It has a bright apple-green color, sometimes with a tinge of blue; a somewhat pearly luster; a hardness of 2.5 (1.5 to 2 for tyrolite in the text-books), and perfect cleavage. Under the microscope it showed little or no pleochroism, and extinction parallel and perpendicular to the radial line. In convergent light the cleavage flake showed the ordinary biaxial figure with the dispersion $\rho > v$. Its double refraction is negative, the acute bisectrix being perpendicular to the cleavage face and coinciding with the crystallographic c . The obtuse bisectrix lies parallel to the radial direction of the crystal, but whether it corresponds with α or \bar{b} can not be determined. It was unfortunate that a crystallographic investigation was impossible, as our knowledge of tyrolite in this respect is of the most meager description.

On heating it flies into fine fragments, which by gentle tapping of the tube collect into spongy masses. The mineral melts in the flame of a Bunsen burner. The sp. gr. of sample I (containing 2.25 per cent. of insoluble gangue) was 3.27 at 20½° C. From sample II, which was the purest and best crystallized to be found, 1.25 per cent. of gangue has been deducted.

| | I. | | | II. | III. |
|--------------------------------------|-------------|----------|-------|-------|---|
| | Hillebrand. | | | | Pearce. |
| | <i>a</i> | <i>b</i> | Mean. | | |
| CuO..... | 45.20 | 45.23 | 45.22 | 46.38 | 42.60 |
| ZnO..... | ..... | 0.04 | 0.04 | trace | 0.97 (Fe ₂ O ₃ , Al ₂ O ₃) |
| CaO..... | 6.86 | 6.82 | 6.84 | 6.69 | 9.10 |
| MgO..... | 0.05 | ..... | 0.05 | 0.04 | ..... |
| As ₂ O ₅ | 28.84 | 28.73 | 28.78 | 26.22 | 27.87 |
| P ₂ O ₅ | trace | ..... | trace | trace | ..... |
| H ₂ O..... | 17.26 | ..... | 17.26 | 17.57 | 16.23 |
| SO ₃ | (?) | (?) | (?) | 2.27 | 2.45 |
| | 98.21 | | 98.19 | 99.17 | 99.22 |

SO₃ was unfortunately not tested for in I. It may, however, reasonably be assumed to be present in about the same amount as in II, and

¹ Edinb. Journ. Sci., vol. 9, 1828, p. 95, and Phil. Mag., vol. 4, 1828, p. 154.

² Pogg. Ann., vol. 18, p. 253.

³ Journ. Chem. Soc., 2d series, vol. 11, p. 108.

if it be considered to be present as gypsum ($\text{CaSO}_4, 2\text{H}_2\text{O}$) the following molecular ratios are obtained:

| | $\text{CuO}(\text{CaO}).$ | | $\text{As}_2\text{O}_5.$ | $\text{H}_2\text{O}.$ | |
|----------|---------------------------|---|--------------------------|-----------------------|----------------------------|
| I..... | 5.00 | : | 0.94 | : | 6.80, or 11 : 2.07 : 14.96 |
| II..... | 5.00 | : | 0.84 | : | 6.81, or 11 : 1.85 : 14.98 |
| III..... | 5.00 | : | 0.90 | : | 6.29, or 11 : 1.98 : 13.84 |

It appears herefrom that the As_2O_5 is somewhat less and the H_2O much less than required to satisfy the formula $5\text{CuO}, \text{As}_2\text{O}_5, 9\text{H}_2\text{O}$, derived from von Kobell's (l. c.) analysis, on the supposition that the CaCO_3 found by him, and later by Frenzel¹ and church (l. c.), is not an essential constituent of tyrolite.

It is improbable that more than a very small quantity of chalcophyllite, if any, was mixed with the material analyzed under I and II, although both appeared on some of the specimens marked tyrolite received from Mr. Pearce, and are not always easily distinguished. In any mixture of tyrolite and chalcophyllite the water found must exceed its percentage in the former mineral. This is here not the case, whence it is to be inferred either that the present mineral is not tyrolite or that the older analyses do not represent its true composition.

A large portion of the water is very loosely combined. Of that in analysis I, 4.69 per cent. escaped at $100^\circ \text{C}.$, the most of it over sulphuric acid; and in analysis II, 4.15 per cent. was removed by sulphuric acid, and, further, 0.91 per cent. escaped at $100^\circ \text{C}.$, making a total of 5.06 per cent. These amounts, subtracted from the total percentage found, leave 12.57 and 12.51 per cent., respectively, or about five molecules (assuming five molecules $\text{CuO}(\text{CaO})$). At $280^\circ \text{C}.$ the loss on sample II was 10.34 per cent., in which is presumably included the water of the gypsum supposed to be present, leaving three molecules firmly combined.

Church (l. c.) likewise noticed a great loss of water in vacuo and at $100^\circ \text{C}.$, but assumed that it was hygroscopic water included between the plates of the mineral. The second of his analyses, with data for calculating the centesimal composition, is as follows:

| | | | |
|---|--------|-------------------------------|--------|
| Substance..... | 0.4585 | CuO | 50.06 |
| H_2O in vacuo | 0.024 | As_2O_5 | 29.29 |
| H_2O at 100° | 0.011 | H_2O | [8.73] |
| CaCO_3 | 0.0505 | CaCO_3 | 11.92 |
| CuO | 0.212 | | |
| $\text{Mg}_2\text{P}_2\text{O}_7$ | 0.205 | | 100.00 |

Whence he deduces the formula $5\text{CuO}, \text{As}_2\text{O}_5, 4\text{H}_2\text{O}$. Assuming that $\text{Mg}_2\text{P}_2\text{O}_7$ is an error for $\text{Mg}_2\text{As}_2\text{O}_7$, or for As_2S_3 , in which latter form it appears that arsenic was usually estimated by him in minerals of a similar character, it is impossible to deduce the above given percentage for As_2O_5 . But considering the latter correct, and including the water lost in vacuo and at 100° , the composition is:

¹ Naumann-Zirkel, Elemente der Mineralogie, p. 540.

| | |
|--------------------------------------|--------------|
| CuO | 46.24 |
| As ₂ O ₅ | 27.05 |
| H ₂ O | 15.70 |
| CaCO ₃ | 11.01 |
| | <hr/> 100.00 |

which furnishes the molecular ratio CuO : As₂O₅ : H₂O as 5.00 : 1.01 : 7.43; not greatly differing from those derived from analyses I and II, above.

CHALCOPHYLLITE.

This mineral occurs in the form of small hexagonal plates arranged in rosettes, differing from the radial arrangement of the supposed tyrolite. It showed the same bright apple-green color, pearly luster, and perfect basal cleavage. An optical examination showed it to be uniaxial, with negative double refraction.

These crystals showed several planes replacing the edges, and measurements were made of them as far as possible. The angles did not agree very closely, owing to the imperfection of all the surfaces, but they were sufficiently exact to prove the presence of r ($10\bar{1}1$, R), e ($01\bar{1}2$, $-\frac{1}{2}R$), and two other rhombohedrons new to the species, having the symbols w ($10\bar{1}6$, $-\frac{1}{6}R$) and d ($01\bar{1}3$, $-\frac{1}{3}R$).

The figure shows the habit of the crystals; but with d absent, this plane being only observed in one instance. The very rough angles obtained are given below:



FIG. 2.—Crystalline form of chalcophyllite.

| | Observed. | Calculated. |
|--|-----------|---------------------|
| $c\wedge r$, $0001\wedge 10\bar{1}1 = 71^\circ 27'$ | | $71^\circ 16'$ |
| $c\wedge w$, $0001\wedge 00\bar{1}6 = 26^\circ 10'$ | | $26^\circ 10' 20''$ |
| $c\wedge e$, $0001\wedge 01\bar{1}2 = 56^\circ 51'$ | | $55^\circ 51' 10''$ |
| $c\wedge d$, $0001\wedge 01\bar{1}3 = 41^\circ 50'$ | | $44^\circ 30' 30''$ |

The above angles are the means of several measurements, which vary among themselves from one to three degrees. The fair agreement in the first two results therefore is merely accidental, and no value can be attached to these measurements, which are inserted because the measurements of this species are extremely few.

The mineral was not analyzed, for want of sufficient material. On heating it decrepitated as violently as the last-mentioned mineral, and in the flame of the burner fused, though not with the same readiness.

CLINOCLASITE.

The clinoclasite occurs in two distinct habits—one distinctly crystallized and the other in barrel-shaped or globular forms. It is of a dark bluish green color, almost black by reflected light, bright green by transmitted light. Streak and powder bluish green. Sp.

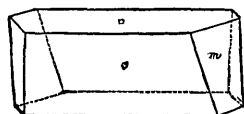


FIG. 3.—Crystalline form of clinoclasite.

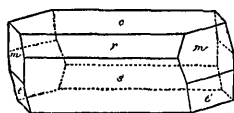


FIG. 4.—Crystalline form of clinoclasite.

gr. at 19° C. 4.38 (4.36 Pearce). Hardness, 2.5 to 3.

At first sight these crystals seemed to be very promising and likely to afford good measurements for the species. But on further examination they did not come up to our expectations, c (001) and s ($\bar{3}02$) being the only two faces giving even fairly good measurements. m (110), r (101), t ($\bar{1}11$), and p ($\bar{1}13$), the other planes observed, were all dull or rounded, and only capable of giving angles accurate enough to identify the forms. Of the planes above, t and p are new to the species. Most of the crystals were apparently made up of two or more individuals in nearly parallel position, but inclined slightly in the zone c/b .

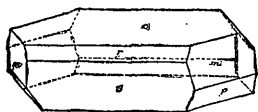


FIG. 5.—Crystalline form of clinoclasite.

A measurement in one case gave the angle $40^\circ 10'$, but as it is not the result of twinning, this angle of course is not constant, and only shows the very slight inclination of the individual crystals. A consequence of this method of growth will be described later.

The crystals were all simple, the form in Fig. 3, or a combination of that with r being the most usual. Occasionally the lower half of m is replaced by t , as shown in Fig. 4, giving the angle $130^\circ 20'$ (calculated $130^\circ 17'$) for $m \wedge t$. The new plane p ($\bar{1}13$) was observed in several crystals and is shown in Fig. 5.

The following angles were obtained for it:

| | Observed. | Calculated. |
|--|-----------------|---------------------|
| $c \wedge p$, 001 \wedge $\bar{1}13$ | $=61^\circ 6'$ | $61^\circ 26' 30''$ |
| $s \wedge p$, 302 \wedge $\bar{1}13$ | $=50^\circ 14'$ | $51^\circ 19' 10''$ |
| $p \wedge p'$, $\bar{1}13 \wedge \bar{1}13$ | $=82^\circ$ | $85^\circ 48'$ |

The angles are merely approximate, but sufficient to establish the form. The crystals are for the most part elongated in the direction of the b axis, with a length of from 2 to 3 millimeters, and show easy cleavage parallel to c .

The other type of clinoclasite is interesting as showing the consequence of the nearly parallel growth of the crystals mentioned above. In some of the specimens the crystals are grouped about the b axis, with c exposed. They are inclined a trifle in the zone c/b and also in the zone a/b , thus rounding off the group in two directions, but decidedly more in the latter zone, forming, with the elongation in the direction of b , distinctly barrel-shaped forms. Occasionally the curvature in the zone c/b is carried still further, producing globular forms. In all cases c forms the outer surface and the crystals are closely crowded together, producing a bright and coarsely rough surface.

The material analyzed consisted of the globular masses mentioned above, and was probably not as pure as the crystals and barrel-shaped forms. A trifling amount of insoluble matter (0.05 per cent.) has been deducted. For comparison, Mr. Pearce's partial analyses are also quoted.

| | I. Hillebrand. | | | II. Pearce. | | Theoretical composition. |
|--------------------------------------|-------------------|----------|--------|----------------|----------|-----------------------------|
| | <i>a</i> | <i>b</i> | Mean. | <i>a</i> | <i>b</i> | |
| CuO | 62.34 | 62.54 | 62.44 | 61.68 | 61.22 | 62.65 |
| ZnO | 0.06 | 0.04 | 0.05 | | | |
| As ₂ O ₅ | 29.59 | 29.60 | 29.59 | 29.36 | 28.85 | 30.25 |
| P ₂ O ₅ | 0.05 | 0.05* | 0.05 | | | |
| H ₂ O | 7.73 | 7.72 | 7.72 | 7.31 | 7.27 | 7.10 |
| Fe ₂ O ₃ | 0.12 | 0.12 | 0.12 | | | |
| SiO ₂ | 0.06 | 0.06* | 0.06 | | | |
| | 99.95 | 100.13 | 100.03 | 98.35 | 97.34 | 100.00 |

* Assumed the same as in *a*.

These results reveal nothing worthy of remark, except that the water, as in most earlier analyses, is found uniformly higher than that required by the formula 6CuO , As_2O_5 , $3\text{H}_2\text{O}$, or $\text{Cu}^3 [\text{AsO}_4]^{12} + 3\text{Cu} [\text{OH}]^{12}$.

MIXITE (?).

On some specimens of ore, but apparently not in close association with the other minerals mentioned, was a mineral occurring in delicate tufts of silky needles of a whitish to pale greenish color, as described by Mr. Pearce.¹

It was impossible to procure enough of the needles free from an underlying non-crystallized greenish coating of cavities for a satisfactory analysis. A good deal of the latter was necessarily included in the sample tested, but qualitative tests showed that both needles and coatings contained the same constituents. It is hardly to be doubted that both have the same centesimal composition.

| | I. Hillebrand. | | | II. Pearce. |
|--------------------------------------|-------------------|----------|--------|----------------|
| | <i>a</i> | <i>b</i> | Mean. | |
| CuO..... | 43.89 | 43.88 | 43.89 | 50.50 |
| ZnO..... | 2.79 | 2.62 | 2.70 | |
| CaO..... | 0.26 | 0.26 | 0.26 | 3.19 |
| Bi ₂ O ₃ | 11.14 | 11.22 | 11.18 | |
| As ₂ O ₅ | 27.78 | 28.79 | 28.79† | 27.50 |
| P ₂ O ₅ | 0.06 | | 0.06 | |
| H ₂ O..... | 11.04 | 11.04 | 11.04 | 12.55 |
| SiO ₂ | 0.36 | 0.48 | 0.42 | |
| Fe ₂ O ₃ | 0.97 | | 0.97 | |
| | 98.29 | | 99.31 | 93.74 |

† The higher value was undoubtedly nearer the truth than the lower.

That an error as to the CuO occurs in Pearce's analysis is beyond question. The above results agree fairly well with Schrauf's analysis of mixite,² which contained 43.21 CuO, 13.07 Bi₂O₃, 30.45 As₂O₅, and 11.07 H₂O, besides a little CaO and FeO; but the form of this mineral was given by Schrauf differs from that of the present one, and its colors given as emerald to bluish green. Schrauf's number for the specific

¹ Proc. Colorado Sci. Soc., vol. 2, p. 151, under the title "New Mineral."² Zeit. f. Kryst., vol. 4, p. 277.

gravity (2.66) is unquestionably much too low. That of the material now analyzed was 3.79 at $23\frac{1}{2}^{\circ}\text{C}$. When treated with dilute nitric acid it becomes at once covered with the brilliant white coating of bismuth arseniate, so characteristic of mixite. The latter mineral is stated to belong to the monoclinic or the triclinic system, while the observations of Mr. Whitman Cross would indicate that the present one can belong to neither of those systems. He says:¹ "The needles are very slender, with a length of more than 1mm in some cases, by a thickness of less than 0.05mm . They are deeply striated vertically, and the crystal system could not be determined, although the extinction in polarized light makes reference to the tetragonal, the hexagonal, or the rhombic system necessary. The index of refraction is high. Pleochroism distinct, the colors observed being for the thicker crystals, a (and b) sea green, c sky blue."

PHARMACOSIDERITE.

For want of sufficient material no analyses were made.

BROCHANTITE.

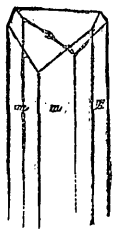


FIG. 6.—Crystal-line form of brochantite.

This hydrous sulphate of copper occurs in two distinct types in the specimens examined. The first, or ordinary brochantite, is of a prismatic habit, as is shown in Fig. 6. The crystals are dark green and transparent, but do not give good measurements, owing to the imperfection of the surface. The cleavage parallel to b (010) is perfect. The measured angle of $m \wedge b$ ($110 \wedge 010$) = $51^{\circ} 46'$ is only approximate, and differs considerably from Miller, who gives $52^{\circ} 5'$, and Schrauf, who gives 52° .

The second type is like Waringtonite from Cornwall, described by Maskelyne.² This variety was suspected by Mr. Pearce (*loc. cit.*, p. 135). It is of a light green color, and has a curved double-wedge-shaped habit. The forms observed are shown in Figs. 7 and 8. The crystals were poor for measuring, all the planes, with the exception of b , being curved to a great degree. The crystals were none of them more than two or three millimeters long, with the relative proportions of the figures. They were implanted by b . m , in Fig. 8, was identified with certainty; the angle for $b \wedge m$ being 52° approximately. The plane lettered k was very much curved in all cases, and its symbol, consequently, is not known with exactness. It corresponds in its angles, very roughly, it is true, to the k , 12. 1. 4

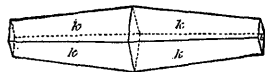


FIG. 7.—Crystalline form of brochantite.

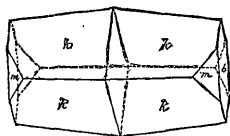


FIG. 8.—Crystalline form of brochantite.

¹ Proc. Colorado Sci. Soc., vol. 2, p. 153.

² Chem. News, vol. 10, p. 263, 1864, and Phil. Mag., ser. 4, vol. 29, p. 475,

of Schrauf, some of the angles obtained from these crystals and the corresponding ones of Schrauf's Waringtonite being given here:

| | Washington. | Schrauf. |
|-----------------------|---|------------------|
| $b \wedge k, 010$ | $\wedge 12.1.4 = 80^{\circ}-82^{\circ}$ | $86^{\circ} 43'$ |
| $m \wedge k, 110$ | $\wedge 12.1.4 = 45^{\circ}$ | $43^{\circ} 11'$ |
| $k \wedge k', 12.1.4$ | $\wedge 12.1.4 = 75^{\circ}-80^{\circ}$ | |

In most of the crystals of this type b was undulating parallel to c .

Want of material forbade an analysis of this mineral, but blow-pipe tests and the crystallographic examination establish its identity beyond doubt.

MINERALOGICAL NOTES,¹

By W. F. HILLEBRAND.

Although the results of analysis of the herein-mentioned minerals, unsupported as they are, with one exception, by any crystallographic evidence, lead to complete identification of the species only in one case, they are deemed of sufficient importance to place on record, together with such information regarding their physical properties as could be gathered from the material at hand, which was in some cases rather scanty.

A few years ago in granitic débris on Devil's Head Mountain, Douglas County, Colo., in the Pike's Peak region, Mr. W. B. Smith found a number of minerals which appeared worthy of examination. Two of these, allanite and gadolinite, have already been analyzed by Mr. L. G. Eakins.² The following analyses, I-VI, represent the composition of the others, of which all but No. III were made in the laboratory of the U. S. Geological Survey, in Denver, over two years ago.

1. SAMARSKITE ?

The mineral first to be mentioned occurred in fragments of all sizes up to that of a chestnut, without any evidence of crystal form except on a small portion of one piece, where a structure resembling that shown in Fig. 9 was apparent. The color was pitch black, with brilliant vitreous luster, but pale brown in thin splinters; streak dirty brown. The pieces were very brittle, and when heated flew into fine, sharp fragments. Fracture subconchoidal. These characteristics agree very

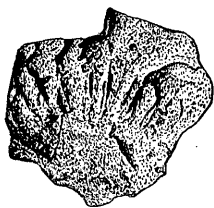


FIG. 9.—Samarските (?).

closely with those given by J. Lawrence Smith³ for the purest North Carolina samarskite, but the density is much greater, being 6.18 at 22° C. for I, as might be expected from the percentage of Ta₂O₅, which is much higher than that as yet found in any recognized samarskite. Hardness, 5.5 to 6. Slight solubility in HCl was shown on prolonged boiling, and a somewhat greater in H₂SO₄. Before the blow-pipe a splinter became dull, but did not fuse. Analysis I shows the composition.

A single piece of but a few grammes weight, while in its general behavior and appearance resembling those just described, presented two points of difference. The streak was salmon colored, and the rather thin piece was bounded on two opposed sides by flat surfaces, which

¹ Read in part before the Colorado Scientific Society, March 5, 1888.

² Proc. Colorado Sci. Soc., vol. 2, p. 32.

³ Am. Jour. Sci., 3d series, vol. 13, 1877, p. 359; Ann. Chim., vol. 12, 1877, p. 253; Original Researches in Mineralogy and Chemistry, p. 197.

might possibly be the result of cleavage. These observed differences led to analysis II. The density at 25° C. was 6.12, and the hardness 5.5. As the analysis reveals a remarkable agreement in composition with the first-described specimens, there is no reason to suspect the presence of distinct species.

Analysis III gives the composition of the specimen shown in Fig. 9, which it was thought might be an altered state of the above-described mineral. It was evidently in an advanced stage of alteration, being very easily broken, and so much stained (brown) that scarcely any evidence of its original color and luster could be observed, though what little of these features remained indicated agreement with those above mentioned. As some water escaped at 100° C., and still more for each further slight increase in temperature, air-dried material was taken for the analysis. This shows in most respects so close an agreement with I and II, that the assumption of original identity with the brilliant black mineral does not seem far-fetched. The chief differences lie in the much lower percentage of Ta_2O_5 in III, and the presence of UO_3 instead of UO_2 . The density at 16° C. was 5.45.

Analyses of samarskite.

| | I. | II. | III. |
|--------------------|--------|--------|------------------------|
| Ta_2O_5 | 27.03 | 28.11 | 19.34 |
| Cb_2O_5 | 27.77 | 26.16 | 27.56 |
| WO_3 | 2.25 | 2.08 | 5.51 |
| SnO_2 | 0.95 | 1.09 | 0.82 |
| ZrO_2 | *2.29 | *2.60 | 3.10 (with TiO_2) |
| UO_2 | 4.02 | 4.22 | 6.20 (UO_3) |
| ThO_2 | 3.64 | 3.60 | 3.19 |
| Ce_2O_3 | 0.54 | 0.49 | 0.41 |
| $(Di, La)_2O_3$.. | 1.80 | 2.12 | 1.44 |
| Er_2O_3 | +10.71 | +10.70 | +9.82 |
| Y_2O_3 | +6.41 | +5.96 | +5.64 |
| Fe_2O_3 | 8.77 | 8.72 | 8.90 |
| FeO | 0.32 | 0.35 | 0.39 (or 0.74 UO_3) |
| MnO | 0.78 | 0.75 | } 0.77 |
| ZnO | 0.05 | 0.07 | |
| PbO | 0.72 | 0.80 | 1.07 |
| CaO | 0.27 | 0.33 | 1.61 |
| MgO | | | 0.11 |
| K_2O | 0.17 | 0.13 | } 0.36 |
| $(Na, Li)_2O$.. | 0.24 | 0.17 | |
| H_2O | 1.58 | 1.30 | 3.94 |
| Fl | ? | ? | ? |
| | 100.31 | 99.75 | 100.18 |

* Probably containing some TiO_2 .

† Calculated from the molecular weight of the mixed oxides of this group on the unsupported assumption that only Er_2O_3 and Y_2O_3 were present. The molecular weight in the case of I was 304.9; in that of II, 307.7.

The method of analysis followed was, with certain modifications, that devised by J. Lawrence Smith.¹ Two instead of five grammes of material were taken for greater convenience in manipulation.

A few remarks in regard to certain points in the course of analysis may prove of service to those having similar analyses to make. By the method of Smith the constituents of the mineral are divided at once into two portions, those soluble in HFl and those insoluble. The former portion includes Ta, Ob, Sn, W, U (if present as UO_3), Fe,² Ti, Zr in part, Zn, Mn, Mg, K, and Na, while the latter contains the earths of the cerium and yttrium groups, Th, U (if present as UO_2), part of the Zr when other earths are present, a small part of the Fe, and the Pb and Ca.

It was found, after converting the insoluble fluorides into sulphates and dissolving in water, that a white insoluble residue remained, which, according to Smith in the case of samarskite, should be Cb_2O_5 and Ta_2O_5 . Neither of these could be found in it, however, the whole being lead sulphate. After filtering, the remainder of the lead was thrown down by H_2S . The uranium then having been oxidized by nitric acid, the earths (except ZrO_2 and some CaO) were thrown down by oxalic acid (not ammonium oxalate) in excess. The use of oxalic acid was rendered necessary by the observed solubility of the earths of the yttrium group in ammonium oxalate. These when freed from bases of the cerium group were not precipitated by this reagent, or, more properly, the precipitate at first formed dissolved *completely* in excess of the precipitant on very gentle warming and was not again precipitated on cooling. This behavior indicates the presence of erbium in quantity, which may influence the yttrium present, for the latter by itself is stated to be only partially soluble in concentrated boiling ammonium oxalate and to be again thrown out on cooling. It should be remarked, however, that the solubility above mentioned was very much greater than when to a hot solution of erbium and yttrium sulphates,³ prepared according to the data furnished by the above analyses, ammonium oxalate was added in excess.

The filtrate from the insoluble fluorides was evaporated to dryness, dissolved in water and a few drops of HFl, and the tin was thrown down by H_2S , as done by Marignac.⁴ The filtrate was then evaporated with large excess of H_2SO_4 , heated till all HFl was certainly removed;

¹Ann. Chem. Journ., vol. 5, pp. 44, 73; Chem. News, vol. 48, pp. 13, 29; Original Researches in Mineralogy and Chemistry, p. 350.

²Treatment with HFl at once reveals whether the iron is present as admixed hematite or limonite (as in analysis III, where it remained suspended in the liquid in an extremely fine state of division), or is chemically combined with the acids of the mineral. In the first case it resists the solvent action of HFl for some time after the tantalates and columbates are thoroughly decomposed.

³From T. Schuchhardt. Though marked *chem. pure*, it is not at all probable that they were so.

⁴Ann. Ch. Phys., 4th series, vol. 13, p. 5.

then, without driving off the excess of H_2SO_4 , diluted and boiled (stirring constantly to prevent bumping) in a very large platinum dish for ten or fifteen minutes. The precipitate collected on a filter was then dissolved in HFl , the filtrate evaporated with excess of H_2SO_4 and treated in every way as above described till after the third precipitation by boiling. The combined filtrates were then evaporated, most of the H_2SO_4 was driven off, the residue taken up with water and boiled for some time. The remainder of the metallic acids, except some TiO_2 if present, is now entirely precipitated, but to free altogether from ZrO_2 , Fe_2O_3 , and from most of the TiO_2 the precipitate was again dissolved in HFl , the filtrate was evaporated with H_2SO_4 , the excess of the latter partly driven off, and the acids were again thrown down by boiling.

This process is somewhat tedious, but seemed to possess the advantage of entirely separating Ta, Cb, and W from Fe and Zr and in great measure from Ti, unless the latter is present in quantity. The point to be observed is that the first precipitations shall be made in strongly acid solutions, the latter in solutions less strong. The procedure of Smith—driving off nearly all H_2SO_4 at first and then boiling with HCl —is objectionable; the metallic acids become strongly caked during removal of the H_2SO_4 and retain much iron, which no amount of boiling with HCl can remove. The further treatment of the combined filtrates requires no special mention.

For the separation of WO_3 the ignited and weighed oxides were fused with Na_2CO_3 and S and separated as recommended by Rose. The method, however, leaves much to be desired, for a considerable quantity of the R_2O_5 acids goes into solution with the W. Cb_2O_5 , and Ta_2O_5 were separated by Marignac's method.

FeO was estimated by titration with KMnO_4 after solution of the very finely powdered mineral in H_2SO_4 by heating for two or three days in sealed tubes, a blank experiment being made with H_2SO_4 alone in another tube. The excess of KMnO_4 above that required for the conversion of all uranium (when assumed present as UO_2) to UO_3 was considered to be equivalent to the FeO . The accuracy of the determination is of course not affected by the fact that uranous salts reduce ferric salts in solution.

Fluorine could not be found quantitatively, but from the slightly acid reaction of the water evolved on heating the mineral, its presence is rendered probable.

From the two first analyses it is impossible to identify the mineral with any known species beyond doubt, although it appears to be more nearly allied to samarskite than to any other. The presence of the iron as Fe_2O_3 distinguishes it from most other tantalates and columbates containing much iron. That the greater part of the iron exists in the ferric condition is certain, for if the uranium existed as UO_3 instead of UO_2 , as assumed, the amount of KMnO_4 required to oxidize 4.02 per cent. of UO_2 (anal. I) would indicate but 2.13 per cent. of FeO .

2. AN ILL-DEFINED ZIRCONIUM MINERAL.

With the mineral just described occurred peculiar growths, from an inch to an inch and three-quarters in length, of a pale brown color, and having the forms shown in Figs. 10 and 11, of which analyses IV-VI represent the composition. Evidences of crystal faces were observed on the upper terminations of some specimens. It seemed not at all probable from its appearance that the substance was homogeneous, and a thin section showed plainly a mixture of two or more minerals. One of these is probably limonite, and the action of HFl supports this view; for, while the powder as a whole was instantly decomposed, brown oxide of iron remained for some time suspended in the liquid.



FIG. 10.—Cyrtolite (?).



FIG. 11.—Cyrtolite (?).

The specimen represented by analysis VI differed much in appearance in places from the others, fractured surfaces being coarsely granular, and showing clear reddish grains of some size which could easily be detached. The sp. grs. were 3.70 (IV), 3.60 (V), 3.64 (VI). The analyses give the composition of air-dried material, for it was found that at 100° C. and with each further increase in temperature water was lost. They are only of value as showing the composition of these characteristic forms, which are mixtures of perhaps cyrtolite, or some allied alteration product of zircon, with limonite and a phosphate.

Analyses.

| | IV. | V. | VI. |
|---|--------|--------|--------|
| Ta ₂ O ₅ | 47.99 | 0.71 | 51.00 |
| SnO ₂ | | 0.03 | |
| ZrO ₂ | | 47.81 | |
| SiO ₂ | 20.06 | 20.64 | 19.21 |
| ThO ₂ | 1.16 | 1.20 | 0.60 |
| Ce ₂ O ₃ | 0.06 | | |
| (Di,La) ₂ O ₃ | 0.19 | | |
| Er ₂ O ₃ | 4.77 | 4.76 | 4.55 |
| Y ₂ O ₃ | 2.27 | 2.48 | 3.13 |
| Fe ₂ O ₃ | 5.53 | 5.97 | 4.86 |
| MnO | 0.47 | 0.57 | 0.33 |
| CaO | 1.99 | 1.93 | 2.15 |
| MgO | 0.13 | 0.11 | ..... |
| K ₂ O | 0.20 | 0.10 | 0.17 |
| Na ₂ O | 0.46 | 0.50 | 0.42 |
| H ₂ O | 12.87 | 12.00 | 12.97 |
| P ₂ O ₅ | 1.64 | 1.75 | 0.93 |
| Fl. | 0.25 | 0.42 | 0.42 |
| | 100.04 | 100.98 | 100.74 |

3. WHITE BERYL.

The crystals analyzed were from a specimen in the National Museum found in a tin mine near Winslow, Me. The beryl is of interest on account of its color, which is white, with a faint greenish hue under certain conditions of light. Mr. J. S. Diller examined the crystals and reported as follows:

The white beryl which you gave me to examine is full of gas and liquid inclusions, most probably air and water, to which the light color of the beryl is due. Besides these it contains a considerable amount of fine ferritic dust, but on the whole is about as pure as minerals usually are. The beryl itself is fresh, and has suffered but little, if any, alteration.

The sp. gr. at 27°C. was 2.707.

VII.

| | | | |
|--------------------------------------|--------|-------------------------------------|-------|
| SiO ₂ | 65.21 | K ₂ O } | 0.14 |
| TiO ₂ | trace | Cs ₂ O } | |
| Al ₂ O ₃ | 18.50 | Na ₂ O | 0.87 |
| Fe ₂ O ₃ | *0.33 | Li ₂ O | 0.16 |
| BeO | †13.03 | H ₂ O | ‡1.80 |
| MgO | 0.09 | P ₂ O ₅ | none |

100.13

* FeO, if present, not estimated.

† BeO and Al₂O₃ separated in the manner described by Penfield. (Am. Jour. Sci. [3], xxxii, 114).

‡ After drying at 110° C.

4. A SULPHIDE OF COPPER, SILVER, AND ZINC.

Mr. Richard Pearce gives an analysis¹ of a mineral from the Gagnon Mine, Butte, Mont., which he describes as massive, and in appearance much like bornite, with density 4.95 and hardness 3.5 to 4. A specimen received from Mr. Pearce, and analyzed at his request, had a density of 5.407 at 20° C. It was rather brittle, but flattened out in part under the pestle. From analysis VIII 0.12 per cent. of gangue has been deducted. Pearce's analysis is given under IX.

| | VIII. | IX (Pearce.) |
|-----------------|-------|--------------|
| Cu | 40.24 | 41.10 |
| Ag | 21.80 | 24.66 |
| Pb | 1.46 | ..... |
| Zn | 12.83 | 9.80 |
| Fe | 1.98 | 2.09 |
| S | 20.88 | 20.51 |
| Insoluble ..... | ..... | 1.02 |
| | 99.19 | 99.18 |

¹Proc. Colorado Sci. Soc., vol. 2, p. 70.

The general formula deduced from both analyses is RS , with the different constituents apparently in varying proportions. It is impossible from the specimens examined to decide whether the mineral is new or only a mixture.

5. AN ARGENTIFEROUS ARSENIDE OF NICKEL AND COBALT.

From Mr. W. George Waring, through Mr. Whitman Cross, a mineral from the Rose Mine, Grant County, N. Mex., was received, which has the composition given under X. It is said to occur also in the Black Hawk Mine, in the same county. It has a steel-gray color, and the particles abraded by a sharp blow of the hammer "take fire, and the pathway of each particle thus ignited as it falls to the ground is marked very distinctly by a trail of dense, white smoke," according to Waring. In a closed tube a heavy sublimate of arsenic is formed on very moderate heating. The gangue of the mineral is mainly carbonate of lime and iron with quartz. The carbonates may be extracted with HCl , when the arsenide is left entirely unaffected and showing evidences of crystalline structure ("pyritohedral," Waring). The sp. gr., after correcting for 4.80 per cent. of quartz, was 6.644 at $20^{\circ} C$.

| | X. | | X. |
|----------|-------|------------|--------|
| As | 74.04 | Ni } | *19.52 |
| S | 0.13 | Co } | |
| Ag | 4.78 | CaO | 0.09 |
| Cu | 0.04 | MgO | 0.05 |
| Pb | 0.03 | | 99.12 |
| Fe | 0.44 | | |

* The separation of Ni and Co miscarried. According to a blow-pipe analysis by Waring the proportion of Ni to Co is as 3 to 1.

The atomic ratio of Ni, Co, Ag, Fe to As is much above 1: 2.5, showing either that the substance is a mixture of two minerals with the general formulas RAs_2 and RAs_3 , or of arsenic with one of the formula RAs_2 .

6. A BASIC CUPRIC SULPHATE.

Two soft lumps of ore of a light green color (rubbing off on the fingers) from the Antler mine, Yucca Station, on the Atlantic and Pacific Railroad, in Mohave County, Ariz., gave the following composition, after deducting 8 and 6 per cent. respectively of gangue, which latter consisted mainly of quartz and a brownish foliaceous mineral. Sp. gr. at $16^{\circ} C$, 3.93, after correcting for gangue, the density of which was assumed to be 2.6.

| | XI. | XII. |
|-----------------------|--------|-------|
| CuO..... | 68.19 | 67.64 |
| ZnO..... | 0.29 | 0.04 |
| CaO..... | 0.05 | 0.04 |
| SO ₃ | 20.46 | 21.49 |
| H ₂ O..... | 11.11 | 10.76 |
| | 100.10 | 99.97 |

The molecular ratios are:

| | RO | SO ₃ | H ₂ O |
|---------|-------|-----------------|------------------|
| I..... | 10.00 | : 2.98 | : 7.19 |
| II..... | 10.00 | : 3.15 | : 7.01 |

which lead to the formula $3\text{CuSO}_4 + 7\text{Cu}[\text{OH}]_2$, for which theory requires 68.45 CuO, 20.69 SO₃, 10.86 H₂O. If in time this should prove to be a well-defined species, which conclusion the absence of crystalline form and want of very close agreement in the analyses do not warrant at present, the name *antlerite*, from the mine in which it occurs, is suggested as appropriate.

ANALYSES OF NATURAL BORATES AND BOROSILICATES.

BY J. EDWARD WHITFIELD.

Most of the published analyses of natural borates have the boric acid determined either by difference or by some of the methods which have been shown to be inaccurate, and they are therefore subject to question as to the exact ratios and formulas. A method for the direct estimation of boric acid having been devised in this laboratory by Dr. F. A. Gooch,¹ it was thought advisable to repeat the analyses of a few of the borates, and verify, if possible, the given formulas or correct errors caused by defective analytical methods. With this object in view, the following analyses were undertaken.

The methods employed differ in many cases from those used by other analysts in the already published accounts of these minerals. In the estimation of the ferrous iron, the method employed was to decompose the finely ground mineral with hydrofluoric and hydrochloric acids in an atmosphere of carbonic acid, and heating to a temperature of about 100° C. in a tightly sealed platinum vessel, devised and used expressly for such determinations, and when thoroughly decomposed—which is generally the case after standing twelve hours, with occasional shaking—to titrate with permanganate of potassium. This method is undoubtedly superior to that employed by Rammelsberg and Tschermak in their analyses.

The direct estimation of the water was made, after drying the mineral at 104° C., with the apparatus devised by Dr. Gooch,² by which the error caused by calculating the water from ignition and ignoring the oxidation of the ferrous iron is eliminated.

The silica in every case has been corrected by evaporation with hydrofluoric and sulphuric acids, and the residue added to the precipitate of iron and alumina.

COLEMANITE, FROM DEATH VALLEY, CALIFORNIA.

Of this mineral there was put at my disposal two specimens very different in appearance. One, designated as A, was a large, transparent crystal of the ordinary type, to all appearances perfectly clear and free from impurities.

¹ Bulletin U. S. Geological Survey, No. 42, p. 647.

² Am. Chem. Jour., vol. 2, 1880, p. 247.

By analysis the following results were obtained, and I insert for comparison the analysis by Mr. J. T. Evans¹ and the theoretical composition calculated from the formulas given below:

| | A. | J. T. Evans. | Theory. |
|-------------------------------|---------|--------------|---------|
| H ₂ O | = 21.87 | = 21.835 | = 21.9 |
| B ₂ O ₃ | = 50.70 | = 50.990 | = 50.9 |
| CaO | = 27.31 | = 27.175 | = 27.2 |
| MgO | = .10 | = | = |
| | 99.98 | 100.000 | 100.0 |

The molecular ratios from analysis A are CaO : B₂O₃ : H₂O—2 : 3 : 5, resulting in the simple formula 2CaO, 3B₂O₃, 5H₂O, the calculated composition of which does not differ much from the results of the analysis. Mr. Evans calculated the same formula from his analysis, in which the boric acid was determined by difference.

The second specimen, B, was from the same locality, but was in the form of a deposit, implanted on gangue, and consisted of small blade-like crystals, almost white, but in some lights appearing of a greenish cast.

By duplicate analyses the following results were obtained:

| B. | | |
|-------------------------------------|--------|--------|
| H ₂ O..... | 22.66 | 22.70 |
| B ₂ O ₃ | 49.56 | 49.62 |
| CaO..... | 27.36 | 27.40 |
| MgO..... | .25 | .26 |
| SiO ₂ | .44 | .47 |
| | 100.27 | 100.45 |

These results prove the mineral to be the same as variety A, but containing very slight impurities. The difference in the general appearance of the two specimens suggested a crystallographic examination of variety B; and, through the kindness of Prof. E. S. Dana, the following description was furnished by Mr. H. S. Washington, of New Haven:

The white transparent crystals, of about 2 to 5^{mm} in length, occur implanted on a light porous gangue, either in parallel position or in rosette-like aggregations, overlapping one another like shingles on a roof. They have in several places implanted on them small, white opaque, spheroidal masses, presumably of priceite. The habit of the crystals is remarkable, being unlike almost all the forms of colemanite previously described. Prof. A. W. Jackson² gives one figure resembling these forms, though more complex. They look at first sight like two rhombohedræ of calcite; the combination of prism and ortho-dome giving the mineral a decidedly rhombohedral aspect, as shown in Figs. 12, 13.

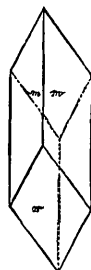


FIG. 12.—Crystalline form of colemanite.

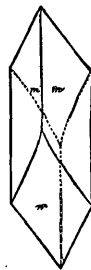


FIG. 13.—Crystalline form of colemanite.

¹ Proc. Cal. Acad. Sci., No. 1; Neues. Jahr., 1886, 1-1-37.

² Bull. Cal. Acad., No. 4, pp. 358-374, plates.

None of the crystals examined admitted of good measurements, the faces being broken, rough, or curved. They were accurate enough, however, for determining the symbols. The plane W 301 was curved very conspicuously and regularly, the face having, near a 100, the position approximately represented by the symbol $\bar{5}01$. This habit was very constant, the prism m 110 and orthodome W 301 being the only planes observed, with the exception of b 010, produced by the perfect cleavage, and a small and very uncertain plane observed in one or two cases replacing the edge W 301 / m' 110.

PRICEITE, FROM CURRY COUNTY, OREGON.

The specimen examined was white and chalky, and proved to be very pure material. An analysis gave the following composition, and I copy the results of an analysis by Silliman¹ and another by Mr. Thomas Price² for comparison:

| | Whitfield. | Silliman. | Price. |
|---|--------------|--------------|--------------|
| H ₂ O | 19.42 | 18.29 | 22.75 |
| B ₂ O ₃ | 48.44 | 49.00 | 47.04 |
| CaO | 32.15 | 31.83 | 29.96 |
| NaCl, Fe ₂ O ₃ , Al ₂ O ₃ ..... | ..... | .96 | .25 |
| | <hr/> 100.01 | <hr/> 100.08 | <hr/> 100.00 |

The ratios from my figures are CaO: B₂O₃: H₂O—19: 23: 36, which do not conform to any simple formula. In both the earlier analyses the boric acid was determined by difference, and there is a discrepancy between them of about 2 per cent.

PANDERMITE, FROM THE ISLAND OF PANDERMA, IN THE BLACK SEA.

The material was hard and compact, somewhat resembling marble.

| | |
|-------------------------------------|--------------|
| H ₂ O | 19.40 |
| B ₂ O ₃ | 48.63 |
| CaO | 32.16 |
| | <hr/> 100.19 |

From these figures it will be seen that the priceite and the pandermite are in composition identical, the difference being wholly in the physical appearance of the material. The priceite is soft and friable, while the pandermite is compact. From the results obtained it is apparent that they are the same mineral.³

ULEXITE, FROM RHODES' MARSH, ESMERALDA COUNTY, NEVADA.

The material for analysis was taken from one of the nodules found in this locality, which on being broken exposed the fine, silky fibers characteristic of the mineral.

¹ Am. Jour. Sci., ser. 3, vol. 6, pp. 128-130.

² Am. Jour. Sci., ser. 3, vol. 5, pp. 287-290.

³ Dana, Syst. Min., app. III-97.

An analysis gave the following figures :

| | Found. | Calculated. |
|-------------------------------------|-------------|--------------|
| SiO ₂ | 0.04 | ..... |
| Cl..... | 2.38 | ..... |
| B ₂ O ₃ | 43.20 | 45.34 |
| SO ₃ | 0.28 | ..... |
| CaO..... | 14.52 | 15.04 |
| Na ₂ O..... | 10.20 | 8.83 |
| K ₂ O..... | 0.44 | ..... |
| H ₂ O..... | 29.46 | 30.79 |
| | <hr/> 100.5 | <hr/> 100.00 |
| Deduct O=Cl..... | .53 | |
| | <hr/> 99.99 | |

The molecular ratios from these figures are Na₂O : CaO : B₂O₃ : H₂O = 16 : 26 : 62 : 163, which conform to no simple formula. If, however, we correct for impurities by throwing out the SiO₂, the K₂O, as KCl, the remaining Cl as NaCl, and the SO₃ as gypsum (CaSO₄, 2H₂O) we can calculate the composition given above, from which we deduce the formula NaCaB₅O₉, 6H₂O, which lies between the two formulas given by Rammelsberg.¹

LUDWIGITE, FROM MORAWITZA, BANAT, HUNGARY.

The material consisted of fine, radiating, silky fibers, almost perfectly black, but showing a tinge of violet when freshly broken, very tough when hammered, but easily cut, associated with quite pure magnetite.

Analysis gave—

| | |
|--------------------------------------|--------------|
| B ₂ O ₃ | 12.04 |
| Fe ₂ O ₃ | 37.93 |
| FeO..... | 15.78 |
| MgO..... | 30.57 |
| MnO..... | 0.16 |
| H ₂ O..... | 3.62 |
| | <hr/> 100.10 |

The ratios are B₂O₃ : Fe₂O₃ : FeO : MgO : H₂O = 17 : 24 : 24 : 76 : 20. Taking all the protoxides, together with the water, as basic, we have B₂O₃ : Fe₂O₃ : RO = 3 : 4 : 20. G. Tschermak² obtained for boric acid, by Marignac's and by Stromeyer's methods, 16.09 per cent. and 15.06 per cent. respectively, but gives no water; and from his results deduces the formula 3MgO, B₂O₃ + FeO, Fe₂O₃. If he sought for water by ignition, the oxidation of ferrous iron might easily have led to error.

DATOLITE.

The material investigated was the well-known mineral from Bergen Hill, New Jersey, and consisted of crystals about 5^{mm} in diameter, trans-

¹ Pogg. Ann., vol. 97, p. 301.

² Tsch. Min. Mitth., 1874, p. 59.

lucent, white, or of a pale greenish color. I have been unable to find any published analyses of the mineral from this locality, although it has been known for so long a time.

By analysis I obtained—

| | |
|-------------------------------------|-------------|
| SiO ₂ | 35.74 |
| FeO..... | .31 |
| CaO..... | 35.14 |
| B ₂ O ₃ | 22.60 |
| H ₂ O..... | 6.14 |
| | <hr/> 99.93 |

The small amount of iron is undoubtedly present as an impurity; leaving this out, the molecular ratios are SiO₂ : CaO : B₂O₃ : H₂O = 60 : 63 : 32 : 34, giving the formula



DANBURITE, FROM RUSSELL, ST. LAWRENCE COUNTY, NEW YORK.

This mineral has been fully described by Profs. George J. rush and Edward S. Dana,² although from the description given by them of the color of their specimen I imagine they had material differing somewhat from mine. The mineral analyzed by me was reddish yellow to pink in color, brilliant in luster, and associated with quartz, pyroxene, and calcite.

In the analysis referred to³ the boric acid was determined by Stro. myer's method. The figures obtained by my analysis are given in the first column; the second is the analysis made by Mr. W. J. Comstock for Professor Brush.

| | 1. | 2. |
|--|-------------|-------------|
| SiO ₂ | 49.70 | 48.23 |
| B ₂ O ₃ | 25.80 | 26.93 |
| CaO | 23.26 | 23.24 |
| Fe ₂ O ₃ +Al ₂ O ₃ | 1.02 | .47 |
| Ignition..... | .20 | .63 |
| | <hr/> 99.98 | <hr/> 99.50 |

The comparison of the two analyses shows the material difference to be in the amount of impurities.

AXINITE.

Two specimens of this mineral from different localities were analyzed. The first, from Cornwall, England, was of selected crystals of a dark, clove-brown color, translucent, and implanted on quartz. The second

² Am. Jour. Sci., pt. 3, vol. 20, 1880, pp. 111-118.

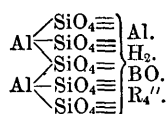
³ Loc. cit.

was the axinite from Bourg d'Oisans, Dauphiny, France. This specimen was of a beautiful pearl-gray color, and in some of the smaller crystals almost colorless and quite transparent. The third analysis in the series is one of the Dauphiny axinite, by Rammelsberg, and is copied from his description of the mineral¹ for comparison.

| | 1 Cornwall. | 2 Bourg d'Oisans. | 3 Bourg d'Oisans. Rammelsberg. |
|--------------------------------------|----------------|----------------------|--------------------------------------|
| SiO ₂ | 42.10 | 41.53 | 43.46 |
| Al ₂ O ₃ | 17.40 | 17.90 | 16.33 |
| Fe ₂ O ₃ | 3.06 | 3.90 | 2.80 |
| FeO | 5.84 | 4.02 | 6.78 |
| CaO | 20.53 | 21.66 | 20.19 |
| MnO | 4.63 | 3.79 | 2.62 |
| MgO | 0.66 | 0.74 | 1.73 |
| K ₂ O | | | .11 |
| B ₂ O ₃ | 4.64 | 4.62 | 5.61 |
| H ₂ O | 1.80 | 2.16 | 1.45 |
| | 100.66 | 100.32 | 101.08 |

The ratios from the results of analysis No. 2 are: SiO₂ : Al₂O₃ + Fe₂O₃ : (FeO + MnO) + (CaO + MgO) : B₂O₃ : H₂O = 69 : 20 : 51 : 6 : 12, or 10 : 3 : 8 : 1 : 2—giving

B₂O₃ . 3 . R₂'''O₃ . 8R''O . 2H₂O . 10SiO₂, or BR₃'''R₄''H₂ (SiO₄)₅O.
This expression will allow of the graphic formula:



In these analyses the value of R₄ is approximately three atoms of calcium and one atom of iron and manganese taken together. It is therefore probable that axinite is an isomorphous mixture of two species, having R = Ca₃Fe and Ca₃Mn respectively. If we reckon all the R as calcium, we shall have the following theoretical composition:

| | |
|--------------------------------------|-------------|
| Al ₂ O ₃ | 20.9 |
| SiO ₂ | 41.1 |
| H ₂ O | 2.5 |
| CaO | 30.7 |
| B ₂ O ₃ | 4.8 |
| | <hr/> 100.0 |

¹ Zeit. d. geol. Gesellsch. xxi, 689.

These results, while differing from those deduced by Rammelsberg from his formula, agree very well with all the results of analysis No. 2.

Although the Stromeyer and the Marignac methods of estimating boric acid have been shown to be unreliable, and the determination of any constituent of a mineral by difference is unsatisfactory, nevertheless, on comparing the results of the various analyses, it will be seen that the directly determined percentages of boric acid do not differ greatly from the older values.

My sincere thanks are due to Mr. H. S. Washington for kindly furnishing the description of the unusual variety of colemanite.

METEORITES FROM JOHNSON COUNTY, ARKANSAS, AND ALLEN COUNTY, KENTUCKY.

BY J. EDWARD WHITFIELD.

1. METEORITE FROM JOHNSON COUNTY, ARK.

A fragment of this meteorite was received by Prof. F. W. Clarke from the former owner, Mr. J. C. Betten, of Eureka Springs, Ark. This fragment weighed a little more than thirty-five grammes; the exposed surfaces were oxidized, the oxide of iron extending into the numerous cracks; in some cases almost through the specimen. The trace of chlorine found by analysis will account in some degree for this oxidation.

The following analysis gives the composition of the iron. The loss is due to the partial oxidation of the iron:

| | |
|------------------------|-------|
| Fe..... | 91.87 |
| Ni..... | 6.60 |
| Co..... | trace |
| S..... | 0.05 |
| Combined C | 0.15 |
| P..... | 0.41 |
| Mn..... | trace |
| Cl..... | trace |
| Insoluble in HCl..... | 0.34 |
| | <hr/> |
| | 99.42 |
| | <hr/> |
| Specific gravity | 7.837 |

This meteorite has since passed into the hands of Mr. G. F. Kunz, who has fully described it¹, and from his description I copy the main points of interest.

This meteorite is of unusual interest on account of the observance of its fall, which occurred about three o'clock on the afternoon of March 27, 1886. It struck the ground about 75 yards from the house of Mr. Christopher C. Shandy, six miles east of Cabin Creek, Johnson County, Ark. It measures 44^{cm} by 39^{cm}, and weighs 48,732 kilos (107½ pounds). A high ridge 12.5^{cm} high at the highest point runs through the center; one-half the mass is not over 7.5^{cm} thick, part of it is only 5^{cm}, and around the edge it is only 2.5^{cm} or less.

Mr. Kunz gives two figures, which show how very dissimilar the two sides are; the upper side is ridged and deeply dented, while the lower

¹ Am. Jour. Science for June, 1887.

side is flat, and covered with shallow but very large pittings. The upper side is remarkable for striæ showing the flow and burning, and all running from the center toward the edge, identical with those in the Rowton, Nedagolia, and Mazapil irons, but on a larger scale.

On the upper side ten nodules of troilite are exposed, measuring from 33^{mm} in diameter to 55^{mm} long and 25^{mm} wide; on the lower side there are twelve nodules, the largest measuring 19^{mm} by 39^{mm}. On the upper side these nodules are coated in spots with a black crust similar to that found on the mass, but on the lower side the crust extends completely around the side of the nodules, showing the fusion very plainly. The troilite is very bright, and in some cases where the nodules were broken they were found to be iridescent. This is one of the octahedral irons showing the Widmanstätten figures beautifully on etching, and is one of the Caillite group of Stanislas Meunier and of the Mittlere Lamellen of Brezina.

2. A METEORITE FROM ALLEN COUNTY, KY.

This meteorite was found about the middle of June, 1867, by Mr. James H. More, while hoeing tobacco, near Scottsville, Allen County, Ky. In shape it resembles a wedge, the thickness at base being 14^{cm}, width 18^{cm}, and length 16^{cm}; the mass, as found, weighing a little more than 10 kilos, and having the characteristic pitted surface. A section shows nodules of troilite varying in diameter from barely visible points to about 12^{mm}. The markings on an etched surface are exceedingly fine, and require the aid of a lens to distinguish them. There appear to be two sets of figures, one of long, very fine lines, representing octahedral cleavage, the other series being smaller, more crowded, and barely perceptible. An analysis gave the following composition:

| | |
|-----------------------|-------------------|
| Fe..... | 94.32 |
| Ni..... | 5.01 |
| Co..... | trace |
| S..... | 0.34 |
| P..... | 0.16 |
| Total C..... | 0.12 |
| | <hr/> 99.95 <hr/> |
| Specific gravity..... | 7.848 |

This iron, as regards markings and general appearance of section, resembles the Scriba and Salt River meteorites more nearly than any others represented in the National Museum collection; but as no complete analyses of these two irons are at hand, the chemical comparison can not well be made. The percentage of iron appears rather high, but duplicate determinations gave corresponding figures.

The material for analysis was received by Prof. F. W. Clarke from Messrs. Ward and Howell, of Rochester, N. Y., the present owners of the meteorite, to whom we are indebted for the privilege of description.

SCORODITE FROM THE YELLOWSTONE PARK.

BY J. EDWARD WHITFIELD.

Among a number of deposits and incrustations, submitted for analysis by Mr. Arnold Hague, of the U. S. Geological Survey, was a specimen from the Joseph's Coat spring, on Broad creek, east of the Grand Cañon. This specimen had a coating of a pale greenish color, the mass consisting of alternate layers of light red or brown and white. At first it was supposed that the green color was due to the organic coloring matter so prevalent in the basins of springs in the Park, but on examination it proved to be a compound containing arsenic and iron. Following are the figures obtained by analysis, on material separated as well as possible from the silica and earthy matter that always accompanies the deposits from the springs:

| | |
|--------------------------------------|--------|
| SiO ₂ | 4.35 |
| Fe ₂ O ₃ | 33.29 |
| As ₂ O ₅ | 46.48 |
| H ₂ O | 15.50 |
| SO ₃ | .84 |
| | <hr/> |
| | 100.46 |

The analysis shows the presence of some silica and sulphuric acid, but mainly agreeing with the composition of scorodite. Recalculating, leaving out impurities, we obtain the following figures, which agree closely with the theoretical composition of the mineral:

| | Calculated. | |
|--------------------------------------|-------------|-------|
| Fe ₂ O ₃ | 34.94 | 34.7 |
| As ₂ O ₅ | 48.79 | 49.8 |
| H ₂ O | 16.27 | 15.5 |
| | <hr/> | <hr/> |
| | 100.00 | 100.0 |

There are other localities in the Park where scorodite is being deposited. At the Constant Geyser, in Norris basin, the water is thrown out two or three times a minute to a height of from ten to twenty feet. Around the vents the greenish tints are perceptible in the incrustations, but only on the surface, for on breaking the sinter the cross-section shows the thin layers of alternate scorodite and silica; but here the scorodite has been altered to limonite, and the layers are of a brownish color—the nearer the base of the deposit the stronger—the dark color owing to the discoloration of the silica by the oxide of iron.

It is very difficult to scale off the green-colored matter from the surface of this deposit in quantity sufficient for analysis without admixed silica and iron oxide from the layer beneath it. After separating it as well as possible the following figures were obtained by analysis:

| | |
|--------------------------------------|--------|
| SiO ₂ | 49.83 |
| Al ₂ O ₃ | 4.74 |
| Fe ₂ O ₃ | 18.00 |
| As ₂ O ₅ | 17.37 |
| H ₂ O | 10.62 |
| | <hr/> |
| | 100.56 |

Scorodite, as found in the Park deposits, is a very unstable mineral, and only under favorable conditions is it kept from slowly oxidizing, leaving the limonite carrying varying amounts of As₂O₅.

For a description of the locality and manner of occurrence of scorodite in the Park reference must be made to the paper by Mr. Arnold Hague,¹ in which the whole subject is fully discussed.

¹Am. Jour. Sci., vol. 34, Sept., 1887.

THE FLOW OF SOLIDS, OR THE BEHAVIOR OF SOLIDS UNDER HIGH PRESSURE.

BY WILLIAM HALLOCK.

THE QUESTION.

Among the many physical questions that are of vital interest to the student of structural geology the one which may well contend for a position in the front rank is, What is the effect of pressure, with or without a rise of temperature, upon the rocks and rock-making magmas which form the outer shells of our earth? As a very important subdivision of this general question we have this: What is the effect of pressures upon so-called solids *without* any rise in temperature above a point far removed from their ordinary melting point? In other words, can we liquefy solids by pressure alone? As corollaries we have any peculiarities at the instant of liquefaction and possible chemical reaction during this state of enforced liquidity.

These questions have long formed the subject of theoretical discussion, but in spite of the fundamental importance of their satisfactory and final settlement, they have seldom been investigated experimentally, doubtless owing to the difficulty of obtaining, measuring, and managing sufficiently high pressures.

Walther Spring may perhaps be rightfully called the pioneer in this work, having within the last few years published the results of much experimental work upon this question. His memoirs¹ would seem to prove without doubt and finally that pressures under 7,000 atmospheres will liquefy the large majority² of solids, and it is only a question of a little higher pressure to accomplish the result even with the most refractory. Further than this, Mr. Spring has investigated the second corollary, and finds that chemical reaction takes place during this fusion;¹ at least when the volume of the products is less than that of the original substances.

Unfortunately, however, for the conclusive character of Mr. Spring's works, they have been seriously called into question, especially by

¹ Bull. de l'Acad. de Belg., 2d ser., vol. 49, 1880, and 3d ser., vol. 9, 1885; and Bull. de la Soc. Chim. de Paris, vol. 39, 1883, and 46, 1886.

² Bull. de l'Acad. de Belg., 2d ser., vol. 49, 1880.

Ch. Friedel.¹ Eduard Jannetaz² repeated many of Spring's experiments, and his results confirm Friedel's criticisms rather than Spring's conclusions, which he (Jannetaz) contradicts in every essential point.

Such was practically the condition of the question two years ago, when the Director of the U. S. Geological Survey, J. W. Powell, requested me to devote my time and thoughts to what we hoped would be its final settlement.³

It would be unjust to leave unmentioned here the elaborate and exhaustive series of experiments made by Henri Tresca⁴ on "the Flow of Solids," which are fundamental as regards the point investigated, which, however, is but a small part of the general question.

In order that my meaning may be clear, I wish for myself and for this paper, to impress certain meanings upon certain terms or words. Primarily, I wish strongly to distinguish between causing a body to "flow" and rendering it a true liquid. Any substance may "flow" when the force acting to cause the molecules to change their relative positions is greater than the force with which the molecules are held in their original positions; i. e., is greater than the rigidity or viscosity of the substance. This can occur from two causes: an increase of the force tending to disturb the molecules, or a diminution of the resisting power, the rigidity of the material. The first cause may take the form of pressure, strain, or such like force; the second cause is heat, and possibly other agencies. Whether rupture or flow takes place when the deforming overcomes the resisting force depends upon the nature of the substance, its limiting conditions, and *the time allowed for the accomplishment of the motion.*

It is impossible to draw a sharp line between "liquids" and "solids;" for convenience they may well be classed as true liquids, viscous liquids, viscous solids, true solids. In the first class would fall such substances as, in a small fraction of a second, fill their containing vessel to a horizontal surface. As true liquids we should then have such as alcohol, water, glycerine, molasses, etc. Viscous liquids require several seconds to fill their containing vessel to a level surface; thick tar is a good example. When the substance requires hours or even weeks in which to yield to gravity and change its form, I would call it a viscous solid; paraffine, shoemaker's-wax, and even lead and some other metals are such. A true solid retains its original shape indefinitely under ordinary conditions of pressure and temperature, as steel, glass, etc. Of course such a thing as an *absolutely* or *perfectly* rigid substance is as unknown to us as is an *absolute* or *perfect* fluid.

¹ Ch. Friedel, Bull. de la Soc. Chim. de Paris, vol. 39, 1883, p. 626.

² Ed. Jannetaz, Bull. de la Soc. Chim. de Paris, vol. 40, 1884; Bull. de la Soc. Minéral. de France, vol. 8, 1885, p. 168.

³ This paper is essentially taken from a report made to Major Powell, dated at Watertown, Mass., September, 1885. (See foot note on page 75.)

⁴ Henri Tresca, Mém. de l'Inst. Savantes Étrangers, vol. 18, 1868. Comptes Rendus, vol. 66, 1868; lxxviii, 1869. See Tresca, in Bibliography, p. 75.

If the above ideas are correct, "true liquefaction" is the diminishing of the rigidity or viscosity of a substance until its molecules change their relative positions as easily as in a true liquid.

I give these definitions merely that I may be understood in the use of these terms, and not because I think them new or especially good. In order that a substance may undergo a change in its chemical or crystalline character, it is undoubtedly necessary that it should be in the condition, at least, of a viscous solid, so that the molecules can slowly rearrange themselves, if there be any force urging them thereto. Our question is, will pressure alone impart to the molecules such a freedom of motion? *A priori* it is inconceivable to me how or why it should. For with the exception of a few isolated substances at particular temperatures—as water between 4° C. and ice at zero—an increase of liquidity or a diminution of rigidity is simultaneous with an increase of volume, that is, with an increase of the intermolecular distances, which is accomplished by "heating" the substance. *In general*, for one and the same substance over considerable ranges of condition, the rigidity diminishes as the intermolecular distances increase. How, then, can pressing the molecules nearer together be expected to give them a property which always accompanies their separation?

THE APPARATUS.

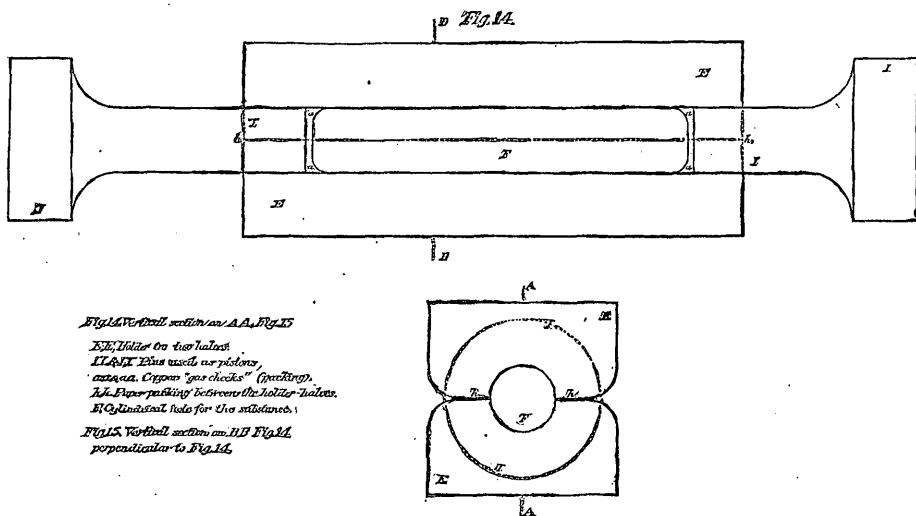
The first requisite for the experiments was pressure, and naturally desiring the best machine, we were able, through the kindness of General Benét, Chief of Ordnance, to have the use in its spare moments of the testing-machine built by A. H. Emery for that department, and situated at Watertown, Mass. This machine undoubtedly enables the operator to obtain, measure, and manage high pressures better than any other.

Personally, I am greatly indebted to Capt. J. Pitman, of the Ordnance Corps, for suggestions as well on the construction of the holders as on the theoretical points; and also to Mr. J. E. Howard, the engineer in charge of the testing-machine, for his knowledge of the capacity of materials, and their best shape and quality to obtain the results desired. The apparatus was constructed by the American Tool and Machine Company of Boston, Mass.

For the preliminary tests it seemed desirable to have a holder which could be opened, so as to show the compressed material in position, and finally the following form was adopted:

Fig. 15 shows a section across the holder on the plane B B of Fig. 14, which in turn is a section on A A of Fig. 15. E E are the two halves in contact at *h h*, inclosing the cylindrical hole F, in which the substance to be pressed is placed. *h h* are strips of tissue paper, used as packing between the two halves. II and I' I', Fig. 14, are the two pins, acting as pistons, fitting into the hole F, to transmit the pressure; *a a* and *a a* are copper "gas-checks," placed in front of these pins, to flare

out and fill tightly the hole, preventing any escape of material. Figures 14 and 15 are one-fifth natural size. Pl. I shows the manner in which the apparatus was held in the testing-machine and the pressure applied. P P P and P' P' P' are the jaws of the hydraulic clamps of the machine (capacity 1,000,000 pounds). H H are merely blocks to enable the clamp to properly hold the holder E E. N is a block to hold the back stationary pin in place. The lettering in Figs. 14 and 15 apply in Pl. I. V V is the hydraulic clamp on the fixed end of the testing-machine where the pressure is weighed. The block B B moves on a spherical surface



FIGS. 14, 15.—Diagram of apparatus used in work on high pressures.

(R R R) on the plate T T T, thus permitting the adjustment of the face of O perpendicular to the line of pressure or parallel to the rear surface of the pin I I. To apply the pressure, the movable clamp P P' is forced toward V V by a hydraulic piston, thus forcing the holder E E over the pin resting against O; the pressure on O is measured by the hydraulic balance of the machine. In this manner a total compressive power of one million pounds was available, but as the pins yielded at 110,000 pounds per square inch, the tests were not carried above 6,409 atmospheres, or 96,000 pounds per square inch.

EXPERIMENTS.

With the above apparatus, used as described, the following tests were made:

FIRST TEST.

A paper roll containing 1.557 pounds "c. p. granulated lead" was placed in the hole F, the gas-checks and pins were inserted, the holder halves clamped together, and the pressure was *slowly* applied; the amount of compression was measured in the distance to which E E had been forced over the right-hand pin. Multiplying the simultaneous

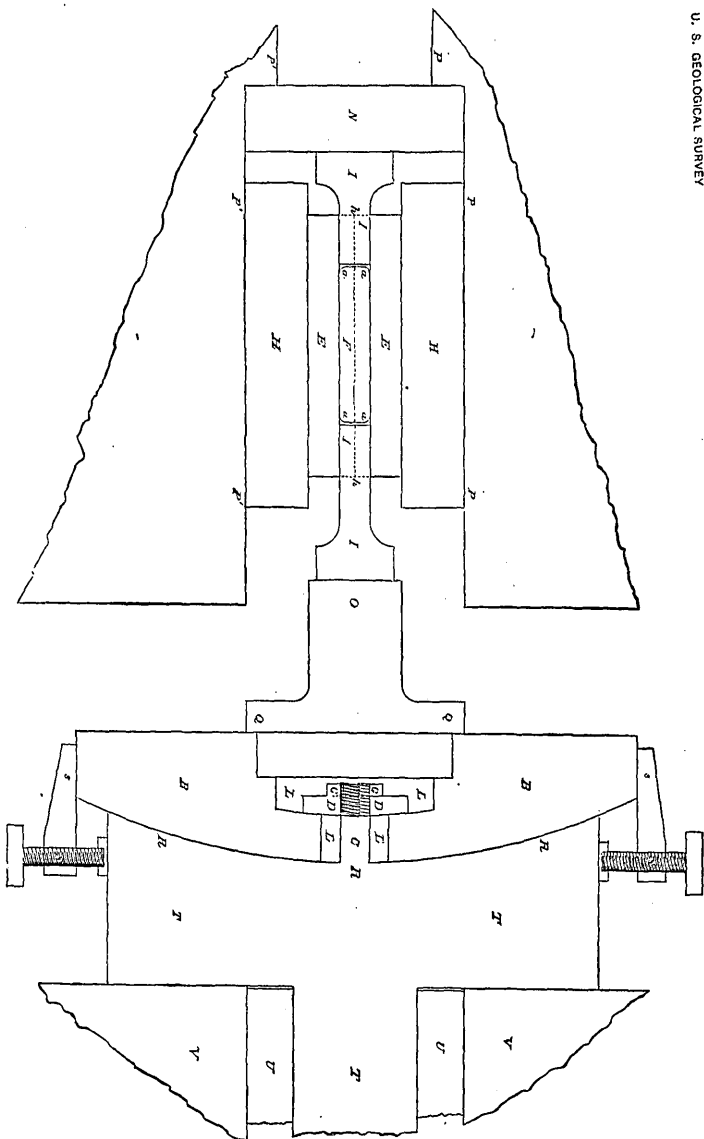


DIAGRAM OF APPARATUS USED IN WORK ON HIGH PRESSURES.

loads and compressions, we obtain the *work* done, and hence the possible heat generated. In this experiment the work done was 2,330 foot-pounds, or 3.0 thermal-units, 1 pound 1° F., sufficient to raise 1.557 pounds lead *alone* about 63° F., or 34° C. If the heat generated is dissipated into the holder E E, as is sure to be the case, the rise in temperature would be less than 1° C., or 1.8° F.

Under a pressure of 6,000 atmospheres the granular lead showed not the least sign of true liquefaction. It was merely pressed together, and could easily be broken up and reduced to the original grains between the thumb and finger. It is true these experiments were not performed *in vacuo*, a condition which Walther Spring considers of importance. But if there is a true liquefaction, why does not the air rise to the top of the cavity and allow fusion, as it does when the granular lead is heated? There is no liquefaction, only a pressing and sticking together.

SECOND TEST.

Next 0.672 pounds¹ of antimony was ground in a mortar until it went through a 48-sieve, and then it was similarly submitted to 6,000 atmospheres pressure, with the same result; the grains were simply stuck together, and were perfectly distinct in their original form. The cylinder formed was hard and tenacious, but gave no signs of liquefaction or recrystallization. The work done in this case might have raised the antimony alone 230° F., or 110° C., or holder and antimony 1.8° F., or 1° C.

THIRD TEST.

Well-crystallized calcite, 0.271 pounds,² was ground, put through a 48-sieve, and submitted to a pressure of 6,000 atmospheres, producing practically no effect; the resulting mass being easily broken between the thumb and finger.

Finding it useless to have large quantities of the compressed material for elaborate examination, it was decided to expedite matters by putting in several substances at one time, and the following rather crucial test was made:

FOURTH TEST.



FIG. 16.—Diagram showing experiment.

L H, left-hand pin, stationary. R H, right-hand pin, entering the hole F, moving.

¹ 0.672 pounds antimony, solid, filled the hole F, 5 inches long.

² 0.271 pounds of solid calcite fills the holder, 5 inches in length.

The charge was composed as follows:

- A. Small section of antimony from test II.
- B. A stick of bees-wax whittled round, nearly fitting the hole.
- C. A stick of paraffine whittled round, nearly fitting the hole.
- D. Bismuth prepared like the antimony for test II.
- E. Paraffine, same as C.
- F. Lead from test I.

d d were double-pointed tacks stuck into the top of the bees-wax and paraffine, and at *a* and *c* two old silver 3-cent pieces were laid on top of the wax and the paraffine in the cylinder.

What are we to expect? The silver pieces and tacks would fall through the liquid wax and paraffine, and B and C, if liquid, would mix. Nay, according to Spring's results, we should expect to find along the lower part of the mold a semi-cylindrical piece of an alloy of lead, antimony, bismuth, possibly silver and iron, and above this the mixture of paraffine and wax. The actual result was that the substances *all came out just as they went into the press*. There was not the slightest trace of a tendency to flow on the part of the metals; the lead and antimony remained as they were, the bismuth acted precisely as did the antimony in test II. There was no sign of fusion of the wax and paraffine, which separated on their surface of contact (between B and C) clear and distinct. *a*, *c*, *d*, and *d* did not sink to the bottom—on the contrary, they retained their original positions; and the silver pieces were forced against the *top* of the cylinder so powerfully, that their impression left in the steel holder was easily seen and *felt*, and the pieces were bent cylindrical, fitting the inside of the holder. Here we find a much greater rigidity of wax and paraffine under pressure than ordinarily supposed possible under any circumstances.

Nowhere was there a sign of true liquefaction. The wax and paraffine had acted only as viscous solids, and flowed only to fill the available opening.

FIFTH TEST.

In a similar way the following substances were subjected to a pressure of 6,000 atmospheres, with the results as stated:

Sodium carbonate, dry.—Stuck together slightly, resembling chalk; easily cut with a knife.

Sodium sulphate.—Probably dissolved in its water of crystallization ($10\text{H}_2\text{O}$); it was forced out between the halves of the holder as a milky liquid which solidified.

The little left in the holder resembled paraffine in appearance, but soon weathered to a white powder.

Zinc sulphate ($+7\text{H}_2\text{O}$).—No signs of fusion; merely stuck together; the original pieces of crystals easily visible.

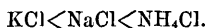
Copper sulphate ($+5\text{H}_2\text{O}$).—Same as zinc sulphate.

SIXTH TEST.

Potassium chloride.—Formed a hard lump, whose fracture resembled that of loaf sugar or that of marble, with the original crystals visible; no trace of fusion.

Sodium chloride.—Similar to potassium chloride, only a little more compact.

Ammonium chloride.—Still more compact, resembles vegetable ivory; possibly the beginning of fusion. Observe the order of increasing effect:



Sulphur roll.—Ground and put through a 48-sieve; formed a hard, solid, brittle mass, but the original grains were easily distinguishable, there being no trace of a true liquefaction.

SEVENTH TEST.

Powdered glass.—No effect; scarcely coherent.

Powdered rosin.—Very good fusion.

Powdered borax.—A compact, chalk-like mass, *slightly* translucent; no crystallization.

Powdered zinc and sulphur.—No trace of fusion or chemical union apparent. Carbon disulphide dissolved out the sulphur so completely, that the remaining zinc gave a mere trace of sulphureted hydrogen on treating with hydrochloric acid. The zinc was slightly coherent, but there was no fusion and no zinc sulphide formed.

After obtaining the above results it seemed useless to continue this line of experiments, and preparations were made to use more rigid steel, by which it was hoped that pressures of at least 10,000 atmospheres might be obtained; also for making the compressions *in vacuo*. Unfortunately thus far nothing but preparations have been made, since the testing-machine is kept fully occupied with the special work of the department to which it belongs. It is hoped, however, that this investigation will soon be taken up again and carried to a close; till then our conclusions are only temporary.

The above substances were also compressed by W. Spring¹ in *vacuo* with the following results:

Lead.—Perfect fusion at a pressure of 2,000 atmospheres. At a pressure of 5,000 atmospheres it ran out of all the cracks (*fentes*) of the apparatus.

Bismuth.—At a pressure of 6,000 atmospheres, perfect fusion.

Tin.—At a pressure of 3,000 atmospheres, fusion.

Zinc.—At a pressure of 5,000 atmospheres, perfect fusion.

Antimony.—At a pressure of 5,000 atmospheres, beginning of fusion.

Sulphur, prismatic.—At a pressure of 5,000 atmospheres, fusion to the octahedral form.

Sulphur, plastic.—At a pressure of 6,000 atmospheres, fusion to the octahedral form.

Sulphur, octahedral.—At a pressure of 3,000 atmospheres, fusion to the octahedral form.

Potassium chloride.—At a pressure of 5,000 atmospheres, perfect fusion.

Sodium chloride.—At a pressure of 5,000 atmospheres, perfect fusion.

Ammonium chloride.—At a pressure of 4,000 atmospheres, perfect fusion.

Sodium sulphate (10H₂O).—At a pressure of 3,000 atmospheres, perfect fusion.

Zinc sulphate (7H₂O).—At a pressure of 5,000 atmospheres, perfect fusion.

Copper sulphate (5H₂O).—At a pressure of 6,000 atmospheres, completely crystallized.

Sodium carbonate, dry.—At a pressure of 5,500 atmospheres, stuck together (*aggloméré*).

Iceland spar.—At a pressure of 6,000 atmospheres, imperfect fusion.

Borax (crystallized).—At a pressure of 7,000 atmospheres, imperfect fusion.

Glass (powdered).—At a pressure of 6,000 atmospheres, no effect.

And so on to the end.

¹ Bull. de l'Acad. R. de Belg., II, xlix, 1880. (See foot-note on page 75.)

Excepting the last four substances mentioned, our results are directly opposed to those of Spring, but support the criticisms of Friedel and Jannetaz.

CONCLUSIONS.

Conclusions at this stage of the investigation are necessarily premature and tentative; still it may not be out of place to summarize the results of these and other experiments.

It seems established that pressure alone can not truly liquefy a solid, i. e., diminish its rigidity. Consequently, we can scarcely expect chemical and crystalline changes by pressure alone. Solids can be made to flow and act in that respect, as liquids, by pressure, which overcomes the rigidity without diminishing it. In this case the time allowed for the motion is of vital importance.

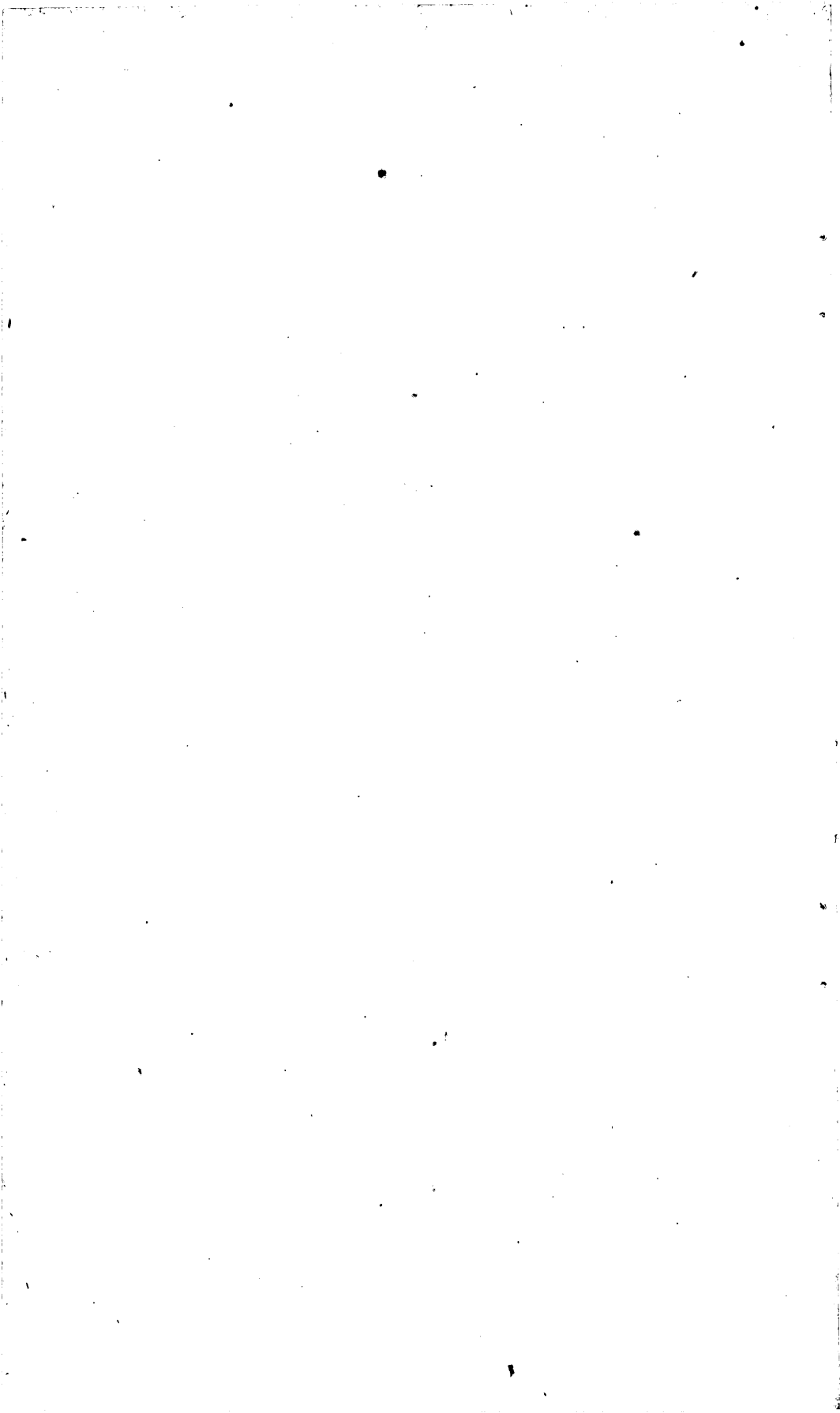
Whether further investigation will alter these conclusions or not is a question of time; at present, I believe them the only true ones to be drawn from the available facts.

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An abstract of the foregoing article appeared in the American Journal of Science, vol. 34, 3d series, 1887, p. 277. In a note published in the same journal (vol. 35, 1888, p. 78), Mr. Spring violently attacks my interpretation of our results, especially my use of the word "fusion," which I have employed in its secondary sense, as meaning *a uniting as if by melting with heat*; the case of actual fusion by heat being specifically excluded. It seemed to me best to leave the word in the above article and make this explanation of its use. See, also, W. Spring, Bull. Acad. roy. Belg., vol. 16, 1888, p. 43; also Am. Jour. Sci., vol. 36, 1888, p. 286. And W. Hallock, Am. Jour. Sci., vol. 36, 1888, p. 59; also *ibid.*, vol. 37, 1889, p. 402; also Zeitschr. für Phys. Chem., vol. 2, 1888, p. 378.



MISCELLANEOUS ANALYSES.



**FELDSPAR. FROM A FELDSPATHIC MICA SCHIST, CENTRAL SHAFT
OF THE HOOSAC TUNNEL, MASS.**

[Collected by J. E. Wolff. Analysis by R. B. Riggs.]

| | |
|--------------------------------------|-------|
| SiO ₂ | 69.69 |
| Al ₂ O ₃ | 18.60 |
| Fe ₂ O ₃ | trace |
| CaO | trace |
| MgO | .20 |
| Na ₂ O | 10.28 |
| K ₂ O | .40 |
| Ignition | .42 |
| | <hr/> |
| | 99.59 |

**TWO FELDSPARS. FROM THE PORPHYRITIC MICA SCHIST OF GREY-
LOCK MOUNTAIN, MASS.**

[Collected by J. E. Wolff. Analyses by R. B. Riggs.]

| | I. | II. |
|---|-------|-------|
| SiO ₂ | 68.08 | 67.83 |
| Al ₂ O ₃ , Fe ₂ O ₃ | 20.11 | 19.92 |
| MnO | trace | trace |
| CaO | trace | trace |
| MgO | trace | trace |
| Na ₂ O | 11.00 | 11.65 |
| K ₂ O | .36 | .25 |
| Ignition | .31 | .12 |
| | <hr/> | <hr/> |
| | 99.86 | 99.77 |

In neither case does the Fe₂O₃ exceed .5 per cent.

THREE FELDSPARS FROM DELAWARE.

[Separated by J. S. Diller from rocks collected by Prof. F. D. Chester. Analyses by R. B. Riggs.]

A. Specific gravity, 2.592-2.877. From a typical gabbro. Brandywine Creek.

B. Specific gravity, 2.592-2.749. From Iron Hill hyperite, changing to diorite. Near Whitaker's ore-pit.

C. Specific gravity, 2.592–2.780. From a typical hypersthene gabbro. Fifth and Van Buren streets, Wilmington.

| | A. | B. | C. |
|--------------------------------------|-------------|--------------|--------------|
| SiO ₂ | 70.37 | 44.09 | 51.44 |
| Al ₂ O ₃ | 18.36 | 35.41 | 30.05 |
| Fe ₂ O ₃ | .58 | .51 | .96 |
| MnO | trace | trace | ..... |
| CaO | 5.08 | 18.47 | 13.19 |
| MgO | .04 | none | trace |
| Na ₂ O | 4.32 | .99 | 4.07 |
| K ₂ O | .63 | .19 | .21 |
| Ignition | .45 | .35 | .35 |
| | <hr/> 99.83 | <hr/> 100.01 | <hr/> 100.27 |

B is evidently anorthite.

TRIASSIC SANDSTONE FROM MARYLAND.

A hard, compact building stone, from the Jaittelle quarry, near Hancock. Color, rich reddish brown. Analysis by F. W. Clarke.

A. Analysis by fusion with alkaline carbonates.

B. Analysis by solution in strong HCl.

| | A. | | B. |
|---|--------|--------------------------------------|-------|
| Ignition | 2.79 | Insoluble | 88.68 |
| SiO ₂ | 76.43 | Fe ₂ O ₃ | 7.13 |
| Al ₂ O ₃ , Fe ₂ O ₃ | 17.78 | CaCO ₃ | 1.32 |
| CaO | .84 | MgO | .66 |
| MgO | .92 | H ₂ O | 2.20 |
| MnO | trace | | <hr/> |
| Alkalies | undet. | | 99.99 |
| | <hr/> | Residue nearly white. | |
| | 98.76 | | |

LIMESTONE FROM THE AUGLAIZE RIVER, NEAR DEFIANCE, OHIO.

[Highly bituminous. Nearly black, resembling a slate. Contains visible pyrite. Partial analysis by J. Edward Whitfield.]

| | |
|---|--------|
| Ignition | 24.03 |
| SiO ₂ | 39.95 |
| Fe ₂ O ₃ , Al ₂ O ₃ | 20.22 |
| MnO | trace |
| CaO | 10.06 |
| MgO | 2.92 |
| Alkalies | undet. |
| S (pyritic) | undet. |
| | <hr/> |
| | 97.18 |
| CO ₂ in carbonates | 12.49 |
| Organic carbon | 5.29 |

TWELVE ROCKS FROM MENOMONEE RIVER, MICHIGAN AND WISCONSIN.

[Collected by R. D. Irving. Analyses by R. B. Riggs.]

- A. Massive diabase. Lower Quinnesec Falls, Wisconsin side.
 B. Green chloritic schist. Shore just below Lower Quinnesec Falls, Wisconsin side.
 C. Light gray gabbro, from near B.
 D. Schistose gabbro, adjoining C.
 E. Silvery schist, adjoining D.
 F. Light-colored gabbro. Barrier Rock, at Sturgeon Falls, Michigan side.
 G. Adjoining and similar to F; altered and somewhat schistose.
 H. Silvery schist, adjoining G.
 I. Uralitic gabbro. Barrier Rock, Big Quinnesec Falls.
 J. Dark-gray granite. Small cove just below the "Horse-Race," Big Quinnesec Falls, Wisconsin side.
 K. "Augengneiss," with red feldspar. Lower end of "Horse-Race," Big Quinnesec Falls, Michigan side.
 L. Porphyroid. Just below Big Quinnesec Falls, Wisconsin side.

| | A. | B. | C. | D. | E. | F. |
|--------------------------------------|--------|--------|--------|--------|--------|--------|
| SiO ₂ | 43.80 | 44.49 | 47.96 | 49.19 | 46.21 | 51.46 |
| Al ₂ O ₃ | 16.08 | 16.37 | 16.85 | 18.71 | 18.38 | 14.35 |
| Fe ₂ O ₃ | 9.47 | 5.07 | 4.33 | 5.03 | 3.30 | 3.90 |
| FeO | 10.50 | 5.50 | 4.17 | 4.04 | 3.90 | 5.28 |
| CaO | 7.81 | 7.94 | 13.25 | 5.92 | 6.28 | 9.08 |
| MgO | 6.54 | 7.50 | 9.15 | 7.98 | 7.03 | 9.54 |
| Na ₂ O | 1.96 | 2.59 | 1.25 | 1.44 | 2.14 | 2.92 |
| K ₂ O | .34 | .56 | .30 | .77 | .35 | .24 |
| H ₂ O | 3.99 | 4.99 | 2.89 | 5.05 | 3.82 | 3.30 |
| CO ₂ | 0.8 | 5.38 | .08 | 1.82 | 8.32 | .20 |
| | 100.57 | 100.39 | 100.23 | 99.95 | 99.73 | 100.27 |
| | G. | H. | I. | J. | K. | L. |
| SiO ₂ | 38.05 | 45.70 | 48.35 | 54.83 | 67.77 | 66.69 |
| Al ₂ O ₃ | 24.73 | 16.53 | 15.40 | 25.49 | 16.61 | 16.69 |
| Fe ₂ O ₃ | 5.65 | 4.63 | 4.04 | 1.61 | 2.06 | 2.06 |
| FeO | 6.08 | 3.89 | 4.63 | 1.65 | 1.96 | .93 |
| CaO | 1.25 | 4.28 | 10.38 | 6.08 | 1.87 | 1.40 |
| MgO | 11.58 | 9.57 | 11.61 | 1.96 | 1.26 | 1.15 |
| Na ₂ O | 2.54 | .55 | 1.87 | 5.69 | 4.35 | 2.46 |
| K ₂ O | 1.94 | 3.82 | .35 | 1.87 | 2.35 | 5.23 |
| H ₂ O | 7.53 | 4.70 | 3.60 | 1.18 | 1.69 | 1.70 |
| CO ₂ | .93 | 5.95 | .08 | .18 | .19 | 1.42 |
| | 100.28 | 99.62 | 100.31 | 100.54 | 100.11 | 99.73 |

ROCKS FROM PIGEON POINT, MINN.

[Collected by R. D. Irving.]

- A. Average granite rock. Analyst, W. F. Hillebrand.
 B. Red granite, part of A. Analyst, J. Edward Whitfield.
 C. Soda orthoclase from A. Analyst, J. Edward Whitfield.
 Bull. 55—6

D. Altered quartzite in contact with B. Analyst, J. Edward Whitfield.

E. Typical olivine gabbro. Analyst, W. F. Hillebrand.

F. Augite from gabbro; partial analysis. Analyst, R. B. Riggs.

G. Rock occurring between A and E. Analyst, W. F. Hillebrand.

H. Quartz porphyry. Analyst, W. F. Hillebrand.

I. Mottlings (greenish) from H. Analyst, W. F. Hillebrand.

J. Groundmass of H. Analyst, W. F. Hillebrand.

K, L, M, N, O, P, Q, R. Altered quartzites. Analyst, R. B. Riggs.

| | A. | B. | C. | D. | E. |
|--------------------------------------|--------|--------|--------|--------|--------|
| SiO ₂ | 72.16 | 68.36 | 65.00 | 63.82 | 49.88 |
| TiO ₂ | .39 | 1.57 | ..... | 2.66 | 1.19 |
| Al ₂ O ₃ | 12.98 | 13.76 | 18.22 | 14.65 | 18.55 |
| Fe ₂ O ₃ | .67 | 2.65 | 2.64 | 3.16 | 2.06 |
| FeO..... | 2.99 | 2.75 | ..... | 5.12 | 8.37 |
| MnO..... | .09 | trace | ..... | none | .09 |
| CaO..... | .65 | .70 | 1.06 | .70 | 9.72 |
| SrO..... | ? | undet. | ..... | undet. | trace |
| BaO..... | .15 | undet. | ..... | undet. | .02 |
| MgO..... | .57 | .68 | .06 | 2.08 | 5.77 |
| K ₂ O..... | 4.94 | 4.48 | 4.18 | 2.81 | .68 |
| Na ₂ O..... | 3.42 | 3.56 | 8.40 | 1.95 | 2.59 |
| Li ₂ O..... | none | none | ..... | none | none |
| H ₂ O..... | 1.20 | .98 | .46 | 2.62 | 1.04 |
| P ₂ O ₅ | .20 | .33 | ..... | .19 | .16 |
| Cl..... | trace | ..... | ..... | ..... | trace |
| SO ₃..... | ..... | .66 | ..... | .33 | ..... |
| | 100.41 | 100.48 | 100.02 | 100.09 | 100.12 |
| | F. | G. | H. | I. | J. |
| SiO ₂ | 48.34 | 57.98 | 74.00 | 77.70 | 76.57 |
| TiO ₂ | 1.98 | 1.75 | .34 | .30 | .42 |
| Al ₂ O ₃ | 2.90 | 13.58 | 12.04 | 7.67 | 9.21 |
| Fe ₂ O ₃ | 4.68 | 3.11 | .78 | 3.55 | 1.67 |
| FeO..... | 14.15 | 8.68 | 2.61 | 3.29 | 3.94 |
| MnO..... | ..... | .13 | .05 | .04 | .05 |
| CaO..... | 15.10 | 2.01 | .85 | .26 | .73 |
| SrO..... | ..... | trace | trace | ? | trace? |
| BaO..... | ..... | .04 | .12 | none | none |
| MgO..... | 11.34 | 2.87 | .42 | 1.83 | 1.51 |
| K ₂ O..... | ..... | 3.44 | 4.33 | 1.04 | 1.02 |
| Na ₂ O..... | ..... | 3.56 | 3.47 | 1.96 | 3.07 |
| Li ₂ O..... | ..... | trace | trace? | trace | trace |
| H ₂ O..... | ..... | 2.47 | .86 | 2.36* | 1.89 |
| P ₂ O ₅..... | ..... | .29 | .06 | none | trace |
| Cl..... | ..... | trace | trace | ..... | ..... |
|  | ..... | 99.91 | 99.93 | 100.00 | 100.08 |

* By difference.

| | K. | L. | M. | N. |
|--------------------------------------|--------------|-------------|--------------|--------------|
| SiO ₂ | 73.14 | 71.00 | 74.22 | 73.65 |
| TiO ₂ | .04 | .44 | .16 | trace? |
| Al ₂ O ₃ | 12.60 | 12.88 | 10.61 | 11.08 |
| Fe ₂ O ₃ | 7.57 | 6.69 | 7.45 | 7.24 |
| FeO | 1.31 | .65 | .85 | .77 |
| MnO | trace | trace | none | trace |
| CaO | .43 | .21 | .56 | .40 |
| SrO | undet. | undet. | undet. | undet. |
| BaO | undet. | undet. | undet. | undet. |
| MgO | 1.67 | 1.68 | 1.48 | 1.52 |
| Na ₂ O | 1.78 | 1.43 | 2.12 | 1.67 |
| K ₂ O | 1.00 | 2.95 | 1.08 | 1.65 |
| Ignition | .83 | 2.03 | 1.79 | 1.88 |
| | <hr/> 100.37 | <hr/> 99.96 | <hr/> 100.32 | <hr/> 99.86 |
| | O. | P. | Q. | R. |
| SiO ₂ | 72.25 | 83.69 | 73.64 | 59.71 |
| TiO ₂ | trace | trace? | trace | trace |
| Al ₂ O ₃ | 10.73 | 7.50 | 11.25 | 18.32 |
| Fe ₂ O ₃ | 8.01 | 1.81 | 6.24 | 8.11 |
| FeO | .38 | .38 | 1.04 | .85 |
| MnO | trace | trace | none | none |
| CaO | .42 | .39 | .36 | 1.05 |
| SrO | undet. | undet. | undet. | undet. |
| BaO | undet. | undet. | undet. | undet. |
| MgO | 1.85 | .35 | 1.57 | 3.54 |
| Na ₂ O | 2.03 | 2.46 | 3.04 | 1.93 |
| K ₂ O | 2.56 | 2.61 | 1.42 | 3.43 |
| Ignition | 2.05 | .72 | 1.98 | 3.24 |
| | <hr/> 100.28 | <hr/> 99.91 | <hr/> 100.54 | <hr/> 100.18 |

TWO ROCKS FROM MONTANA.

[Collected by A. C. Peale. Analyses by T. M. Chatard.]

A. From Cottonwood Creek. B. Hills east of Fort Ellis.

| | A. | B. |
|--------------------------------------|--------------|--------------|
| H ₂ O | 3.19 | 5.42 |
| SiO ₂ | 51.65 | 46.90 |
| TiO ₂ | .55 | .41 |
| P ₂ O ₅ | .21 | .44 |
| SO ₃ | .19 | ..... |
| Al ₂ O ₃ | 13.89 | 10.17 |
| Cr ₂ O ₃ | .08 | .33 |
| Fe ₂ O ₃ | 2.70 | 1.22 |
| FeO | 4.80 | 5.17 |
| MnO | .15 | .10 |
| BaO | .19 | ..... |
| SrO | undet. | ..... |
| CaO | 4.07 | 6.20 |
| MgO | 11.56 | 20.98 |
| K ₂ O | 4.15 | 2.04 |
| Na ₂ O | 2.99 | 1.16 |
| | <hr/> 100.37 | <hr/> 100.54 |

Separations from B. Partial analyses.

| | Groundmass. | Pyroxene. |
|--------------------------------------|-------------|-------------|
| Ignition | 5.40 | ..... |
| SiO ₂ | 65.58 | 51.95 |
| Al ₂ O ₃ | 14.94 | 4.21 |
| Fe ₂ O ₃ | little | ..... |
| FeO ..... | ..... | 5.90 |
| CaO | 3.60 | 23.32 |
| MgO | 3.45 | 13.81 |
| | | <hr/> 99.19 |

FIFTEEN ROCKS FROM CALIFORNIA.

[Collected by J. S. Diller. Analyses A, B, C, by T. M. Chatard; D, by W. F. Hillebrand and T. M. Chatard; E, by R. B. Riggs; and the remainder by W. F. Hillebrand.]

- A. Basalt, from 1 mile southeast of Paine's Creek, on road from Red Bluff to Lassen Peak.
 B. Ancient lava. Old crater at head of Mill creek.
 C. Lava, from Buntingville.
 D. Basalt. Top of Inskip Crater, 25 miles east of Red Bluff.
 E. Lava. Above falls on south fork of Bear Creek, Shasta County.
 F. Basalt. Cinder Cone, 10 miles northeast of Lassen Peak.
 G. Basalt. One mile east of summit of Cascade Range, on road from Fort Klamath to Crater Lake.
 H. Andesite lava. One mile west of Summit, on Bidwell's Road, Butte County.
 I. Lava. West end of Butte Mountain, Plumas County.
 J. Andesite. Tuscan Buttes, 7 miles east of Red Bluff.
 K. Ancient lava. Northeast of Willow Lake, near Geyser, Plumas County.
 L. Lava. Two miles northwest of Deer Creek meadows.
 M. Lava. Slate Creek, west of Deer Creek meadows.
 N. Lava. Slate Creek, northwest of Deer Creek meadows Lassen trail.
 O. Lava. Summit of Mount Stover, Plumas County.

| | A. | B. | C. | D. | E. |
|--------------------------------------|--------------|--------------|--------------|--------------|--------------|
| SiO ₂ | 47.93 | 57.11 | 67.89 | 50.89 | 63.10 |
| TiO ₂ | .73 | .95 | .21 | .79 | .15 |
| Al ₂ O ₃ | 18.51 | 17.78 | 17.29 | 16.76 | 15.50 |
| Fe ₂ O ₃ | 2.07 | 3.54 | 2.39 | 3.86 | 3.20 |
| FeO | 7.25 | 2.74 | .21 | 4.69 | none |
| MnO | .20 | .33 | .12 | .13 | trace |
| CaO | 11.14 | 7.21 | 3.01 | 11.72 | 3.02 |
| SrO ..... | ..... | trace ? | .04 | ..... | trace |
| BaO ..... | ..... | .03 | .03 | trace | .06 |
| MgO | 9.03 | 3.41 | .66 | 8.49 | .10 |
| K ₂ O | .24 | 1.86 | 1.69 | .32 | 3.13 |
| Na ₂ O | 2.28 | 3.81 | 5.11 | 2.61 | 4.20 |
| Li ₂ O ..... | ..... | ..... | ..... | ..... | none |
| H ₂ O | .76 | .98 | 1.34 | .41 | 2.72 |
| P ₂ O ₅ | .11 | .26 | .12 | .09 | .03 |
| | <hr/> 100.25 | <hr/> 100.01 | <hr/> 100.11 | <hr/> 100.76 | <hr/> 100.21 |

| | F. | G. | H. | I. | J. |
|--------------------------------------|--------|--------|--------|--------|--------|
| SiO ₂ | 57.25 | 57.47 | 55.20 | 55.53 | 60.93 |
| TiO ₂ | .60 | .75 | .92 | .56 | .61 |
| Al ₂ O ₃ | 16.45 | 18.86 | 18.68 | 17.63 | 18.56 |
| Fe ₂ O ₃ | 1.67 | 2.21 | 3.14 | 2.81 | 2.68 |
| FeO..... | 4.72 | 4.08 | 4.42 | 3.59 | 2.19 |
| MnO..... | .10 | .10 | .14 | .08 | .10 |
| CaO..... | 7.65 | 7.42 | 8.02 | 8.74 | 6.63 |
| SrO..... | trace | .11 | .02 | .06 | .12 |
| BaO..... | .03 | .03 | .03 | .02 | .02 |
| MgO..... | 6.74 | 4.27 | 4.59 | 5.85 | 2.37 |
| K ₂ O..... | 1.57 | .73 | 1.01 | .92 | 1.33 |
| Na ₂ O..... | 3.00 | 3.85 | 3.66 | 3.09 | 3.79 |
| Li ₂ O..... | none | none | none | none | none |
| H ₂ O..... | .40 | .22 | .51 | 1.24 | .90 |
| P ₂ O ₅ | .20 | .24 | .24 | .21 | .18 |
| | 100.38 | 100.34 | 100.58 | 100.33 | 100.41 |

| | K. | L. | M. | N. | O. |
|--------------------------------------|--------|--------|--------|--------|--------|
| SiO ₂ | 74.24 | 74.65 | 73.62 | 73.64 | 72.40 |
| TiO ₂ | .20 | .21 | .21 | .11 | .18 |
| Al ₂ O ₃ | 14.50 | 14.11 | 14.24 | 13.44 | 14.81 |
| Fe ₂ O ₃ | 1.27 | 1.08 | .93 | .60 | .81 |
| FeO..... | .67 | .29 | .67 | .74 | .88 |
| MnO..... | .06 | .11 | .08 | .06 | .07 |
| CaO..... | .11 | .80 | 1.07 | 1.26 | 1.94 |
| SrO..... | trace | trace | trace | .02 | .04 |
| BaO..... | .18 | .08 | .10 | .11 | .10 |
| MgO..... | .25 | .20 | .33 | .26 | .47 |
| K ₂ O..... | 3.66 | 4.59 | 4.28 | 4.50 | 3.30 |
| Na ₂ O..... | 3.00 | 2.81 | 3.25 | 3.51 | 3.91 |
| Li ₂ O..... | none | none | none | trace | trace |
| H ₂ O..... | 2.04 | 1.40 | 1.29 | 1.99 | .59 |
| P ₂ O ₅ | .07 | trace | .02 | .06 | .03 |
| SO ₃ | .03 | ..... | ..... | ..... | ..... |
| | 100.28 | 100.33 | 100.09 | 100.30 | 100.13 |

ORES OF IRON AND MANGANESE.

A. Iron ore from land of William Tabb, 3 miles from Catherine Furnace, Spotsylvania County, Va.

[Analysis by J. Edward Whitfield.]

| | A. |
|------------------------|-------|
| SiO ₂ | 4.97 |
| Fe..... | 53.39 |
| Mn..... | .60 |
| S..... | .09 |
| P..... | .66 |

B. Iron ore, Church Mountain Mine, Rockingham County, Va.

C. Manganese ore, same locality.

[Analyses by F. W. Clarke.]

| | B. | | C. |
|-----------------|-------|---|-------|
| Ignition | 12.78 | Ignition | 11.30 |
| Insoluble | 12.70 | Insoluble | 22.11 |
| Fe | 43.60 | Fe ₂ O ₃ , Al ₂ O ₃ | 5.14 |
| Mn | 8.45 | Mn | 39.20 |
| S | none | Co | 2.48 |
| P | .14 | | |

The manganese ore contains no manganese dioxide. Its high percentage of cobalt is noteworthy.

D. Iron ore. Ridge north of Clinch River, 5½ miles above Stock creek, near and just west of Peckover Mill, Wise County, Va.

[Analysis by T. M. Chatard.]

| | D. |
|------------------------|-------|
| SiO ₂ | 14.75 |
| Fe | 48.97 |
| MnO | .12 |
| S | .83 |
| P | .067 |

E. Eastern extension of Cranberry bed, three-fourths mile east of Cranberry Creek, Mitchell County, N. C.

F. Western extension of Cranberry bed, Hardy Graves' tract, one-fourth mile southwest of Elk Park, Mitchell County, N. C.

Both samples are magnetite.

[Collected by J. R. Procter. Analyzed by T. M. Chatard.]

| | E. | F. |
|------------------------|-------|-------|
| SiO ₂ | 25.27 | 27.65 |
| Fe | 45.43 | 42.77 |
| MnO | .54 | .59 |
| S | .07 | .08 |
| P | .009 | .007 |

G. Iron ore. Northwest part of Sevier County, Ark.

H. Manganese ore. Southwest part of Polk County, Ark.

[Analyses by J. Edward Whitfield.]

| | G. | H. |
|------------------------|-------|-------|
| SiO ₂ | 12.01 | 4.80 |
| Fe | 42.85 | 11.36 |
| Mn | 6.59 | 13.95 |
| S | .11 | ..... |
| P | 1.48 | ..... |
| Ti | trace | ..... |

The manganese ore contains little dioxide.

I. Two samples iron ore, from Atalla, Ala.: *a*, from outcrops; *b*, 250 feet below surface.

[Analyses by R. B. Riggs, as called for.]

| | A. | B. |
|-----------------------|-------|-------|
| Fe | 57.52 | 7.75 |
| CaO | 1.38 | 47.64 |
| CO ₂ | .30 | 34.90 |

J. Iron ore. Farm of C. J. Garrison, Russ County, Tex.

[Analysis by J. Edward Whitfield.]

| | |
|------------------------|-------|
| SiO ₂ | 14.53 |
| Fe | 48.56 |
| S | .41 |
| P | .405 |

COALS.

A. Lignite. Near light-house, Gay Head, Martha's Vineyard, Mass.

[Collected by N. S. Shaler. Analysis by J. Edward Whitfield.]

| | |
|-----------------------------|--------------|
| Moisture | 10.25 |
| Volatile hydrocarbons | 43.09 |
| Fixed carbon | 34.90 |
| Ash | 11.76 |
| | <hr/> 100.00 |

Ash red. Coal burns well, but is very friable.

B. McNew coal bank, Powell's Mountain, Scott County, Va.

C. Horton mine, south side Powell's Mountain, near base, Scott County, Va.

D. Bear-pen branch, Chimney Rock fork of Stony Creek, Scott County, Va.

E. Hogan's cannel coal. East fork of Staunton Creek, Scott County, Va.

F. Coke from C.

[Collected by J. R. Procter. Analyses B, C, D, E, by F. W. Clarke; F, by W. F. Hillebrand.]

| | B. | C. | D. | E. | F. |
|-----------------------------|--------------|--------------|--------------|--------------|--------------|
| Moisture | 1.92 | 1.19 | 1.29 | .39 | .35 |
| Volatile hydrocarbons | 33.42 | 33.74 | 30.36 | 37.15 | ..... |
| Fixed carbon | 55.62 | 58.92 | 63.27 | 42.05 | 91.36 |
| Ash | 9.04 | 6.15 | 5.03 | 20.41 | 8.29 |
| | <hr/> 100.00 | <hr/> 100.00 | <hr/> 100.00 | <hr/> 100.00 | <hr/> 100.00 |
| Coke | Good | Good | Good | Good | S... .68 |
| Ash | Reddish | Reddish | ..... | ..... | P.. .034 |

G. Burnet County, Tex.

[Analysis by J. Edward Whitfield.]

| | |
|-----------------------------|--------------|
| Moisture | 3.72 |
| Volatile hydrocarbons | 42.27 |
| Fixed carbon | 39.41 |
| Ash | 14.60 |
| | <hr/> 100.00 |

Ash, dark gray. Coke poor, dark, and friable.

IRON AND STEEL.

[Two samples, analyzed by J. Edward Whitfield for the Ordnance Corps, U. S. A.]

A. Sample from a Gruson chilled cast-iron armor plate, tested by the Italian Government at Spezia, April 20-29, 1886.

B. Hardened steel from 43-cm. Krupp shell, fired at Gruson plate "A," April 29, 1886.

| | A. | B. |
|------------------|--------------|--------------|
| Fe..... | 93.91 | 98.00 |
| Mn..... | 1.75 | .46 |
| Ni+Co..... | .58 | .12 |
| Al..... | trace | .38 |
| Ca..... | .20 | ..... |
| Si..... | .86 | .23 |
| P..... | .31 | .02 |
| S..... | .14 | .04 |
| Graphitic C..... | .81 | .03 |
| Combined C..... | 2.04 | .88 |
| | <hr/> 100.60 | <hr/> 100.16 |

NITRE FROM UTAH.

[Analysis by T. M. Chatard.]

| As found. | Probable combination. |
|---|---|
| Insoluble..... 12.12 | Insoluble..... 12.12 |
| H ₂ O..... 1.24 | H ₂ O..... 1.24 |
| SiO ₂ , Al ₂ O ₃..... .20 | SiO ₂ , Al ₂ O ₃..... .20 |
| CaO..... 1.43 | NaCl..... .08 |
| MgO..... trace | CaSO ₄ 3.48 |
| Na..... .03 | NaNO ₃..... .33 |
| Cl..... .05 | KNO ₃ 82.47 |
| SO ₃ 2.05 | |
| K ₂ O..... 38.38 | <hr/> 99.92 |
| Na ₂ O..... .12 | |
| N ₂ O ₅ 44.30 | |
| <hr/> 99.92 | |

SALT FROM WARSAW, N. Y.

["Crescent Fine" brand, made from local brine. Analysis by T. M. Chatard.]

| As analyzed. | Probable combination. |
|---|-----------------------------|
| H ₂ O..... 1.590 | H ₂ O..... 1.59 |
| Insoluble { CaSO ₄..... .008 | Insoluble..... .17 |
| { Al ₂ O ₃..... .080 | CaSO ₄..... .75 |
| { SiO ₂..... .082 | CaCl ₂..... .45 |
| SiO ₂..... .003 | MgCl ₂..... .11 |
| Al ₂ O ₃..... .006 | NaCl..... 97.34 |
| CaO..... .487 | <hr/> 100.41 |
| MgO..... .040 | |
| SO ₃..... .442 | |
| Cl..... 59.370 | |
| Na ₂ O..... 51.410 | |
| <hr/> 113.518 | |
| Less oxygen..... 13.380 | |
| <hr/> 100.138 | |
| Needed, soda, to satisfy acids . .272 | |
| <hr/> 100.410 | |

TWO CLAYS FROM SHORE OF OWEN'S LAKE, CAL.

[Collected and analyzed by T. M. Chatard.]

| | Sandy clay. | Blue clay. |
|---|-------------|------------|
| H ₂ O expelled at 110° | 1.41 | 2.05 |
| H ₂ O expelled at red heat | 2.73 | 2.40 |
| CO ₂ | 8.75 | 7.24 |
| SiO ₂ | 53.24 | 54.92 |
| TiO ₂ | .25 | .30 |
| Al ₂ O ₃ | 10.84 | 11.25 |
| Fe ₂ O ₃ | 2.59 | 2.77 |
| FeO | .77 | .94 |
| MnO | .10 | .08 |
| CaO | 9.18 | 8.76 |
| MgO | 5.82 | 4.91 |
| K ₂ O | 2.64 | 2.77 |
| Na ₂ O | 2.06 | 2.10 |
| SO ₃ | .08 | trace |
| Cl | .05 | trace |
| | 100.51 | 100.49 |
| Soluble in water | 1.26 | |

CLAY, SAND, ETC., FROM MARTHA'S VINEYARD, MASS.

[Collected by N. S. Shaler. Partial analyses, as called for.]

- A. Average sample of white clay, east end of Chilmark cliffs.
- B. Average sample of clay, north end of Gay Head cliffs.
- C. Sandy white clay, south end of Gay Head cliffs.
- D. Average sample of southernmost red clays, Gay Head.
- E. Average sample of fine white clay, south end of Gay Head cliffs.
- F. Average sample of fine clay and soil, east end of Weyquosque cliffs.
- G. Brown clay, 300 feet south of light-house, Gay Head.
- H. Average sample of red clay from the greensand, north end of Gay Head.
- I. Average sample of clays, Weyquosque series, Chilmark cliffs.
- J. Pyritiferous clay, central part of Gay Head section.
- K. Clay containing pyrite, west end of Chilmark cliffs.

[Analyses by F. W. Clarke.]

| | A. | B. | C. | D. | E. |
|---|-------|--------|--------|-------|--------|
| Ignition | 3.47 | 11.47 | 10.79 | 9.83 | 6.36 |
| SiO ₂ | 82.95 | 49.19 | 56.19 | 57.50 | 73.46 |
| Al ₂ O ₃ , Fe ₂ O ₃ | 13.45 | 39.77 | 30.65 | 31.21 | 19.06 |
| CaO | none | none | none | .19 | none |
| MgO | trace | trace | trace | .20 | trace |
| Na ₂ O | | | | | .70 |
| K ₂ O | | | | .40 | .73 |
| SO ₃ | | | 2.45 | | none |
| P ₂ O ₅ | none | none | none | none | none |
| | 99.87 | 100.43 | 100.08 | 99.33 | 100.31 |

| | F. | G. | H. | I. | J. |
|---|-------|--------|-------|--------|-------|
| Ignition..... | 3.39 | 7.57 | 9.98 | 5.76 | 5.69 |
| SiO ₂ | 70.81 | 56.62 | 55.93 | 61.76 | 72.74 |
| Al ₂ O ₃ , Fe ₂ O ₃ | 20.67 | 31.24 | 33.51 | 25.35 | 21.46 |
| CaO..... | trace | trace | none | .51 | none |
| MgO..... | 1.99 | 1.97 | .19 | 1.95 | trace |
| Na ₂ O..... | 1.23 | .40 | undet | 1.83 | ..... |
| K ₂ O..... | 1.67 | 2.76 | undet | 3.01 | ..... |
| SO ₃..... | ..... | ..... | ..... | ..... | ..... |
| P ₂ O ₅ | none | none | none | trace | none |
| | 99.76 | 100.56 | 99.61 | 100.17 | 99.89 |

| | K. |
|---|-------|
| SiO ₂ | 47.76 |
| Al ₂ O ₃ , Fe ₂ O ₃ | 30.93 |
| FeS ₂ | 7.27 |
| SO ₃ | .43 |
| CaO..... | none |
| MgO..... | .38 |
| K ₂ O..... | 1.17 |
| Na ₂ O..... | undet |
| H ₂ O..... | undet |
| P ₂ O ₅ | trace |

L. Average sample of phosphatic nodules from the greensand, north end of Gay Head cliff.

M. Average sample of fossil bones, Gay Head.

N. Greensand, northernmost exposure, Gay Head.

O. Greensand, north end of Gay Head.

P. Average sample of white sand, Gay Head section.

[Partial analyses by R. B. Riggs.]

| | L. | M. | N. | O. | P. |
|--------------------------------------|-----------|-------|-------|-------|--------|
| SiO ₂ | 17.82 | ..... | ..... | ..... | 78.69 |
| Al ₂ O ₃..... | ..... | ..... | ..... | ..... | 15.04 |
| Fe ₂ O ₃..... | ..... | ..... | ..... | ..... | .60 |
| CaO..... | 25.73 | 27.21 | 1.09 | .65 | trace |
| MgO..... | ..... | ..... | ..... | ..... | undet. |
| Na ₂ O..... | undet..15 | .56 | .38 | .33 | .19 |
| K ₂ O..... | | .97 | 3.87 | 4.16 | 1.09 |
| CO ₂ | 2.60 | 3.28 | .16 | .14 | ..... |
| P ₂ O ₅ | 23.88 | 27.80 | .48 | .22 | ..... |

WATER FROM PARIS, ME.

[From a large spring on the farm of William E. Cooper. Analysis by F. W. Clarke. Stated in grammes per liter.]

| | Per cent. of | | Hypothetical combination. | |
|------------------------|--------------|---------------|--|--------|
| | Found. | total solids. | | |
| SiO ₂ | 0.0170 | 2.64 | SiO | 0.0170 |
| SO ₄ | .3696 | 57.41 | K ₂ SO ₄ | .0027 |
| CO ₃ | .0754 | 11.71 | Na ₂ SO ₄ | .0809 |
| Cl | trace | ..... | CaSO ₄ | .4440 |
| K | .0012 | .19 | CaH ₂ (CO ₃) ₂ | .0206 |
| Na | .0262 | 4.07 | MgH ₂ (CO ₃) ₂ | .0391 |
| Ca | .1357 | 21.08 | MgCO ₃ | .0328 |
| Mg | .0158 | 2.45 | FeH ₂ (CO ₃) ₂ | .0067 |
| Fe | .0021 | .33 | | |
| H (bicarbonate) | .0008 | .12 | | |
| | 0.6438 | 100.00 | | 0.6438 |

WATERS FROM SAVANNAH, GA.

[Partial analyses by R. B. Riggs. Stated in parts per million.]

- A. Savannah River, taken at high water, August 17, 1886.
 B. Savannah River, taken at low water, August 17, 1886.
 C. Artesian well adjoining water-works.

| | A. | B. | C. |
|----------------------------------|-------|-------|-------|
| Cl | trace | trace | 7.3 |
| Free NH ₃ | none | none | none |
| Albuminoid NH ₃ | 2.6 | 1.0 | none |
| Inorganic solids | 45.0 | 40.0 | 174.0 |
| Organic solids | 22.0 | 15.0 | ..... |

The inorganic solids in C consist mostly of carbonates.

ARTESIAN WELLS IN GEORGIA AND ALABAMA.

[Partial analyses by R. B. Riggs. Stated in parts per million.]

- A. At Albany, Ga.
 B. At Smithville, Ga.
 C. At Americus, Ga.
 D. At Montezuma, Ga.
 E. At Fitzpatrick's, Ala.

| | A. | B. | C. | D. | E. |
|--------------------------------------|-------|-------|-------|-------|-------|
| Total solids | 181.0 | 140.0 | 177.0 | 111.5 | 271.0 |
| CO ₂ | 96.5 | 65.0 | 74.0 | 42.0 | 93.0 |
| SO ₃ | 9.2 | 17.1 | 5.6 | 6.3 | 38.6 |
| SiO ₂ | 27.0 | 13.0 | 43.6 | 26.2 | 40.8 |
| Al ₂ O ₃ | 1.0 | trace | trace | trace | 2.4 |
| CaO | 21.8 | 6.4 | 48.4 | 11.2 | 19.8 |
| MgO | 1.2 | .2 | .5 | .14 | 1.6 |

Examined with reference to use in steam-boilers. Chlorides and alkalis undetermined.

WATERS FROM ARKANSAS.

A. Happy Hollow Spring, Hot Springs.

[Analysis by R. B. Riggs. Stated in grammes per liter.]

| Found. | Hypothetical combination. |
|---|---|
| CO ₃..... .0081 | NaCl..... .0049 |
| Cl..... .0030 | NaHCO ₃..... .0043 |
| Ca..... .0017 | CaH ₂ (CO ₃) ₂..... .0068 |
| Na (K)..... .0031 | SiO ₂..... .0052 |
| SiO ₂..... .0052 | Al ₂ O ₃ , Fe ₂ O ₃..... .0008 |
| Al ₂ O ₃ , Fe ₂ O ₃..... .0008 | |
| H ₂ (bicarbonate)..... .0001 | |
| CO ₂ , free..... .0220 | CO ₂ , free..... .0220 |
| | |
| .0440 | .0440 |

B. Water of "Potash Sulphur Springs," 8 miles southeast of Hot Springs, Garland County.

[Partial analysis by F. W. Clarke on too small a supply of water. Stated in grammes per liter.]

| Found. | Per cent. of total solids. | Hypothetical combination. |
|--|----------------------------|---|
| SiO ₂..... .0275 | 4.13 | SiO ₂..... .0275 |
| Al ₂ O ₃..... .0020 | .30 | Al ₂ O ₃..... .0020 |
| Ca..... .0032 | .48 | CaCO ₃..... .0080 |
| Mg..... none. | | Na ₂ CO ₃..... .2572 |
| H ₂ S..... none. | | Na ₂ SO ₄..... .2988 |
| K..... .0227 | 3.41 | NaCl..... .0328 |
| Na..... .2216 | 33.28 | KCl..... .0433 |
| Cl..... .0405 | 6.08 | |
| SO ₄..... .2027 | 30.43 | |
| | | |
| .5202 | | 100.69 per cent. |
| CO ₃ by difference. ... .1458 | 21.89 | |
| | | |
| .6600 | 100.00 | |

WATER FROM A SPRING NEAR FORT WINGATE, N. MEX.

[Analysis by F. W. Clarke. Stated in grammes per liter.]

| Found. | Per cent. of total solids. | Hypothetical combination. |
|---|----------------------------|--|
| SiO ₂..... .0160 | 2.25 | SiO ₂..... .0160 |
| K..... .0024 | .35 | KCl..... .0046 |
| Na..... .0156 | 2.20 | NaCl..... .0072 |
| Ca..... .1350 | 19.03 | Na ₂ SO ₄..... .0395 |
| Mg..... .0361 | 5.09 | CaSO ₄..... .3620 |
| Cl..... .0066 | .93 | CaH ₂ (CO ₃) ₂..... .1153 |
| CO ₃..... .2127 | 29.99 | MgH ₂ (CO ₃) ₂..... .0900 |
| SO ₄..... .2822 | 39.79 | MgCO ₃..... .0746 |
| H ₂ (bicarbonate)..... .0026 | .37 | |
| | | |
| .7092 | 100.00 | .7092 |

WATER FROM OWEN'S LAKE, CALIFORNIA.

[Analysis by T. M. Chatard. Stated in grammes per kilo. Sp. gr. 106246, 16°.5.]

| | Found. | Per cent. of total solids. | Hypothetical combination. |
|--------------------------------------|---------------|-------------------------------|--|
| Na | 26.837 | 36.95 | KCl..... 2.957 |
| K..... | 1.548 | 2.13 | NaCl..... 27.694 |
| Al ₂ O ₃ | .023 | .04 | Na ₂ SO ₄ 10.443 |
| Fe ₂ O ₃ | .013 | .02 | Na ₂ B ₄ O ₇..... .438 |
| Ca | .014 | .02 | Na ₂ SiO ₃..... .464 |
| Mg..... | .005 | .01 | Na ₂ CO ₃ 26.319 |
| SO ₄ | 7.060 | 9.71 | NaHCO ₃ 4.233 |
| Cl..... | 18.215 | 25.07 | CaCO ₃..... .035 |
| Br, I, H ₂ S..... | none | ..... | MgCO ₃..... .013 |
| CO ₃ | 18.266 | 25.15 | Al ₂ O ₃..... .023 |
| B ₄ O ₇ | .338 | .47 | Fe ₂ O ₃..... .013 |
| SiO ₃ | .262 | .36 | |
| H ₂ (bicarbonate)... | .050 | .07 | |
| | <u>72.631</u> | <u>100.00</u> | <u>72.632</u> |

INDEX.

95

| | Page. | | Page. |
|---|----------------|--|---------|
| Martha's Vineyard, clays, etc., from..... | 89, 90 | S. | |
| lignite from..... | 87 | Salt..... | 88 |
| Menomonee River, rocks from..... | 81 | Samarskite..... | 48 |
| Mica group..... | 13 | Sandstone..... | 80 |
| Mitchell County, N. C., iron ores from..... | 86 | Savannah, Ga., waters from..... | 91 |
| Mixite..... | 45 | Scorodite..... | 65 |
| Monroe, Conn., tourmaline from..... | 27 | Scott County, Va., coals from..... | 87 |
| Montana, rocks from..... | 83 | Sevier County, Ark., iron ore from..... | 86 |
| Montezuma, Ga., water from..... | 91 | Smithville, Ga., water from..... | 91 |
| Morawitza, ludwigite from..... | 59 | Solids, behavior under pressure..... | 75 |
| Muscovite..... | 13 | Spotsylvania County, Va., iron ore from... | 85 |
| | | Steel, analyses of..... | 88 |
| N. | | Stony Point, N. C., mica from..... | 13 |
| Nantic Gulf, tourmaline from..... | 28 | tourmaline from..... | 28 |
| Nitre..... | 88 | | |
| O. | | T. | |
| Olivenite..... | 39 | Tintic district, Utah, minerals from..... | 38 |
| Orford, N. H., tourmaline from..... | 27 | Titanic oxidé, new form of..... | 38 |
| Owen's Lake, Cal., clays from..... | 89 | Tourmaline..... | 19 |
| water from..... | 93 | Tyrolite..... | 41 |
| P. | | U. | |
| Pandermito..... | 58 | Ulexite..... | 58 |
| Paris, Me., tourmaline from..... | 24 | Utah, minerals from..... | 38 |
| water from..... | 91 | nitre from..... | 88 |
| Pearce, R., analyses by..... | 40, 41, 45, 53 | | |
| Pharmacosiderite..... | 46 | W. | |
| Pierrepont, N. Y., tourmaline from..... | 28 | Warsaw, N. Y., salt from..... | 88 |
| Pigeon Point, Minn., rocks from..... | 81 | Washington, H. S., colemanite..... | 57 |
| Polk County, Ark., ore from..... | 86 | copper minerals..... | 38 |
| Priceite..... | 58 | Whitfield, J. E., analyses by..... | 57, 58, |
| R. | | 59, 60, 61, 63, 64, 65, 80, 82, 85, 86, 87 | |
| Rhodes's Marsh, Nev., ulexite from..... | 58 | on borates and borosilicates..... | 56 |
| Riggs, R. B., analyses by..... | 24, 25, | meteorites..... | 63 |
| 26, 27, 28, 29, 30, 79, 80, 81, | | scorodite..... | 65 |
| 82, 83, 84, 86, 90, 91, 92 | | Wilmington, Del., feldspar from..... | 80 |
| on tourmaline..... | 19 | Winslow, Me., beryl from..... | 53 |
| Rose Mine, N. Mex., mineral from..... | 54 | Wise County, Va., iron ore from..... | 86 |
| Rumford, Me., tourmaline from..... | 23 | | |
| Russ County, Tex., iron ore from..... | 87 | Y. | |
| Russell, N. Y., danburite from..... | 60 | Yellowstone Park, scorodite from .. | 65 |