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SERIES 1

BY

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# MINERALOGICAL NOTES—SERIES 1.

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By WALDEMAR T. SCHALLER.

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## INTRODUCTION.

The miscellaneous papers here assembled are submitted as a report on the mineralogical work of research character conducted by the author in the chemical laboratory of the United States Geological Survey from 1905 to 1909. A similar report on earlier work (1903–1905) was published as Mineralogical Notes in Bulletin 262 (1905), on pages 121–144. Besides these papers, a report on an investigation of the mercury minerals of Terlingua, Tex., made in collaboration with Dr. W. F. Hillebrand, has been published as Bulletin 405, and the study of the tourmaline field of southern California has been continued.

Many of the minerals described in this Bulletin were received for identification and study from members of the United States Geological Survey. Some specimens, however, were received from persons not directly connected with the Survey, and a few were collected by the author in California. Several investigations could not be completed, owing to loss of material by fire on December 16, 1908. Certain of these interrupted studies will be pursued further as opportunity affords.

Some of the papers have, in substance, if not in the exact form here reproduced, already appeared in scientific journals. A number of these papers were originally written and published in conjunction with some of the geologists of the Survey. Full credit has been given to these geologists for their contributions, some of which have been slightly rearranged.

A report similar in character to this one and giving the results of studies extending from January, 1910, to July, 1911, has been prepared and submitted for publication as a Bulletin entitled "Mineralogical notes—series 2."

## CHEMICAL COMPOSITION OF HULSITE AND PAIGEITE.

### INTRODUCTION.

A description of two new borates, hulsite and paigeite, was published in 1908<sup>1</sup> by the writer in conjunction with Adolph Knopf, who discovered these minerals in Alaska. These borates contained both ferrous and ferric iron, magnesia, and a small amount of water. The boric acid was determined by distillation with methyl alcohol and subsequent weighing as lime borate, and although only a single determination was made for each mineral, the analyses footed up well and the ratios were so close to simple numbers that no doubt was entertained as to the correctness of the results obtained. Later, however, Prof. F. W. Clarke, chief chemist of the Geological Survey, informed the author that the determination of boric acid in minerals was being investigated by E. T. Wherry and W. H. Chapin, under the direction of Prof. Edgar F. Smith, of the University of Pennsylvania, and through the kindness of Prof. Smith the boric acid content of the new minerals was redetermined by methods devised by Wherry and Chapin.<sup>2</sup> By this redetermination it was found that the amounts first obtained were much too high. Another examination of the minerals, made to explain the discrepancy, showed the presence of tin in appreciable quantity in both minerals. It therefore became necessary to revise and extend the original analyses in order to fix definitely the composition of the minerals.

### OCCURRENCE AND ASSOCIATION.

The occurrence of these borates and their relation to the tin deposits of Alaska have been described by Knopf. A summary of his description, together with brief mention of the associated minerals, follows.

The Alaskan tin deposits of known economic importance, which are limited to the extreme western part of the Seward Peninsula, about 100 miles northwest of Nome, are genetically associated with granitic intrusives which have invaded limestones of Paleozoic age. Along the margins of the granite bosses an intense pneumatolytic

<sup>1</sup> Knopf, A., and Schaller, W. T., Two new boron minerals of contact metamorphic origin: Am. Jour. Sci., 4th ser., vol. 25, 1908, p. 323.

<sup>2</sup> Determination of boric acid in insoluble silicates: Jour. Am. Chem. Soc., vol. 30, 1908, p. 1687.

contact metamorphism has frequently been produced and a considerable variety of minerals developed. The largest granite boss of the region is that of Brooks Mountain, and the most energetic contact action is displayed along its periphery. Tin deposits also occur in connection with a smaller intrusive a few miles south.

On the northeast flank of Brooks Mountain a prospect cut has been opened on an exposure of contact metamorphic minerals occurring in marmorized limestone 10 feet from the granite contact. Examination of this deposit showed hulsite, often intergrown with magnetite and vesuvianite, in considerable abundance. In the hand specimen taken from this exposure brown-green vesuvianite, magnetite, hulsite, and brown garnet occur scattered through a matrix of coarse white calc-spar. Occasionally some fluorite is visible. The characteristic forms of vesuvianite are  $a\{100\}$ ,  $m\{110\}$ ,  $f\{120\}$ ,  $c\{001\}$ ,  $p\{111\}$ ,  $t\{331\}$ . Less prominent forms are  $h\{130\}$ ,  $\delta\{113\}$ ,  $i\{112\}$ ,  $b\{221\}$ . Among rare and somewhat doubtful ones are  $\{150\}$ ,  $\{180\}$ ,  $\{1.10.0\}$ ,  $v\{151\}$ , and a few others. The angles measured are given in the table below.

*Forms and angles for vesuvianite.*

Let- ter.	Sym- bol.	Reflec- tion.	Size of face.	Measured.		Calculated.	
				$\phi$	$\rho$	$\phi$	$\rho$
<i>a</i>	100	Fair...	Large.....	0 00	90 00	0 00	90 00
<i>c</i>	001	Fair...	Medium.....	0 00	.....	0 00	.....
(?)	1. 10. 0	Poor...	Line face.....	5 49	90 00	5 43	90 00
(?)	180	Poor...	Line face.....	7 13	90 00	7 08	90 00
(?)	150	Poor...	Line face.....	10 47	90 00	11 19	90 00
<i>h</i>	130	Poor...	Line face.....	18 26	90 00	18 26	90 00
<i>f</i>	120	Poor...	Line face.....	26 14	90 00	26 34	90 00
<i>m</i>	110	Fair...	Medium.....	45 00	90 00	45 00	90 00
<i>v</i>	151	Poor...	Minute.....	10 01	69 47	11 18	69 57
<i>d</i>	113	Poor...	Line face.....	45 00	14 20	45 00	14 13
<i>i</i>	112	Poor...	Line face.....	45 00	20 54	45 00	20 49
<i>p</i>	111	Fair...	Large.....	45 00	37 17	45 00	37 14
<i>b</i>	221	Poor...	Narrow.....	45 00	57 03	45 00	56 40
<i>t</i>	331	Poor...	Narrow.....	45 00	66 42	45 00	66 19

The forms  $\{1.10.0\}$ ,  $\{180\}$ , and  $\{150\}$  are too doubtful to warrant their establishment as well defined without additional confirmation. On the Alaskan mineral, they form the merest striae, and the close agreement in angles for  $\{1.10.0\}$  and  $\{180\}$  may be accidental. When the vesuvianite is treated with fluorite mixture, it gives a distinct boron flame, and as it contains 0.89 per cent  $B_2O_3$  is regarded as belonging to the variety wiluite. The magnetite shows  $o\{111\}$ ,

$m\{311\}$ ,  $a\{100\}$ , and  $d\{110\}$  with  $om$  large and  $ad$  small. The angles are shown below.

*Forms and angles for magnetite.*

Symbol.	Measured.	Calculated.
$a\wedge m = 001\wedge 113$	25 20	25 14
$a\wedge o = 001\wedge 111$	54 42	54 44
$a\wedge d = 001\wedge 101$	45 06	45 00

The characteristic features of hulsite are its strong metallic luster, black color, good prismatic cleavage, and tendency toward tabular development. Its surface weathering is almost identical with that of magnetite, and it may, on casual inspection, easily be confounded with that mineral. The tabular individuals of hulsite vary in thickness from a fraction of a millimeter to a little more than a centimeter, so far as known. Under the microscope it is absolutely opaque, and appears dark black in reflected light.

Thin sections show that magnetite is often intimately intergrown with the hulsite, from which it may be distinguished by its bright metallic reflection.

The other mineral, paigeite, which was found at Brooks Mountain in loose blocks and at Ear Mountain, 40 miles northeast, in place, is a lustrous, coal-black mineral of foliated appearance. A thin section of the matrix from Brooks Mountain shows vesuvianite, calcite, hedenbergite, a small amount of biotite, and arsenopyrite in sporadic grains. The paigeite is abundant, and occurs in many places in capillary or trichite-like forms transfixing the various other associated minerals. At Ear Mountain a granite intrusion has produced an extensive development of contact metamorphosed limestones, especially lime silicate hornfels, some of which is flecked with paigeite and chalcopyrite. Under the microscope this variety of hornfels is seen to consist of a confused intergrowth of calcite, zonally banded tourmaline, pleochroic in tones of blue and brown, vesuvianite, fluorite, and zoisite, with accessory phlogopite, chalcopyrite, and magnetite. Paigeite fibers and matted aggregates are embedded in the various constituent minerals, especially in the tourmaline and calcite.

**NOTES ON CHEMICAL EXAMINATION.**

**GENERAL STATEMENT.**

These borates, hulsite and paigeite, which are similar in composition, contain ferrous and ferric iron, magnesia, tin, water, and boric acid. In solutions of samples in hydrochloric acid, silica, alumina, and lime, derived from the gangue, also appear.

The results of considerable work performed on these minerals herein presented are not altogether satisfactory. A complete revision of all the chemical data is highly desirable, but such revision, in order to make determinations exact, would require new material, in considerable quantities, free from gangue.

The present investigation was carried on under great disadvantages, for the amount of material for analysis was insufficient and the presence of foreign matter in very appreciable quantities could not be avoided. Less than a gram of hulsite free from magnetite was available, and only a few grams of paigeite could be obtained in approximately pure condition. In consequence, solutions to various questions that developed after some of the analyses had been completed could not be worked out, owing to lack of material. Individual samples of the minerals, moreover, differed somewhat in composition, owing to the nature of the gangue and to isomorphous replacements in the minerals themselves. All these conditions, which were brought out as the analyses progressed, served to render the results unsatisfactory.

A brief description of the gangue and a somewhat more detailed account of certain of the analytical methods employed will be given in order to present properly the evidence on which are based the formulas here proposed for hulsite and paigeite.

#### THE GANGUE.

The material here designated as gangue comprises those minerals—vesuvianite, arsenopyrite, and several others—which were associated with the borates and could not be separated from them. The amount of gangue present in the specimens available for analysis ranged from 10 to 30 per cent. Hulsite is in nearly all specimens mixed with magnetite, and nonmagnetic hulsite seems to be extremely rare. In the preparation for the new analyses all the material available was broken up and the hulsite was picked out with a hand lens. The greater part of the hulsite—that in which magnetite was present—was then removed with a magnet, leaving less than a gram of nonmagnetic and magnetite-free material, which, however, contained appreciable amounts of vesuvianite, calcite, and other gangue minerals. This sample is referred to later as hulsite sample No. 3.

The samples of paigeite comprised several pieces about an inch thick. The mineral is coal black and massive and of laminated or radiating fibrous structure. The gangue, with which it is intimately mixed, is stained brown, presumably by ferric oxide. Samples of the black paigeite were so selected as to exclude all visible gangue; but a microscopic section of one sample showed that the paigeite occurs as small fibers and irregular masses as inclusions in the gangue

minerals and it therefore contains considerable extraneous matter—generally about 20 per cent.

A small amount of arsenopyrite is always present, even though none is visible to the eye, and appears amid the main mass of whitish residue after the paigeite is dissolved out by hydrochloric acid. Microscopic examination indicates that this gangue or whitish residue is for the most part vesuvianite. Calcite and magnetite seem, in general, to be absent from the massive paigeite samples, but, in addition to the arsenopyrite, tourmaline and fluorite may be present in varying but small quantities. When the paigeite is dissolved out by hydrochloric acid, these substances remain behind and may be filtered off.

Certain conditions, however, indicate that the gangue as a whole is considerably attacked and dissolved by the acid. First, more than 3 per cent of silica was found in the hydrochloric acid solution of one sample of paigeite. Whether the silica has isomorphously replaced the tin in the borate or whether it comes from the gangue is not definitely known, but the latter supposition is by far the most plausible. The excessive values for gravimetric  $R_2O_3$  determinations, which are always several per cent higher than the total amount of iron, are doubtless due to silica and alumina derived from the gangue. Confirmation of the presence of alumina in the solution, however, would not necessarily point to the gangue as its source, for it might come from the iron borate as an isomorph of  $Fe_2O_3$ . Second, some of the gangue, as shown by the microscope, is stained yellow by iron chloride. Hydrochloric acid does not dissolve the stain, and this fact seems to show that the gangue either consists in part of, or is coated by, a layer of colloidal matter able to retain the iron chloride. Crystallized vesuvianite, which is unattacked by acid, is not able to retain the iron chloride stain so tenaciously. Third, when the gangue or insoluble residue was heated at  $110^\circ$  to constant weight it retained considerable water, which was not given off until the crucible was heated to a low red heat. If the gangue were unattacked, its weight dried at  $110^\circ$  should be but little, if any, more than what it weighs on being ignited. The percentages of the insoluble gangue of paigeite, first dried at  $110^\circ$  to constant weight and then carefully ignited, follow:

*Percentage of insoluble gangue in paigeite.*

	No. 5.	No. 6.	No. 7.
Insoluble gangue dried at $110^\circ$ .....	20.24	20.60	19.29
Insoluble gangue ignited.....	17.32	17.51	16.99

The presence in the paigeite solution of considerable calcium, which was shown by qualitative tests on small pieces of the purer mineral to be almost absent from some samples of the borates, also indicates the extent to which the gangue is attacked. The silica and bases thus entering into solution seriously complicate the interpretation of the analyses.

When vesuvianite and arsenopyrite, the chief constituents of the gangue of paigeite, are ignited, they decrease somewhat in weight. Arsenopyrite changes in accordance with the following reaction:  $2\text{FeAsS} + 10\text{O} = \text{Fe}_2\text{O}_3 + \text{As}_2\text{O}_3 + 2\text{SO}_2$ . The weight of the ferric oxide, which remains after the reaction, is about half that of the arsenopyrite; therefore half the weight of the arsenopyrite is lost in ignition. Vesuvianite loses only about 2 per cent water when heated, a loss which, if the amount of material in the paigeite sample were 15 per cent, would amount to 0.3 per cent. The amount of arsenopyrite in the original samples of paigeite is about 2 per cent, and when the gangue is ignited there is a loss of half this amount plus the 0.3 per cent loss of vesuvianite, making a total loss of 1.3 per cent. This amount must therefore be added to the final value of the ignited residues of paigeite, as has been done in the analyses given in this paper.

The amount of calcite in the gangue is generally very small and was not determined in these investigations. The per cent was largest in hulsite sample No. 3. Magnetite was removed from all the samples of hulsite except No. 2, a magnetite-hulsite mixture.

#### METHODS OF ANALYSES.

Ferrous iron is present in both borates in large amount, and was determined by a modification of Pratt's method, which has been shown by W. F. Hillebrand to give reliable values.<sup>1</sup> Both new borates here described dissolve readily in hydrofluoric acid, so that no difficulty was experienced in making the ferrous-iron determinations. The hulsite powder was always coarser than 100 mesh and the paigeite powder coarser than 60 mesh, so that very little, if any, oxidation of the ferrous iron resulted from the grinding. That such oxidation occurs and may be extensive has recently been shown by Mauzelius.<sup>2</sup> Oxidation due to grinding is considerable on the FeO contained in these borates, for in paigeite the amount for FeO falls from 44 per cent in <20> 60-mesh material to 39 per cent in the same material finely ground. The data given below indicate the results of grinding paigeite and a similar borate, ludwigite, from Hungary.

<sup>1</sup> The analysis of silicate and carbonate rocks: Bull. U. S. Geol. Survey No. 305, 1907, p. 138.

<sup>2</sup> Sveriges Geol. Undersökning, Yearbook 1, No. 3, 1907. Consult Chem. Abstract, 1907, p. 2861, for an abstract of this article. See also Hillebrand, W. F., The influence of fine grinding on the water and ferrous-iron content of minerals and rocks: Jour. Am. Chem. Soc., vol. 30, 1908, p. 1120.

*Oxidation of ferrous iron on samples of paigeite.*

	Pratt's method.	Cooke's method.
FeO (<40> 100 mesh):		
At beginning of test.....	Per cent. 43.87	Per cent. 43.91
After grinding 1 hour.....	41.38	40.88
After grinding 2 hours.....	40.23	39.98
After grinding 7 hours.....	39.78	39.59
FeO (<20> 40 mesh):		
At beginning of test.....	44.30	.....
After grinding 1 hour.....	42.24	.....
When finely ground.....	39.39	.....

A sample of ludwigite containing about 16 per cent of ferrous iron gave the following results on the oxidation of FeO by grinding:

*Oxidation of ferrous iron on ludwigite (two determinations by Pratt's method).*

	1	2
FeO (<20> 40 mesh):		
At beginning of test.....	Per cent. 15.84	Per cent. 15.88
When crushed to 120 mesh.....	15.50	15.53
When finely ground.....	15.43	15.34

The oxidation of ludwigite is not nearly so great as that of paigeite, the remarkable oxidation of which is probably largely due to the presence of an abundance of gangue material, such as vesuvianite and arsenopyrite, much harder than the borate itself.

The amount of ferrous oxide given in the analyses of hulsite and paigeite also includes that of the vesuvianite present, but this amount is probably so small that it may be neglected. The vesuvianite has not been analyzed, but the ferrous iron in it is doubtless less than 1 per cent. The arsenopyrite present had no effect on the determination of ferrous oxide, for the mineral particles were so large that the arsenopyrite remained undissolved in the hydrofluoric-acid solution.

The total iron content of the borates, and thereby the amount of ferric iron present in them, was determined in the usual manner by dissolving the precipitated  $R_2O_3$  in sulphuric acid or by fusion of the ignited precipitate with sodium pyrosulphate and subsequent titration with potassium permanganate. By fusing the ignited precipitate the silica present could be recovered and determined.

The amount of tin was determined by precipitating it with  $H_2S$  from the HCl solution of the minerals and by weighing it as oxide. The easy solubility of both the minerals in cold dilute acid indicates that the tin occurs as some form of stannic acid. Qualitative tests showed that the tin was present in solution in the stannic condition.

Boric-acid determinations were made in the original analyses by distilling with methyl alcohol. It is not known why high results were obtained, for the method is more likely to give low values. The method adopted for the reanalyses of the borates, that proposed by Wherry,<sup>1</sup> was first tested on samples of known  $B_2O_3$  content. The values here given do not agree closely, because of the small amount of material available and the varying amount of gangue present in the samples.

The percentage of water was determined by heating the mineral to be tested (size  $<20>$  60 mesh) in a glass tube and weighing the water directly in a portion of that tube (Penfield's method).

As the determination of total water was made on coarse material the amount of hygroscopic water in the sample was reduced to a minimum. What increase in the water content is caused by grinding these borates is not known, but experiments with ludwigite, a mineral of analogous composition, show that a very considerable amount of water is taken up. (See p. 15.) Total water determinations for such minerals as these borates must, therefore, to be of value, be made on coarse material, such as was used in these investigations. It is believed that the water content given for these minerals is an essential part of their composition, rather than hygroscopic or accessory water, but definite proof of this hypothesis is lacking, and future work may show the water associated with these two minerals to be extraneous. Hillebrand,<sup>2</sup> who has made a study of the effect of grinding on the ferrous-iron content of minerals, called the writer's attention to these conditions, which served to explain the varying results first obtained on paigeite for ferrous iron.

The same general method was followed in the analyses. The powdered or coarsely crushed sample was treated in a beaker with a small amount of HCl and allowed to stand some hours. Platinum dishes should not be used, as the large amount of iron chloride and possibly also tin chloride readily attacks and dissolves the platinum. Solution of the finely crushed borate samples was usually complete in a few hours. Solution of the coarser samples was hastened by gentle warmth. The solution must not be allowed to boil, on account of volatility of  $SnCl_4$  in steam. Under the conditions described the arsenopyrite is not attacked, though partial solution of the vesuvianite occurs. After filtration and ignition of the gangue (see p. 13),  $H_2S$  was conducted into the diluted solution, the tin sulphide filtered off and determined, the solution boiled, the iron oxidized, and the analysis continued as usual. A determination of the alkalies was made in one sample, 0.54 per cent of  $K_2O$  and 0.70 per cent of  $Na_2O$  being found. As the operations were made in glass vessels and many reagents had been added to the solution, these values, even

<sup>1</sup> Determination of boric acid in insoluble silicates: Jour. Am. Chem. Soc., vol. 30, 1908, p. 1687.

<sup>2</sup> Jour. Am. Chem. Soc., vol. 30, 1908, p. 1120.

though small in quantity, probably do not represent alkalies originally in the mineral. Traces of manganese and titanium are present in the samples, but the following elements and radicals were never found, though several qualitative tests for them were made: Ba, Bi, Cd, Zn, rare earths, Cb, Ta, Li, Mo, Te, W, U, Zr, V, F, sulphates, phosphates, and chlorides.

### HULSITE.

#### CRYSTALLOGRAPHY.

Hulsite always occurs in crystalline form, either as small crystals about 1 millimeter in diameter or as large tabular masses, extending several centimeters and showing well developed prismatic cleavage. The crystals, though they may be complete, are always uneven, and the faces dull and rough, so that no measurements could be obtained from any of the natural faces. Inspection with a hand lens shows that these crystals are often rectangular, and as hulsite is provisionally considered orthorhombic these rectangular prisms consist of the three pinacoids. Sometimes the crystals are bounded by the prism faces and the basal pinacoid, though it is not always possible to decide whether the prisms are natural crystal faces or whether they are due to cleavage. Often one pair of prism faces becomes much larger than the other pair. The cleavage parallel to the prism is good, and measurements of three such cleavage angles gave the values:

$m \wedge m''' = 57^\circ 44'$ ,  $57^\circ 38'$ ,  $57^\circ 33'$ . Average value  $57^\circ 38'$ . Assuming that hulsite is orthorhombic, the crystallographic elements become:

$$a : b : c = 0.5501 : 1 : ?$$

Forms :  $a\{100\}$ ,  $b\{010\}$ ,  $c\{001\}$ ,  $m\{110\}$ .

Many of the crystals are twinned; one individual being turned about  $120^\circ$  to the other and the two basal pinacoids remaining in the same plane. They are also often grouped in parallel position, especially when the individual crystals are elongated parallel to a prism face.

#### GENERAL PROPERTIES.

Hulsite is black, but when free from inclosed magnetite has a greenish, brownish, or reddish tinge. Many of the smaller crystals are covered with a brownish coating, probably limonitic in character. The streak is black and the luster generally submetallic, though that of the pure mineral tends rather to vitreous, like hornblende. The hardness is about 3 and the density is 4.31. The cleavage is good, being prismatic parallel to  $m\{110\}$ . Hulsite is readily soluble in HCl and HF, but dissolves in other acids with some difficulty. It

gives off water in a closed tube, and fuses quietly before the blowpipe to a dull black slag, giving a slightly green flame. When heated with potassium bisulphate and fluorite, it gives a persistent green color to the flame.

The composition of sample No. 2 (see beyond) was found by calculation to be approximately as follows:

Vesuvianite.....	2.2
Hulsite.....	80.6
Magnetite.....	17.2
	100.0

The density of this mixture is 4.438. If the density of vesuvianite is taken as 3.40 and that of magnetite as 5.17, the density of hulsite is found by calculation to be 4.31.

#### CHARACTER OF SAMPLES.

The sample of hulsite first submitted for chemical investigation was apparently homogeneous. It was, however, strongly magnetic, and though it was suspected that it consisted of a mixture of a non-magnetic borate with magnetite, various tests failed to show the presence of the latter mineral. When powdered finely and suspended in water, the particles were still attracted by the magnet, and none of the many chemical tests attempted led to a separation of the magnetite from the borate. After the analytical work on this sample had been finished, some specimens of hulsite collected in previous years were tested and found to be nonmagnetic. These specimens showed that the earlier ones contained admixed magnetite and a careful examination of all of the samples on hand showed the very common presence of magnetite in varying amounts included in the hulsite.

The few specimens that were nonmagnetic and free from magnetite seemed to weather more easily than the others, and several of them were more or less altered to a limonitic substance, so that the amount of fresh material on hand was very small. After the presence of tin in hulsite was established, all the specimens at hand were again gone over for material for reexamination, but only a very small quantity of hulsite free from magnetite was obtainable.

Three samples of hulsite were obtained and analyzed. Sample No. 1 consisted of about half a gram of hulsite free from magnetite, which was crushed into grains of <60> 100 mesh size and partially analyzed, only ferrous and ferric iron, magnesia, and the insoluble matter being determined. The value given for the magnesia content is doubtless high, for a little lime was probably present and, if so, was determined as magnesia. A part of the magnesia, too, was

derived from the gangue. Sample No. 2 consisted of about a gram of material at first supposed to be homogeneous, but later found to consist of a mixture of hulsite and magnetite with a small amount of gangue. Tin was not determined in either sample, and the value for boric acid in sample No. 2 was furnished by Wherry and Chapin.<sup>1</sup> Sample No. 3 was obtained by reexamining all the available material and picking out a small amount of nonmagnetic hulsite mixed with considerable gangue. The relatively large amount of gangue soluble in acid complicated the interpretation of the results.

#### ANALYSES AND RATIOS.

The analysis of the first sample yielded the following results:

*Partial analyses of hulsite, sample No. 1.*

	1	2	Average.
FeO.....	33.27	.....	33.27
MgO.....	.....	10.17	10.17
Fe <sub>2</sub> O <sub>3</sub> .....	.....	.....	17.83
Total iron as Fe <sub>2</sub> O <sub>3</sub> .....	54.40	54.20	.....
Insoluble.....	.....	10.00	10.00
B <sub>2</sub> O <sub>3</sub> , SnO <sub>2</sub> , H <sub>2</sub> O.....	.....	.....	.....

The ferrous iron and magnesia are doubtless not present in any definite ratio, but vary reciprocally, so that hulsite may be considered as a mixture of a ferrous with a magnesian borate. In the above analysis the ratio of FeO : MgO is about 9 : 5. Ferrous iron and magnesia are probably isomorphous in hulsite as well as in paigeite, and similarly in the related borate ludwigite. An analysis of ludwigite from Montana shows this isomorphism particularly well, for this mineral contains but little ferrous iron, while that from Hungary contains about 15 per cent. (See p. 32.)

The ratios in sample No. 1 are shown in the following table:

*Ratios of average analysis of hulsite, sample No. 1.*

FeO.....	0.462	}=6.63
MgO.....	.254	
Fe <sub>2</sub> O <sub>3</sub> .....	.108	

The ratio of RO : Fe<sub>2</sub>O<sub>3</sub> as given by the analysis is 6.63 : 1, but the true value is probably better represented by the ratio 6 : 1, for, as already stated, the magnesia value is doubtless high.

The second sample, in which the hulsite was mixed with magnetite, gave the following results on analysis:

<sup>1</sup>Loc. cit.

*Analyses of hulsite, sample No. 2.*

	1	2	3	4	5	Average.
FeO.....	34.48	34.35				34.44
MgO.....	8.60	8.83	8.36	8.12		8.48
Fe <sub>2</sub> O <sub>3</sub> .....						27.64
Total iron as Fe <sub>2</sub> O <sub>3</sub> .....	66.24	67.08	65.70	65.42	65.32	
H <sub>2</sub> O.....	1.63	1.68				1.66
B <sub>2</sub> O <sub>3</sub> .....					10.44	10.44
Insoluble.....	2.25	1.97	2.24	2.48		2.24
SnO <sub>2</sub> .....						

The ratios obtained from the above analyses, as given, are:

*Ratios of average analysis of hulsite, sample No. 2.*

FeO.....	0.479
MgO.....	.212
Fe <sub>2</sub> O <sub>3</sub> .....	.173
H <sub>2</sub> O.....	.092
B <sub>2</sub> O <sub>3</sub> .....	.149
SnO <sub>2</sub> .....	

Analysis of sample No. 3 shows the ratio of B<sub>2</sub>O<sub>3</sub> to Fe<sub>2</sub>O<sub>3</sub> to be 3 : 2. From this ratio the amount of magnetite present in sample No. 2 can be calculated, for the amount of ferric iron entering into the composition of the borate can be easily determined, and the remainder must therefore belong to the magnetite. When the proper amount of FeO required to form FeO.Fe<sub>2</sub>O<sub>3</sub> is deducted from the ratios, they reduce to figures representing the composition of the magnetite-free hulsite.

*Ratios showing composition of hulsite free from magnetite.*

	Ratios from analysis.	Ratios of magnetite.	Ratios of hulsite.
FeO.....	{ 0.691	-0.074	0.617
MgO.....		- .074	12.4
Fe <sub>2</sub> O <sub>3</sub> .....	.173	.092	2.0
H <sub>2</sub> O.....	.092		1.9
B <sub>2</sub> O <sub>3</sub> .....	.149		3.0
SnO <sub>2</sub> .....			

The ratios from the above analyses give as the formula for pure hulsite 12.4RO. 2.0Fe<sub>2</sub>O<sub>3</sub>. 1.9H<sub>2</sub>O. 3.0B<sub>2</sub>O<sub>3</sub>+?SnO<sub>2</sub>.

The results obtained from the analyses of sample No. 3 are given below. Considerable insoluble gangue was present, but magnetite was entirely absent. The results shown under the heading 1a were obtained from analysis of a small sample of less pure material. They

are not taken into the average, and are of value chiefly because they confirm the figures given for tin in the other analyses. The amount of ammonia precipitate in 1a was not determined, since it was used for various qualitative tests, and the calcium precipitate was accidentally lost. The higher value for the amount of boric acid is taken in the average instead of the mean of the two values, for the second determination is believed to be low.

*Analyses of hulsite, sample No. 3.*

	1a	1	2	3	Average.
FeO.....				27.71	27.71
MgO.....	3.62		4.13	4.45	4.29
CaO.....		7.98	9.82	9.54	9.11
Fe <sub>2</sub> O <sub>3</sub> .....					15.21
Total iron as Fe <sub>2</sub> O <sub>3</sub> .....			46.30	45.67	
SnO <sub>2</sub> .....	6.13	6.85	7.15	7.20	7.07
B <sub>2</sub> O <sub>3</sub> .....		9.20	8.27		9.20
Insoluble.....	27.42	19.92	17.52	18.44	18.63
H <sub>2</sub> O, CO <sub>2</sub> , SiO <sub>2</sub> , Al <sub>2</sub> O <sub>3</sub> .....			diff.		8.78
					100.00

The following ratios were calculated from the figures for the average analysis:

*Ratios of average analysis of hulsite, sample No. 3.*

FeO.....	0.385	10.47
MgO.....	.107	
Fe <sub>2</sub> O <sub>3</sub> .....	.095	= 2.02
SnO <sub>2</sub> .....	.047	= 1
B <sub>2</sub> O <sub>3</sub> .....	.131	= 2.79

Analyses of paigeite samples reported in this paper indicate the amount of calcium oxide derived from the gangue. Where the insoluble matter is approximately 15 per cent, the calcium-oxide content is about 4 per cent. If this ratio remains fairly constant, there should be in the above analysis of hulsite sample No. 3 about 5 per cent of lime derived from the gangue, leaving approximately somewhat less than 4 per cent of CaO, which may belong to the borate mineral. If this CaO enters into the composition of the borate, the ratio of (FeO, MgO, CaO) to Fe<sub>2</sub>O<sub>3</sub> would become 11.9 : 1, or nearly 12 : 1. The analysis of sample No. 3, shows the formula of hulsite to be either 10½RO.2Fe<sub>2</sub>O<sub>3</sub>.SnO<sub>2</sub>.3B<sub>2</sub>O<sub>3</sub> + ?H<sub>2</sub>O or 12RO.2Fe<sub>2</sub>O<sub>3</sub>.SnO<sub>2</sub>.3B<sub>2</sub>O<sub>3</sub> + ?H<sub>2</sub>O.

#### DISCUSSION OF FORMULAS.

From the results of the analyses of the three samples of hulsite, as given, there are derived the following partial formulas for the mineral:

*Partial formulas for hulsite.*

Sample.	RO.	Fe <sub>2</sub> O <sub>3</sub> .	SnO <sub>2</sub> .	B <sub>2</sub> O <sub>3</sub> .	H <sub>2</sub> O.
No. 1...	13.2	2.0	.....	.....	.....
No. 2...	12.4	2.0	.....	3.0	1.9
No. 3...{	10.5 12.0	2.0 2.0	1.0 1.0	2.8 2.8	.....

From this incomplete compilation the most probable formula is  $12\text{RO}_2\text{Fe}_2\text{O}_3 \cdot 1\text{SnO}_2 \cdot 3\text{B}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$  or  $(\text{Fe}, \text{Mg})_{12}\text{Fe}_4\text{SnB}_6\text{H}_4\text{O}_{31}$ . Hulsite can hardly be considered a borate of iron (ferrous and ferric), tin and magnesia, for the bases are present in overwhelming amount; therefore the ferric iron may be considered to be present as an acid, playing the same rôle as the borates. On the basis of this assumption the formula may be written  $\text{R''}_9(\text{BO}_3)_6\text{R''}_3[\text{Sn}(\text{OH})]'''\text{H}_3(\text{FeO}_3)_4$ .

The tin in hulsite occurs in a condition so easily soluble in dilute acid that it is probably present in some form of stannic acid. The possible presence of stannic acid, however, in combination with boric and possibly some iron acids, leads to complications which can not well be discussed at present.

**PAIGEITE.****GENERAL DESCRIPTION.**

Specimens of paigeite from Brooks Mountain are coal black and lustrous. The mineral has a laminated appearance. No distinct crystals were visible, but the entire mass has a crystalline appearance and in thin sections is seen to be composed of innumerable hair-like needles, which often form radiating groups. The hardness of paigeite is about 3, and the density is 4.78. Both color and streak are coal black. It dissolves readily in HCl and HF, and resembles hulsite in its pyrognostic properties.

The density of sample No. 1 was determined as 4.544. Calculation shows the density of pure paigeite to be 4.78, in accordance with the following analysis of the sample:

*Component minerals and densities of paigeite, sample No. 1.*

	Densities.	Per cent of sample.
Vesuvianite.....	3.40	19
Arsenopyrite.....	6.0	2
Paigeite.....	4.78	79
	.....	100

## CHARACTER OF SAMPLES.

Three different samples of paigeite were prepared and analyzed. The amount of gangue varied only slightly as compared with the large variations encountered in hulsite. The first analysis was made on sample No. 1; on this sample no determination of tin was made, and the value given for  $B_2O_3$  is that determined by Wherry and Chapin. The other samples were prepared from specimens at hand. Sample No. 2 consisted of finely ground material, and consequently the value given for  $FeO$  may be somewhat low. The material of sample No. 3 was coarser, but otherwise very similar in character to No. 2.

## ANALYSES AND RATIOS.

The results of the analyses of sample No. 1 are shown below.

*Analyses of paigeite, sample No. 1.*

	1	2	3	4	Average.
$FeO$ .....	43.91	44.30	45.82	43.87	44.48
$MgO$ .....	1.70	1.22	1.39	.....	1.44
$Fe_2O_3$ .....	.....	.....	.....	.....	16.72
Total iron as $Fe_2O_3$ .....	66.26	65.95	66.22	.....	.....
$H_2O$ .....	2.03	.....	.....	.....	2.03
$B_2O_3$ .....	.....	.....	.....	9.83	9.83
Insoluble.....	15.55	15.76	15.65	.....	15.65

The amounts of  $SnO_2$  and of its soluble gangue were not determined.

*Ratios from average analysis of paigeite, sample No. 1.*

$FeO$ .....	0.618	}=31.1
$MgO$ .....	.036	
$Fe_2O_3$ .....	.105	= 5
$H_2O$ .....	.113	= 5.4
$B_2O_3$ .....	.140	= 6.7

From the above analysis, the incomplete formula derived for paigeite is  $31.1RO \cdot 5.0Fe_2O_3 \cdot 5.4H_2O \cdot 6.7B_2O_3 + ?SnO_2$ .

Analyses of the second sample yielded the following results:

*Analyses of paigeite, sample No. 2.*

	1	2	3	Average.
$FeO$ .....	40.82	.....	.....	40.82
$MgO$ .....	2.02	2.01	2.10	2.04
$CaO$ .....	4.28	4.31	3.81	4.13
$Fe_2O_3$ .....	18.19	19.34	18.48	18.67
Total iron as $Fe_2O_3$ .....	63.54	64.69	63.83	.....
$SnO_2$ .....	3.15	3.14	3.26	3.18
$B_2O_3$ .....	9.10	.....	.....	9.10
Insoluble.....	16.18	15.74	16.38	16.10
$SiO_2, Al_2O_3, H_2O$ (difference).....	.....	.....	.....	5.96
				100.00

If all the lime is considered as resulting from solution of the gangue, the ratios deduced from the above analyses are:

*Ratios of average analysis of paigeite, sample No. 2.*

FeO.....	0.567	0.567	= 29.4
MgO.....	.051	.051	
Fe <sub>2</sub> O <sub>3</sub> .....	.117	.117	= 5.6
SnO <sub>2</sub> .....	.021	.021	= 1
B <sub>2</sub> O <sub>3</sub> .....	.130	.130	= 6.2
H <sub>2</sub> O.....			

These ratios give the following formula, which is incomplete in respect to the water content: 29.4RO.5.6Fe<sub>2</sub>O<sub>3</sub>.1SnO<sub>2</sub>.6.2B<sub>2</sub>O<sub>3</sub>+?H<sub>2</sub>O.

Evidence that the gangue was considerably dissolved by HCl led to direct determinations of the silica and alumina in analyses of the third sample, with the following results:

*Analyses of paigeite, sample No. 3.*

	1	2	3	Average.
FeO.....	34.68	34.86	35.52	35.02
MgO.....	2.25	1.89	2.22	2.12
CaO.....	8.97	8.56	8.84	8.79
Fe <sub>2</sub> O <sub>3</sub> .....	14.69	14.84	15.18	14.90
Total iron as Fe <sub>2</sub> O <sub>3</sub> .....	53.22	53.57	54.62	
SnO <sub>2</sub> .....	2.77	2.86	<sup>a</sup> 2.76	2.80
B <sub>2</sub> O <sub>3</sub> .....			6.71	6.94
Insoluble.....	18.62	18.81	18.29	18.57
SiO <sub>2</sub> .....	3.28	2.78	3.25	3.10
Al <sub>2</sub> O <sub>3</sub> .....	2.51	2.41	2.09	2.34
H <sub>2</sub> O, etc. (difference).....				5.42
				100.00

<sup>a</sup> A fourth determination of SnO<sub>2</sub> gave 2.97 per cent.

In the ratios derived from the above analysis, which are given herewith, the CaO, SiO<sub>2</sub>, and Al<sub>2</sub>O<sub>3</sub> are excluded as belonging with the insoluble matter of the gangue.

*Ratios of average analysis of paigeite, sample No. 3.*

FeO.....	0.486	0.486	= 28.5
MgO.....	.056	.056	
Fe <sub>2</sub> O <sub>3</sub> .....	.093	.093	= 4.9
SnO <sub>2</sub> .....	.019	.019	= 1
B <sub>2</sub> O <sub>3</sub> .....	.099	.099	= 5.2
H <sub>2</sub> O.....			

As in one of the hulsite analyses, the amount of calcium oxide is considerably higher in sample No. 3 than in sample No. 2, a fact that seems to indicate that some of the lime belongs to the borate. Only 1.57 per cent of CaO would be needed to raise the ratio of FeO+MgO+CaO to SnO<sub>2</sub> from 28.5 : 1, as given above, to 30 : 1, and this

small amount of lime is therefore considered as belonging to the borate. The ratios obtained above are 28.5 or 30.0 RO. 4.9Fe<sub>2</sub>O<sub>3</sub>. 1SnO<sub>2</sub>. 5.2B<sub>2</sub>O<sub>3</sub> + ?H<sub>2</sub>O.

#### DISCUSSION OF FORMULAS.

The following formulas are deduced for paigeite from the above three series of analyses:

*Formulas for paigeite.*

Sample.	RO.	Fe <sub>2</sub> O <sub>3</sub> .	SnO <sub>2</sub> .	B <sub>2</sub> O <sub>3</sub> .	H <sub>2</sub> O.
No. 1...	31.1	5.0	.....	6.7	5.4
No. 2...	29.4	5.6	1.0	6.2	.....
No. 3...{	28.5 30.0	4.9 4.9	1.0 1.0	5.2 5.2	.....

Averages of these figures give as the most probable formula for paigeite, and the one proposed for the mineral, 30FeO.5Fe<sub>2</sub>O<sub>3</sub>.1SnO<sub>2</sub>.6B<sub>2</sub>O<sub>3</sub>.5H<sub>2</sub>O.

The above formula is complex and yields a high ratio of FeO to SnO<sub>2</sub>, but no other interpretation of the analyses can be made. It is not impossible that paigeite may be a mixture of two or more closely related minerals, but only the unusual composition indicates such a mixture. The constant small percentage of tin oxide shows the material to be essentially different in ratios from the corresponding hulsite. The occurrence of the mineral in wavy, lamellar masses or in fine radiating fibers, its intense shiny black color, and the marked tendency shown in thin sections by the individual fibers and masses to fray out at the ends into a bunch of very thin fibers serve to differentiate this mineral from hulsite, which never shows any indication of fibrosity.

An alternative interpretation of the composition of paigeite is that it is a mixture of hulsite and a fibrous borate. Subtracting from the formula of paigeite the constituents of hulsite in the amounts necessary to include all the tin, the following results are obtained:

Paigeite.....	30	FeO	5	Fe <sub>2</sub> O <sub>3</sub>	1	SnO <sub>2</sub>	6	B <sub>2</sub> O <sub>3</sub>	5	H <sub>2</sub> O
Equivalent of hulsite...	12	FeO	2	Fe <sub>2</sub> O <sub>3</sub>	1	SnO <sub>2</sub>	3	B <sub>2</sub> O <sub>3</sub>	2	H <sub>2</sub> O
Remainder.....	18	FeO	3	Fe <sub>2</sub> O <sub>3</sub>	.....		3	B <sub>2</sub> O <sub>3</sub>	3	H <sub>2</sub> O

This remainder may be written 6FeO.Fe<sub>2</sub>O<sub>3</sub>.B<sub>2</sub>O<sub>3</sub>.H<sub>2</sub>O.

Should future investigation prove this interpretation correct, the material now called paigeite would consist of a mixture of 1 part of hulsite and 3 parts of the borate 6FeO.Fe<sub>2</sub>O<sub>3</sub>.B<sub>2</sub>O<sub>3</sub>.H<sub>2</sub>O, to which the name paigeite could then be referred. It is most reasonable, however, from the evidence at hand, to regard paigeite as homogeneous and as having the composition ascribed to it.

## CHEMICAL COMPOSITION OF JAMESONITE AND WARRENITE.

### INTRODUCTION.

Knowledge of the difficult group of sulpho-salts has, in the last few years, been much enriched by the labors of English mineralogists, particularly those of the British Museum. Spencer, whose work has been especially notable, in a recent paper considers warrenite, which was described as a new mineral by Eakins, a former member of the U. S. Geological Survey laboratory, as identical with jamesonite, for which he proposes a new formula.<sup>1</sup>

This criticism naturally created considerable interest at the Survey laboratory, and at the suggestion of Prof. F. W. Clarke, the writer undertook a reexamination of the subject. W. F. Ferrier generously furnished for the investigation his collection of warrenite, consisting of over a dozen specimens, which agreed in general character with those in the British Museum, as described by Spencer.<sup>2</sup> The gangue of the specimens examined consists of pink rhodochrosite, in the cavities of which the felted aggregates of short and straight needles characteristic of the mineral occur.

As much of the felted material as possible was picked out. Though the bulk was large, the weight was inconsiderable; in fact, the quantity of material was entirely insufficient to warrant any chemical analysis. Press of routine work necessitated laying the problem aside for a time, and before more material could be separated from the gangue the specimens were practically ruined by fire on December 16, 1908. The loss precluded any chemical work being done, but some of the results obtained by review of previous work led to conclusions which may further contribute to knowledge of these minerals.

### FORMULA OF JAMESONITE.

Spencer concluded that the most probable formula for jamesonite was  $7(\text{Pb}_{\frac{1}{3}}, \text{Fe}_{\frac{1}{3}})\text{S}.4\text{Sb}_2\text{S}_3$ . If this be expanded, we obtain  $\text{Pb}_{28}\text{Fe}_7\text{Sb}_{40}\text{S}_{95}$ , a formula resembling so closely the simple formula  $\text{Pb}_{28}\text{Fe}_7\text{Sb}_{42}\text{S}_{98}$ , or  $\text{Pb}_4\text{FeSb}_6\text{S}_{14}$ , that inquiry was directed as to whether or not the latter might represent the composition of jamesonite. The suggestion that iron seems to be present in amount nearly constant (between 2 and 3 per cent) certainly seems to be justified by the analyses given. Spencer has selected from the literature of the subject those analyses of jamesonite made on material with characteristic and well defined physical properties, such as the

<sup>1</sup> Spencer, L. J., Note on "feather ore;" identity of "domingite" (= "warrenite") with jamesonite: Mineralog. Mag., vol. 14, 1907, p. 207; Analysis of crystallized jamesonite, idem, p. 310.

<sup>2</sup> Idem, p. 208.

basal cleavage. Since these are the only analyses that can be used, they are repeated below,<sup>1</sup> together with the values calculated for a new formula proposed for jamesonite, namely  $4\text{PbS} \cdot \text{FeS} \cdot 3\text{Sb}_2\text{S}_3$ .

*Analyses of jamesonite.*

	Calculated.	1	2	3	4	5	6	7	8	9	10
S.....	21.86	20.52	21.37	22.15	22.53	[23.01]	21.78	21.52	20.86	21.35	21.75
Sb.....	35.10	34.53	34.70	34.40	34.90	33.47	32.62	33.03	31.94	( <sup>a</sup> )	32.00
Pb.....	40.32	41.18	40.08	40.75	39.45	40.35	39.97	40.13	42.79	40.47	39.05
Fe.....	2.72	2.76	2.79	2.30	2.65	2.96	3.63	(a)	2.83	2.68	2.00
Cu.....		.26	.22	.13	.19	.21			1.01	.50	3.45
Zn.....							.42	.36	1.84	5.82	.62
Bi.....							1.06				
Ag.....	.01		.13								1.34
As.....											.20
	100.00	99.26	99.29	99.73	99.72	100.00	99.48		101.27		100.41

<sup>a</sup> Not determined.

Copper and zinc in considerable quantities are present in the last three analyses, provided, of course, that the samples were pure, an assumption not necessarily true. These analytical figures are very close to the values calculated for the formula here proposed, and support that formula quite as much as the more complicated one of Spencer. Loczka has published an analysis<sup>2</sup> of "a felted aggregate of dark steel-gray fibers," which he refers to plumosite, and from which he calculated a formula identical with the one here proposed, namely  $4\text{PbS} \cdot \text{FeS} \cdot 3\text{Sb}_2\text{S}_3$ . In abstracting Loczka's article Spencer states<sup>3</sup> that "the figures agree still more closely with the jamesonite formula,  $7(\text{Pb}_{\frac{1}{2}}\text{Fe}_{\frac{1}{2}})\text{S} \cdot 4\text{Sb}_2\text{S}_3$ ," a statement hardly borne out by the facts. Loczka's analysis and the values calculated for Spencer's formula<sup>4</sup>  $7(\text{Pb}_{\frac{1}{2}}\text{Fe}_{\frac{1}{2}})\text{S} \cdot 4\text{Sb}_2\text{S}_3$ , and for the formula  $4\text{PbS} \cdot \text{FeS} \cdot 3\text{Sb}_2\text{S}_3$ , appended for purposes of comparison, are given in the following table:

*Loczka's analysis and values calculated for the two formulas.*

Loczka's analysis.	$7(\text{Pb}_{\frac{1}{2}}\text{Fe}_{\frac{1}{2}})\text{S} \cdot 4\text{Sb}_2\text{S}_3$ .	$4\text{PbS} \cdot \text{FeS} \cdot 3\text{Sb}_2\text{S}_3$ .
S.....	21.59	21.70
Sb.....	35.80	34.23
Pb.....	39.38	41.29
Fe.....	2.65	2.78
Mn.....	.12	
Zn.....	.10	
Cu.....	Trace.	
Insoluble matter.....	.50	
	100.14	100.00
		100.00

<sup>1</sup> Analyses 1 and 2 (Bolivian material), are by Prior; 3, 4, and 5 by Rose (1826, 1829); 6 and 7 by Schaffgotsch (1836); 8 and 9 by Rammelsberg (1849); 10 by Sievert (1873). For references see Mineralog. Mag., vol. 14, 1907, p. 313.

<sup>2</sup> Loczka, Josef, Analysis of plumosite from Felsobanya: Ann. musei Nat. Hungarici, vol. 6, 1908, p. 586.

<sup>3</sup> Jour. Chem. Soc., vol. 96, 1909, p. 153.

<sup>4</sup> The figures are calculated from the 1909 table of atomic weights and differ very slightly from those given by Spencer.

Loczka's analysis agrees more closely with the simple formula, which is certainly the one to be preferred. It is much to be regretted that Loczka did not state definitely whether the fibers were flexible or brittle, but from the analytical figures alone his analysis must be referred to jamesonite and not to plumosite.

The evidence herein cited gives ample support to the formula first given by Loczka and reached independently by the writer. The chemical formula for jamesonite may then be given as  $4\text{PbS} \cdot \text{FeS} \cdot 3\text{Sb}_2\text{S}_3$  (Loczka), while for plumosite the simpler composition  $2\text{PbS} \cdot \text{Sb}_2\text{S}_3$  (Spencer) holds, the two minerals being distinguished chemically by the respective presence and absence of iron.

### COMPOSITION OF WARRENITE.

Spencer includes warrenite under jamesonite, and the analysis given by Eakins agrees well both with Spencer's and with Loczka's formulas, though the iron is nearly 1 per cent low. Spencer states<sup>1</sup> that "It was, however, determined that the needles (of warrenite) are brittle and not flexible. \* \* \* This latter character indicates that the material must be referred to jamesonite." He further classifies "feather-ores" as flexible and brittle, all the latter being referred to jamesonite and the former either to zinckenite, plumosite, boulangerite, or meneghinite. His statement that the needles of warrenite are not flexible was not confirmed by an examination of the specimens at the writer's disposal, for many were so flexible that they could be bent double without breaking, and sprang back to their original position when released. Other needles, however, were decidedly brittle, and instead of bending always broke across the elongation. Warrenite, then, has both flexible and brittle needles, and Eakin's analysis shows it to consist of a mixture of jamesonite and zinckenite.

*Eakin's analysis of warrenite, with ratios.*

	Analysis.	Ratios. Jame- sonite.	Zinck- enite.	Zinckenite ratios recal- culated.
S.....	21.19	0.661 = 0.448 + 0.213		4.00
Sb.....	36.34	.302 = .196 + .106		2.00
Pb.....	39.33	.190 = .128 + .062		1.17
Fe.....	1.77	.032 = .032 + .0		
Insol.....	.52			
	99.15			

The last column of ratios leads to the zinckenite formula,  $\text{PbS} \cdot \text{Sb}_2\text{S}_3$ . The analysis of warrenite, then, shows it to consist of a mixture of about 2 parts of jamesonite with 3 parts of zinckenite.

<sup>1</sup>Spencer, L. J., Note on "feather ore;" identity of "domingite" (= "warrenite") with jamesonite: Mineralog. Mag., vol. 14, 1907, p. 207.

## LUDWIGITE FROM MONTANA.

### OCCURRENCE AND ASSOCIATION.

The ludwigite here described was collected at Philipsburg, Mont., by Donald F. MacDonald, and was sent to the chemical laboratory of the survey for determination by F. C. Calkins. It is said to occur in metamorphosed limestone in connection with large bodies of magnetite. Examination of a thin section showed that a member of the olivine group was sprinkled throughout the ludwigite, and that a carbonate and a secondary fibrous mineral were also present in minute amounts.

The ludwigite forms small spherulites composed of radiating fibers of a very dark green or nearly black color, and resembles in its physical properties the original ludwigite from Hungary. With high magnification the fibers extinguish parallel and show a strong pleochroism, parallel to the elongation a sea green, and normal thereto a chestnut brown, with stronger absorption in the brown than in the green. The refractive index is much higher than 1.67. The olivine mineral has a mean refractive index of about 1.66, and cleavage sections parallel to  $b(010)$  showing  $\alpha$  and  $\beta$  have refractive indices lying between 1.65 and 1.66. The mineral must therefore be very low in ferrous iron, and is referred to forsterite. As no calcium was noted in the analysis, the carbonate is either magnesite or siderite.

### ANALYSIS.

The sample free from magnetite, but containing a small quantity of forsterite and minute amounts of the colorless fibrous mineral and the carbonate, gave on analysis the following results, the figures in the last column showing the values with the forsterite and carbonate deducted and the analysis recalculated to 100 per cent.

*Analyses of ludwigite from Montana.*

	Analyses of ludwigite mixed with forsterite and carbonate.				Analysis of ludwigite.
	1	2	3	Average.	
FeO.....	6.12	5.53	5.74	5.79	7.27
MgO.....	39.09	38.60	39.42	39.04	33.78
Total iron as Fe <sub>2</sub> O <sub>3</sub> .....	36.33	36.01	.....	.....	.....
Fe <sub>2</sub> O <sub>3</sub> .....	.....	.....	.....	29.73	37.37
SiO <sub>2</sub> .....	8.97	8.74	8.85	8.85	.....
Al <sub>2</sub> O <sub>3</sub> .....	1.98	1.64	.....	1.81	2.27
H <sub>2</sub> O+.....	.97	.....	.....	.97	1.24
H <sub>2</sub> O-.....	.91	.95	.85	.90	1.13
CO <sub>2</sub> .....	.28	.43	.....	.36	.....
B <sub>2</sub> O <sub>3</sub> .....	13.48	.....	.....	13.48	16.94
				100.93	100.00

The ferrous iron was determined by a modification of Pratt's method,<sup>1</sup> the material used being finely ground. Experiments conducted by Hillebrand on samples of this mineral showed that the oxidizing effect of grinding on the ferrous iron was slight. The first value for alumina, 1.98 per cent, was obtained as the difference between the gravimetric determination of R<sub>2</sub>O<sub>3</sub> and the subsequent volumetric titration of the iron with permanganate solution. The iron and aluminum chloride solution was repeatedly evaporated with methyl alcohol to expel all the boric acid. The second value, 1.64 per cent, was determined by precipitating the alumina by phenylhydrazine, as described by Allen.<sup>2</sup> As the two determinations agree fairly well, the presence of a small amount of alumina in the sample seems well confirmed. The higher result of the first case is probably due to retention of a small amount of boric acid. Whether the alumina belongs to the ludwigite or to one of the accompanying minerals is difficult to decide, but it has here been included in the borate. The boric acid content has also been determined by Wherry and Chapin,<sup>3</sup> who give as the average of their results 12.82 per cent B<sub>2</sub>O<sub>3</sub>, a value slightly lower than the one here given.

The water content, though small, is still of sufficient importance to merit consideration. Although no definite conclusion has been reached, it is believed that the greater part, if not all, of the water is not essential to the composition of the mineral. The determinations were made on finely ground material, which no doubt took up con-

<sup>1</sup> Hillebrand, W. F., The analysis of silicate and carbonate rocks: Bull. U. S. Geol. Survey No. 305, 1907, p. 138.

<sup>2</sup> Jour. Am. Chem. Soc., vol. 25, 1903, p. 421. See also Bull. U. S. Geol. Survey No. 305, 1907, p. 95.

<sup>3</sup> Wherry, E. T., and Chapin, W. H., Determination of boric acid in insoluble silicates: Jour. Am. Chem. Soc., vol. 30, 1908, p. 1691.

siderable water. A preliminary experiment on some ludwigite from Hungary gave the following values for the amount of water given off by the mineral when heated in a toluene bath at 110° in a current of dry air. Duplicate determinations were made, first on coarsely crushed material and then on another part of the same sample finely ground.

	(1)	(2)
Sample crushed <10> 20 mesh.....	0.09 per cent.	0.12 per cent.
Same finely ground.....	0.50 per cent.	0.52 per cent.

As some water may also have been furnished by the fibrous material, it seems justifiable to conclude that a large part, if not all, of the water reported in the analysis is extraneous. It has been omitted in the consideration of the ratios deduced from the analyses.

#### DISCUSSION OF FORMULA.

Ratios calculated from the figures of the average analysis are as follows:

*Ratios of average analysis of ludwigite.*

	Ratios.	Forsterite and magnetite deducted.	Ludwigite.
MgO.....	9760	8195	$\left\{ \begin{array}{l} 7532 = 4 \\ 0.43 \end{array} \right. \begin{array}{l} \text{MgO.} \\ \text{FeO.} \end{array}$
FeO.....	804	.....	
Fe <sub>2</sub> O <sub>3</sub> .....	1858	.....	
Al <sub>2</sub> O <sub>3</sub> .....	177	.....	$2035 = 1.08.$
SiO <sub>2</sub> .....	1475	1475	.....
CO <sub>2</sub> .....	82	82	.....
B <sub>2</sub> O <sub>3</sub> .....	1926	.....	$1926 = 1.02.$

The ratios agree well with the formula generally given for ludwigite, 4RO.Fe<sub>2</sub>O<sub>3</sub>.B<sub>2</sub>O<sub>3</sub>. The high water content obtained by Whitfield,<sup>1</sup> on Hungarian material, 3.62 per cent, is substantiated neither by the analysis of the Montana mineral given above nor by the analysis of Hungarian ludwigite described in this paper, but each sample yields about 1 per cent of water which can not as yet be proved foreign to the mineral and may ultimately be shown to be one of its essential constituents. If the water given off above 107° (H<sub>2</sub>O+) be considered as essential to the mineral, a formula of about the proportions, RO:Fe<sub>2</sub>O<sub>3</sub>:B<sub>2</sub>O<sub>3</sub>:H<sub>2</sub>O = 16:4:4:1 would result.

Although the ratios agree well with the general formula of ludwigite, the amount of ferrous iron is too small for the formula FeO.Fe<sub>2</sub>O<sub>3</sub>.3MgO.B<sub>2</sub>O<sub>3</sub>, even if all the ferrous iron in the analysis is referred to ludwigite and none either to forsterite or to the car-

<sup>1</sup> Whitfield, J. E., Natural borates and borosilicates: Am. Jour. Sci., 3d ser., vol. 34, 1887, p. 284.

bonate. These data indicate that the formula for the Montana ludwigite may be written .57MgO. .43FeO.  $\text{Fe}_2\text{O}_3$ . 3MgO. $\text{B}_2\text{O}_3$ , thus showing an isomorphous mixture of a *ferrous* ferric magnesian borate with a *magnesian* ferric magnesian borate, the latter being in excess.

Analyses by Ludwig and Sipöcz and by Whitfield are confirmed by the analysis published in this paper in the respect that the Hungarian mineral approximates closely to the definite formula  $\text{FeO} \cdot \text{Fe}_2\text{O}_3 \cdot 3\text{MgO} \cdot \text{B}_2\text{O}_3$ . Only one analysis by Ludwig and Sipöcz shows a slight deficiency in the ferrous iron.

The mineral from Montana, however, is very much lower in ferrous iron and correspondingly higher in magnesia, the ratios of  $\text{B}_2\text{O}_3:\text{Fe}_2\text{O}_3:\text{FeO} + \text{MgO}$  remaining constant. This condition supplies sufficient evidence of the existence of a magnesian ferric borate  $\text{MgO} \cdot \text{Fe}_2\text{O}_3 \cdot 3\text{MgO} \cdot \text{B}_2\text{O}_3$  free from ferrous iron, not yet found in nature in the pure state, but preponderant in the Montana ludwigite, in which it is present in isomorphous mixture with the corresponding ferrous ferric magnesian borate to the extent of 57 per cent. If some of the ferrous iron present in the sample belongs to the forsterite or to the carbonate, the percentage of the magnesian borate would be still greater.

#### LUDWIGITE FROM HUNGARY.

For comparison with the Montana mineral, an analysis was made of a sample of ludwigite from Hungary. The results of the quantitative analysis, made on the finely radiating black mineral, is as follows:

*Analyses of ludwigite from Hungary.*

	1	2	3	Average.
FeO.....	15.84	15.68	15.80	15.84
MgO.....	28.88	28.88	.....	28.88
Total iron as $\text{Fe}_2\text{O}_3$ .....	53.35	52.74	53.72	.....
$\text{Fe}_2\text{O}_3$ .....	.....	.....	.....	35.67
$\text{H}_2\text{O}$ —	.50	.52	.....	.51
$\text{H}_2\text{O}$ +.....	.78	.86	.....	.82
$\text{CO}_2$ .....	.90	.....	.....	.90
Insol.....	.32	.40	.....	.36
$\text{B}_2\text{O}_3$ .....	[17.02]	.....	.....	[17.02]
				100.00

The ratios from the average analysis give, after the  $\text{CO}_2$  is deducted, together with sufficient  $\text{MgO}$  to form magnesite, the formula  $\text{FeO} \cdot \text{Fe}_2\text{O}_3 \cdot 3\text{MgO} \cdot \text{B}_2\text{O}_3$ , as shown below.

*Ratios of average analysis of ludwigite from Hungary.*

FeO.....	0.220	0.99
MgO.....	.702	3.06
$\text{Fe}_2\text{O}_3$ .....	.223	1.00
$\text{B}_2\text{O}_3$ .....	.243	1.09
$\text{CO}_2$ .....	.020	.....

### SUMMARY.

The isomorphous relation of  $\text{FeO}$  and  $\text{MgO}$  in ludwigite can be well shown by bringing together the available analyses, which also show how closely the mineral from Hungary agrees with the calculated values for the pure ferrous-iron ferric magnesian borate. The first column gives the calculated values for  $\text{FeO} \cdot \text{Fe}_2\text{O}_3 \cdot 3\text{MgO} \cdot \text{B}_2\text{O}_3$ , the second, third, fourth, and fifth the analyses of the Hungarian mineral, and the sixth that of ludwigite from Montana.

*Analyses of ludwigite.*

FeO. $\text{Fe}_2\text{O}_3$ . 3MgO. $\text{B}_2\text{O}_3$ .	Ludwigite from Hungary analyzed by—					Ludwig- ite from Montana.
	Ludwig and Sipöcz.	Schaller.	Whitfield.	Ludwig and Sipöcz.		
	1	2	3	4	5	
FeO.....	17.01	17.67	15.84	15.78	12.46	7.27
MgO.....	28.61	26.91	28.88	30.57	31.69	33.78
$\text{Fe}_2\text{O}_3$ .....	37.81	39.29	35.67	37.93	39.92	37.37
$\text{Al}_2\text{O}_3$ .....						2.27
$\text{B}_2\text{O}_3$ .....	16.57	15.06	[17.02]	12.04	16.09	16.94
MnO.....		Trace.		.16	Trace.	.....
$\text{H}_2\text{O}$ —			.51			1.13
$\text{H}_2\text{O}$ +.....			.82	3.62		1.24
$\text{SiO}_2$ .....			.36			.....
$\text{CO}_2$ .....			.90			.....
	100.00	98.93	100.00	100.10	100.16	100.00

The last analysis by Ludwig and Sipöcz (No. 5 above) shows a slight replacement of the ferrous iron by magnesia, which has been carried out to a much larger extent in the mineral from Montana. All new occurrences of ludwigite should be carefully examined chemically, as the possibility of the existence of the ferrous-iron-free magnesian borate is strongly indicated by the above analyses.

## BISMITE FROM NEVADA.

### OCCURRENCE AND PHYSICAL PROPERTIES.

According to Ransome,<sup>1</sup> bismite occurs in the Goldfield district of Nevada in the January, Combination, and Sandstorm mines, and probably also in other mines, as minute, pearly scales of brilliant and almost metallic luster, which suggest at first glance delicate and untarnished crystals of native silver. This mineral, identified by him as bismite, is limited to the oxidized zone, is generally accompanied by limonite, and is not uncommonly associated with rich ore. It occurs as single glittering scales or specks on the walls of cavities in spongy limonite or rusty ledge matter, as delicate frost-like films on the same materials, and as spongy aggregates with quartz. In the last-named form it is clearly pseudomorphous after bismuthinite, the material having consisted originally of a mass of bismuthinite prisms held together by a siliceous gangue. The prismatic structure of the bismuthinite is retained as hollow casts in the quartz, lined or partly filled with scales of bismite. The single scales are doubtless also derived from bismuthinite, but migration has taken place either during or after oxidation, and the bismite scales do not occupy the exact position of the parent needles of bismuthinite.

Natural crystals of bismite do not appear to have been found hitherto, and, inasmuch as the mineral has been assigned to the orthorhombic system in Dana's and Hintze's mineralogies on the basis of Nordenskiöld's work on artificial crystals in 1860 and 1861, considerable interest attaches to the Goldfield occurrences on account of the crystallinity of the material.

When examined under the microscope in gently powdered material, the crystals appear as thin colorless scales, with occasionally a suggestion of hexagonal outline. On account of their tenuity, it is rare that an edge view of a scale can be obtained. The larger flat-lying scales are dark in all positions between crossed nicols, and give a negative uniaxial figure with convergent light. There are no colored rings, and double refraction, apparently, is not great. The refractive index, on the other hand, is comparatively high—greater than that of anorthite. The mineral has a perfect basal cleavage and the scales, when viewed without the analyzing Nicol, commonly show delicate interference colors, due to refraction and reflection at the surfaces of the exceedingly thin cleavage sheets.

<sup>1</sup> Ransome, F. L., The geology and ore deposits of Goldfield, Nev.: Prof. Paper U. S. Geol. Survey No. 66, 1909, p. 121.

## CRYSTALLOGRAPHY.

The minute, tabular crystals are too incomplete to make possible a determination of their geometrical form by crystallographic measurements alone. The uniaxiality and hexagonal outline of the crystals, the triangular markings on their bases, and the distribution of faces so far as known justify their provisional reference to the rhombohedral division of the hexagonal system.

The value of the  $c$  axis, derived in a manner presently to be described, is 0.5775. Seven faces are recognized—the base and one negative and five positive rhombohedra—and indications of two more positive rhombohedra appear. A brief description of these forms follows.

$c\{0001\}$ . Always very large, even, and highly polished. When triangular markings or striæ are shown the faces parallel to these markings are taken as positive.

$o\{10\bar{1}6\}$ . Occurs on two crystals as broad faces, giving, however, poor reflections. One face was considerably striated, giving two signals a degree apart.

$g\{10\bar{1}5\}$ . Broad faces giving fairly good reflections.

$u\{10\bar{1}4\}$ . Narrow faces, one striated with a fair reflection, and one as a line face giving a very poor reflection.

$k\{10\bar{1}3\}$ . Usually as a line face, striated and giving a very poor reflection.

(?) $\{20\bar{2}5\}$ . A doubtful face, narrow, giving no distinct signal.

(?) $d\{10\bar{1}2\}$ . Another doubtful face, narrow, and giving no distinct reflection.

$y\{20\bar{2}1\}$ . Line faces, giving exceedingly faint reflections.

$z\{01\bar{1}1\}$ . The only negative rhombohedron observed. Very faint line faces, giving no reflection. Its negative position could be determined only on crystal No. 6.

The measurements of the forms are shown below.

Measurements of forms on bismite crystals.

Symbol.	Measured.		Calculated.
$c\wedge o=(0001) : (10\bar{1}6)$ .....	6	37	6 21
$c\wedge q=(0001) : (10\bar{1}5)$ .....	7	33	7 36
$c\wedge u=(0001) : (10\bar{1}4)$ .....	9	31	9 28
$c\wedge k=(0001) : (10\bar{1}3)$ .....	{ 12	11 26	{ 12 32
	13	18	
$c\wedge y=(0001) : (20\bar{2}1)$ .....	54	54	53 08
$c\wedge z=(0001) : (01\bar{1}1)$ .....	35	32 $\frac{1}{2}$	33 42
Doubtful forms:			
$c\wedge ?=(0001) : (20\bar{2}5)$ .....	15	.....	14 56
$c\wedge d=(0001) : (10\bar{1}2)$ .....	16	20	18 26

The value for the  $c$  axis was obtained from three measurements considered most accurate. The others gave values agreeing fairly well with the one adopted, as is shown in one of the following tables. The crystals were measured on the two-circle goniometer and the  $\rho$  angle for these forms is the angle between that form and the base. The value  $p_o$  is obtained directly from the  $\rho$  angles and from the values for  $p_o$ , the  $c$  axis is readily calculated. The three best measurements are:

*Three best values of  $p_o$ , bismite.*

Crystal No. 1:  $\rho\{10\bar{1}5\}=7^\circ 33'$ ; therefore  $p_o=0.6627$

Crystal No. 4:  $\rho\{10\bar{1}5\}=7^\circ 36'$ ; therefore  $p_o= .6672$

Crystal No. 2:  $\rho\{10\bar{1}4\}=9^\circ 31'$ ; therefore  $p_o= .6706$

Average..... = 0.6668;  $c=0.5775$

An average of the other measurements gave values closely agreeing.

*Other values of  $p_o$ , bismite.*

Crystal No. 3:  $\rho\{10\bar{1}6\}=6^\circ 37'$ ; therefore  $p_o=0.6960$

Crystal No. 6:  $\rho\{10\bar{1}6\}=6^\circ 41'$ ; therefore  $p_o= .7031$

Crystal No. 6:  $\rho\{10\bar{1}4\}=9^\circ 31'$ ; therefore  $p_o= .6706$

Crystal No. 6:  $\rho\{10\bar{1}3\}=12^\circ 11'$ ; therefore  $p_o= .6477$

Crystal No. 4:  $\rho\{10\bar{1}3\}=12^\circ 26'$ ; therefore  $p_o= .6614$

Crystal No. 1:  $\rho\{10\bar{1}3\}=13^\circ 18'$ ; therefore  $p_o= .7102$

Average..... = 0.6815

The following measurements of faces giving no distinct reflections also showed close agreement:

*Additional values of  $p_o$ , bismite.*

Crystal No. 1:  $\rho\{10\bar{1}3\}=12^\circ-14^\circ$  (average  $13^\circ$ ); therefore  $p_o=0.69$

Crystal No. 2:  $\rho\{20\bar{2}\bar{5}\}=15^\circ$ ; therefore  $p_o= .67$

Crystal No. 1:  $\rho\{10\bar{1}2\}=16^\circ-20^\circ$  (average  $18^\circ$ ); therefore  $p_o= .65$

Crystal No. 5:  $\rho\{01\bar{1}1\}=35^\circ$ ; therefore  $p_o= .70$

Crystal No. 6:  $\rho\{01\bar{1}1\}=32\frac{1}{2}$ ; therefore  $p_o= .64$

Crystal No. 1:  $\rho\{20\bar{2}1\}=54^\circ$ ; therefore  $p_o= .69$

Crystal No. 6:  $\rho\{20\bar{2}1\}=54^\circ$ ; therefore  $p_o= .69$

The values for  $p_o$  given in these tables show that the interpretation of the forms is the correct one.

Of the six crystals (all incomplete) that were measured, only two require special mention. Figure 1 is an orthographic projection of crystal No. 1, showing the trigonal distribution of the rhombohedra, and the triangular markings on the base. Figure 2 shows a similar projection of crystal No. 6, with a negative rhombohedron.

So uneven is the development of the faces of these crystals that no two faces of the same form are present on the upper half of a crystal. This feature is, however, due in part to the incompleteness of the crystals.

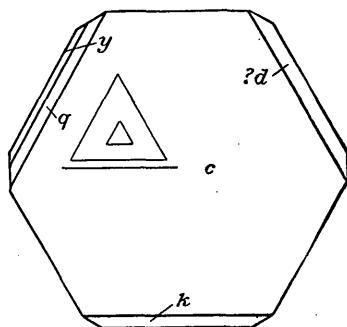


FIGURE 1.—Bismite crystal No. 1, orthographic projection.

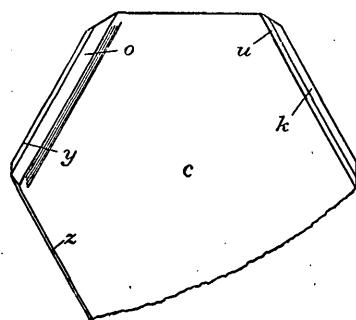


FIGURE 2.—Bismite crystal No. 6, orthographic projection.

### CHEMICAL COMPOSITION.

The best material obtainable consisted of the spongelike aggregates with quartz, and this, on analysis, yielded the following results:

#### *Analyses of bismite.*

	1	2	3	Average.
Matter insoluble in HCl (mostly quartz gangue).	78.95	78.87	79.01	78.94
$\text{Bi}_2\text{O}_3$ .....	17.29	17.00	16.84	17.04
$\text{H}_2\text{O}$ (loss on ignition).....	3.96	.....	.....	3.96
$\text{Fe}_2\text{O}_3$ .....	.36	.50	.21	.36
				100.30

The phosphate, chloride, carbonate, and sulphate radicles, as well as vanadium, arsenic, calcium, magnesium, and the alkalies were absent.

The analysis shows that the mineral is either bismite or a hydrous oxide of bismuth. If it is the latter, the mineral is a new species (providing, of course, that  $\text{Bi}_2\text{O}_3$  is the correct formula for the bismuth ocher found in nature and called bismite). Attempts to isolate a sufficient quantity of the pearly scales from the gangue for separate analysis were not successful. According to a recent paper<sup>1</sup> by the writer the mineral bismite is probably  $\text{Bi}(\text{OH})_3$ , as it seems very doubtful if  $\text{Bi}_2\text{O}_3$  exists in nature as such.

<sup>1</sup> Schaller, W. T., Bismuth ochers from San Diego County, Cal.: Jour. Am. Chem. Soc., vol. 33, 1911, p. 162.

## **AXINITE FROM CALIFORNIA.**

### **LOCALITIES.**

Well-crystallized axinite has been found at two widely separated points in California. In 1903-4 some large brownish crystals were found in Moosa Canyon, near Bonsall, San Diego County, by Mr. T. Freeman and forwarded by him to Dr. G. F. Kunz of New York, who determined them as axinite. The writer visited the locality in 1904 and collected a suite of the specimens which form the basis of this description. The work of collection was greatly facilitated through the kindness of Mr. Freeman and of Mr. J. J. Mack, both of San Diego County, whose assistance was of great value. A specimen of axinite from the Consumnes Copper Mine, Amador County, was lent to the writer from the collection of the University of California through the kindness of Prof. A. S. Eakle. The axinite, which is probably of contact origin, is associated with large epidote and small quartz crystals.

### **AXINITE FROM SAN DIEGO COUNTY.**

#### **OCCURRENCE.**

The axinite of San Diego County appears in detached crystals associated with quartz, epidote, and a little laumontite in a much decomposed granite, and its true mode of occurrence is not determinable, for all the rock in the vicinity is greatly altered. The crystals range from minute size to a length of nearly 5 centimeters; they are generally flattened, rough, worn, and opaque, with small transparent areas scattered throughout the crystal mass. A few, which are highly decomposed, appear as a black mass consisting largely of manganese dioxide. The quartz on which the axinites are often grouped is found both in massive pieces and in distinct crystals. It is characteristically of the smoky variety, and often very closely resembles the axinite in color. A very few specimens consisted of radiated greenish epidote, surrounded by idiomorphic axinite into which the epidote fibers penetrate. The laumontite occurs sparingly as isolated white crystals situated on the other minerals.

#### **CRYSTALLOGRAPHY.**

The larger crystals of axinite are simple in their combinations and show the usual axinite forms, such as *m*, *M*, *r*, *z*, *c*, *s*, and *x*. The smaller crystals are more perfect and show a greater number of

forms. Only a few of the crystals are at all suitable for measurement, most of them being too dull and uneven. Many, too, are considerably striated, and often a number are grouped in nearly parallel position.

The forms identified on these crystals are as follows, the position chosen being that of Miller as modified by Goldschmidt in his Winkeltabellen: {010}, {110}, {1 $\bar{1}$ 0}, {1 $\bar{2}$ 0}, {0 $\bar{3}$ 1}?, {0 $\bar{1}$ 1}, {0 $\bar{1}$ 2}, {101}, {112}, {1 $\bar{2}$ 1}, {111}, {1 $\bar{1}$ 2}, {221}.

The following table gives the measurements of these forms as compared with the calculated values taken from Goldschmidt's Winkeltabellen and with the letters and symbols given by Dana for the same forms:

*Forms and angles for axinite from San Diego County.*

Goldschmidt's symbols.		Dana's symbols.		Measured.		Calculated.	
Letter.	Symbol.	Letter.	Symbol.	$\phi$	$\rho$	$\phi$	$\rho$
c	010	M	1 $\bar{1}$ 0	0 00	90 00	0 00	90 00
w	110	w	1 $\bar{3}$ 0	60 27	90 00	60 16	90 00
u	1 $\bar{1}$ 0	m	110	135 22	90 00	135 24	90 00
l	1 $\bar{2}$ 0	a	100	150 42	90 00	151 23	90 00
$\phi$	0 $\bar{3}$ 1	$\phi$	3 $\bar{3}$ 1	176 50	68 11	177 20	71 36
r	0 $\bar{1}$ 1	r	1 $\bar{1}$ 1	172 03	46 22	172 02	45 21
z	0 $\bar{1}$ 2	z	1 $\bar{1}$ 2	164 07	27 36	164 24	27 32
a	101	y	021	106 00	49 00	104 04	49 10
o	112	o	1 $\bar{3}$ 2	53 38	32 00	53 49	31 19
s	1 $\bar{2}$ 1	s	201	153 31	68 29	153 49	68 32
x	1 $\bar{1}$ 1	x	111	138 44	59 44	138 48	59 36
n	1 $\bar{1}$ 1	n	1 $\bar{3}$ 1	117 17	57 43	117 16	57 38
$\delta$	1 $\bar{1}$ 2	$\delta$	1 $\bar{3}$ 2	115 27	40 28	115 08	40 26

Of these forms {010}, {110}, {1 $\bar{1}$ 0}, {1 $\bar{2}$ 1}, and {0 $\bar{1}$ 1} are large, the other forms occur as small faces.

The form  $\kappa$  {221} was noted on one crystal in a zone with the forms {110} large, {221} line face, {111} medium, and {112} line face.

#### CHEMICAL COMPOSITION.

A large sample was crushed and the clear fragments of axinite picked out. Treatment with heavy solution served to remove a little quartz similar in color and appearance which had been picked up with the axinite. The following is the average of several analyses. The water was given off above 110° and its amount was determined directly.

*Analysis of axinite, San Diego County.*

SiO <sub>2</sub> .....	42.61
Al <sub>2</sub> O <sub>3</sub> .....	17.43
Fe <sub>2</sub> O <sub>3</sub> .....	.38
FeO.....	7.53
MnO.....	4.10
MgO.....	.44
CaO.....	19.74
H <sub>2</sub> O.....	1.56
B <sub>2</sub> O <sub>3</sub> .....	6.04
	99.83

As this analysis was made before the oxidizing effect of grinding was known, the true amount of ferric oxide in the mineral may be even less than that given.

The ratios calculated from the analysis are shown herewith.

*Ratios of analysis of axinite, San Diego County.*

SiO <sub>2</sub> .....	0.710=8.00
Al <sub>2</sub> O <sub>3</sub> .....	
Fe <sub>2</sub> O <sub>3</sub> .....	}
FeO.....	
MnO.....	}
MgO.....	
CaO.....	.353=3.97
H <sub>2</sub> O.....	.087=.98
B <sub>2</sub> O <sub>3</sub> .....	.086=.97

The above figures indicate the formula for axinite to be 8SiO<sub>2</sub>, 2Al<sub>2</sub>O<sub>3</sub>, 2(Fe, Mn, Mg)O, 4CaO, 1H<sub>2</sub>O, 1B<sub>2</sub>O<sub>3</sub>. If all the bivalent bases are grouped together, the formula reduces to 8SiO<sub>2</sub>, 2Al<sub>2</sub>O<sub>3</sub>, 1B<sub>2</sub>O<sub>3</sub>, 7RO, the one proposed by Ford<sup>1</sup> for the mineral in a discussion of several analyses including his own, in the course of which paper he shows that the general formula for axinite may be written:



Examination of the more recent trustworthy analyses of axinite has convinced the writer that the calcium content is constant, and that, as the iron and manganese vary reciprocally, there are two end products, one free from iron and the other free from manganese, and that all axinites may be considered as isomorphous mixtures of these two end products.

Thirteen trustworthy analyses, in nearly all of which the water was determined directly, were selected, and the ratios of the various constituents calculated. These analyses, arranged in the order of increasing amounts of manganese, are given below.

<sup>1</sup> Ford, W. J., On the chemical composition of axinite: Am. Jour. Sci., 4th ser., vol. 15, 1903, p. 195.

*Analyses of axinite.*

No.	SiO <sub>3</sub>	B <sub>2</sub> O <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	FeO.	MnO.	CaO.	MgO.	H <sub>2</sub> O.	K <sub>2</sub> O.	Na <sub>2</sub> O.	(Cu, Zn, Pb)O.
1	42.89	6.02	18.25	0.64	7.11	1.06	19.89	2.23	2.14	0.11	0.36	.....
2	43.46	5.61	16.33	2.80	6.78	2.62	20.19	1.73	1.45	.11	.....	.....
3	42.78	6.12	17.67	.99	6.02	2.99	20.16	2.41	1.40	.....	.....	.....
4	41.53	4.62	17.90	3.90	4.02	3.79	21.66	.74	2.16	.....	.....	.....
5	42.10	4.64	17.40	3.06	5.84	4.63	20.53	.66	1.80	.....	.....	.....
6	42.40	4.71	17.39	.59	4.89	6.16	19.57	1.69	1.64	.25	.24	(F = .22)
7	42.40	4.88	17.26	1.33	4.27	6.97	19.53	1.30	1.90	.....	.....	.....
8	42.55	4.20	16.37	3.79	4.06	7.69	19.28	1.02	(1.33)	.....	.....	.....
9	41.96	4.61	17.69	.81	3.61	8.51	19.71	.97	1.93	.....	(F = 1.11)	.....
10	42.85	5.17	16.96	5.00	.....	9.59	18.49	.87	(.75)	.....	.....	.19
11	41.80	5.61	17.15	1.11	2.84	10.71	19.51	.21	1.22	.....	.....	.....
12	42.47	5.05	16.85	1.16	.....	13.14	18.35	.26	1.21	.....	.....	1.73
13	42.77	5.10	16.73	1.03	.....	13.69	18.25	.23	1.29	.....	.....	1.60

1. Jannasch and Locke, Zeitschr. anorg. Chemie, vol. 6, 1894, p. 57.

2. Rammelsberg, Zeitschr. Deutsch. geol. Gesell., vol. 21, 1869, p. 689.

3, 11. Ford, Am. Jour. Sci., 4th ser., vol. 15, 1903, p. 195.

4, 5. Whitfield, Am. Jour. Sci., 3d ser., vol. 34, 1887, p. 286.

6, 7, 9. Mauzelius, Geol. für Föhr., vol. 17, 1895, p. 279.

8. Cleve, Geol. für. Föhr., vol. 17, 1895, p. 279.

10, 12, 13. Genth, Am. Jour. Sci., 3d ser. vol. 41, 1891, p. 394.

In analyses 8 and 10 the water content was determined by ignition, and the ratios are for that reason omitted in the following table. The figures for the water content in analyses 12 and 13 are those obtained by Ford.<sup>1</sup> The percentage of fluorine (1.11) given in analysis 9 is undoubtedly too high.

Ratios from the foregoing analyses are shown in the following table. The small amounts of zinc, lead, copper, soda, and potash present have been added to the magnesia ratio.

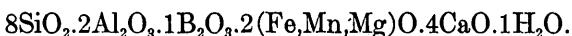
*Ratios of axinite analyses.*

Analysis No.—	SiO <sub>2</sub>	B <sub>2</sub> O <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub>	FeO.	MnO.	CaO.	MgO.	H <sub>2</sub> O.
1	7.96	0.96	2.06	1.10	0.16	3.98	0.70	1.34
2	8.14	.90	2.00	1.06	.42	4.04	.50	.90
3	8.02	.98	1.98	.94	.48	4.04	.74	.86
4	7.82	.76	2.28	.64	.60	4.38	.20	1.36
5	7.92	.74	2.14	.92	.74	4.14	.18	1.14
6	7.84	.76	1.96	.76	.98	3.92	.54	1.16
7	7.84	.78	2.00	.66	1.10	3.90	.12	1.18
8	8.10	.70	2.12	.64	1.24	3.96	.32	.....
9	7.88	.74	2.02	.56	1.36	4.00	.28	1.32
10	8.10	.84	2.26	None.	1.54	3.78	.26	.....
11	7.84	.92	1.98	.44	1.72	3.98	.06	.76
12	8.08	.84	1.98	None.	2.12	3.76	.32	.78
13	8.38	.86	1.96	None.	2.28	3.84	.30	.84

The average of the above ratios of the 13 analyses given is 7.99SiO<sub>2</sub>. 0.83B<sub>2</sub>O<sub>3</sub>. 2.06 (Al,Fe)<sub>2</sub>O<sub>3</sub>. 2.07 (Fe,Mn,Mg)O. 3.90CaO. 1.05H<sub>2</sub>O. The boric acid ratio is a little low because of the incomplete extraction of B<sub>2</sub>O<sub>3</sub> in the analyses. The average ratios, like

<sup>1</sup> Loc. cit.

those of the analysis of axinite from Bonsall, San Diego County, are very close to the simple formula:



As can be seen by the table of analyses on page 40, the ferrous iron and manganese vary reciprocally, because of which fact the writer considers axinite an isomorphous mixture of the two minerals, ferro-axinite,  $\text{Al}_2\text{BHCa}_2\text{FeSi}_4\text{O}_{16}$  and manganoaxinite,  $\text{Al}_2\text{BHCa}_2\text{MnSi}_4\text{O}_{16}$ . Whitfield<sup>1</sup> suggested that there were two such end products, but his formulas differed from those given above. These two compounds may be readily distinguished qualitatively, where either preponderates sufficiently in a mixture, by the color of the bead of the fused mineral. That of ferroaxinite is black, and that of manganoaxinite is very light colored or gray if a slight amount of iron is present.

One analysis, that by Baumert,<sup>2</sup> is purposely omitted, as the high calcium content (30.21 per cent) obtained occasions some doubt as to the accuracy of the analysis, especially as the sequioxides are also low.

The specific gravity of the mineral apparently increases with the amount of manganese present, as is shown in the following table, but it is probable that careful determinations on pure material will show that ferroaxinite is slightly the heavier.

*Specific gravity of axinite.*

Analysis No.—	Per cent MnO.	Specific gravity.
1	1.06	3.268
2	2.62	.....
3	2.99	3.287
4	3.79	.....
5	4.63	.....
6	6.16	3.28
7	6.97	3.30
8	7.69	.....
9	8.51	3.30
10	9.59	3.299
11	10.71	a 3.302
12	13.14	3.306
13	13.69	3.358

<sup>a</sup> Given by Ford (*loc. cit.*) as 3.028 by mistake. Ford has informed the writer that the value should be as given above.

It was proposed to investigate the various physical constants of axinite in order to see if corresponding variations could be determined for the different ratios of FeO to MnO, but the material available was lost by fire before the work could be undertaken.

<sup>1</sup> Am. Jour. Sci., 3d ser., vol. 34, 1887, p. 286.

<sup>2</sup> Zeitsch. Nat. Halle, vol. 42, 1889, p. 1, and Dana's System of Mineralogy, 6th ed., p. 529.

## AXINITE FROM AMADOR COUNTY.

## CRYSTALLOGRAPHY.

The crystals of axinite from the Consumnes copper mine, Amador County, are very small, their dimensions rarely exceeding 2 millimeters, and are for the most part transparent and highly polished. They are associated with large epidote and quartz crystals, which are covered with a drusy coating of small axinites. These axinites lie on the epidote and quartz, and also penetrate them to some extent, some axinite being entirely embedded in the quartz. Preliminary measurements of two crystals showed that the small crystals were very rich in forms, and it was intended to continue the study of these crystals, as well as of the mineral axinite in general, at some future time. Of 24 forms noted on the crystals, 8 are apparently new. The list of forms follows, the symbols being given in Miller's orientation as modified by Goldschmidt in his Winkeltabellen. New forms are starred. {010}, {100}, {110}, \*{210}, {120}, \*{14.1.0}, {110}, {340}, {230}, {350}, {130}, {970}, \*{940}, \*{720}, \*{9.10.0}, \*{290}, {120}, \*{780}, \*{1.13.0}, {112}, {011}, {011}, {121}, {111}.

The average measurements of these forms as compared with the calculated values are shown in the table below.

*Forms and angles, axinite.*

[Asterisks indicate new form.]

Goldschmidt.		Dana.		Measured.		Calculated.	
Letter.	Symbol.	Letter.	Symbol.	$\phi$	$\rho$	$\phi$	$\rho$
c	010	M	110	0 00	90 00	0 00	90 00
M	100	b	010	102 27	90 00	102 30	90 00
r	120	.....	120	36 15	90 00	36 15	90 00
w	110	w	130	61 58	90 00	60 16	90 00
*A	210	.....	160	80 22	90 00	80 06	90 00
*C	14. 1. 0	.....	1. 29. 0	99 23	90 00	99 22	90 00
*D	720	.....	160	113 56	90 00	114 08	90 00
*E	940	.....	270	119 45	90 00	119 51	90 00
S	970	.....	7. 11. 0	129 55	90 00	129 58	90 00
u	110	m	110	135 24	90 00	135 24	90 00
*F	9. 10. 0	.....	540	137 49	90 00	137 47	90 00
*G	780	.....	430	138 22	90 00	138 26	90 00
$\alpha$	340	$\alpha$	210	142 19	90 00	141 58	90 00
H	230	H	310	144 07	90 00	144 40	90 00
$\beta$	350	$\beta$	510	147 24	90 00	147 03	90 00
l	120	a	100	151 21	90 00	151 23	90 00
h	130	h	310	159 18	90 00	158 58	90 00
*N	290	.....	950	165 18	90 00	165 12	90 00
*P	1. 13. 0	.....	13. 15. 0	174 34	90 00	174 26	90 00
e	011	e	111	6 36	45 42	7 58	45 16
x	111	x	111	138 45	60 57	138 48	59 36
s	121	s	201	153 00	69 05	153 49	68 32

Of the above forms,  $\gamma\{120\}$  was first given by Sjögren<sup>1</sup> on axinite from Nordmarken.

The measurements of the narrow face gave the following values:

*Measurements of  $\gamma\{120\}$ .*

Symbol.	Meas- ured.	Cal- culated.	Differ- ence.
010 $\wedge$ 120	36 15	36 15	0 00
110 $\wedge$ 120	24 12	24 01	0 11
1 $\bar{1}$ 0 $\wedge$ 120	98 55	99 09	0 14

The form  $S\{9\bar{7}0\}$  was first noted by Franck<sup>2</sup> and was observed once as a narrow face giving a poor reflection.

*Measurements of  $S\{9\bar{7}0\}$ .*

Symbol.	Meas- ured.	Cal- culated.	Differ- ence.	Franck's measure- ment.
010 $\wedge$ 9 $\bar{7}0$	50 05	50 02	0 03	49 44
1 $\bar{2}0\wedge 9\bar{7}0$	21 27	21 25	0 02	.....
100 $\wedge$ 9 $\bar{7}0$	27 07	27 28	0 21	.....
9. 10. 0 $\wedge$ 9 $\bar{7}0$	7 54	7 49	0 05	.....

The following eight prisms are evidently new—at least they are not described in the literature of the subject, so far as known to the writer.

The form  $A\{210\}$  occurs as a line face giving a poor reflection.

*Measurements of  $A\{210\}$ .*

Symbol.	Meas- ured.	Cal- culated.	Differ- ence.
100 $\wedge$ 210	22 08	22 24	0 16
14. 1. 0 $\wedge$ 210	19 01	19 16	0 15

The prism  $C\{14.1.0\}$  has more of a vicinal symbol than most of the new prisms, but the measured and calculated angles agree so well that the form is considered established. It occurs as a line face giving a poor reflection.

<sup>1</sup> Sjögren, HJ., Beiträge z. Mineralogie Schwedens: Bull. Geol. Inst. Upsala, vol. 1, 1892, p. 1.

<sup>2</sup> Franck, A., Bull. Acad. Belgique, vol. 25, 1893, p. 17.

*Measurements of C{14.1.0}.*

Symbol.	Meas- ured.	Cal- culated.	Differ- ence.
110 $\wedge$ 14.1.0	° / 36 01	° / 36 02	° / 0 01
100 $\wedge$ 14.1.0	3 07	3 08	0 01

The new form  $D\{7\bar{2}0\}$  is present once as a line face giving a poor reflection.

*Measurements of D{7\bar{2}0}.*

Symbol.	Meas- ured.	Cal- culated.	Differ- ence.
010 $\wedge$ 720	° / 66 04	° / 65 52	° / 0 12
100 $\wedge$ 720	11 08	11 38	0 30
940 $\wedge$ 720	5 49	5 43	0 06

The prism  $E\{9\bar{4}0\}$  occurs with the preceding form, and, like it, is a line face giving a poor reflection.

*Measurements of E{9\bar{4}0}.*

Symbol.	Meas- ured.	Cal- culated.	Differ- ence.
010 $\wedge$ 940	° / 60 15	° / 60 09	° / 0 06
100 $\wedge$ 940	16 57	17 21	0 24
9.10.0 $\wedge$ 940	18 04	17 56	0 08

The form  $F\{9.\bar{1}0.0\}$  approaches to a vicinal form, though the measured and calculated angles agree well. It is present as a narrow face much broader than a line face and gives a fairly good reflection. Apparently, it replaces the form  $u\{1\bar{1}0\}$ , for the two are not found together.

*Measurements of F\{9.\bar{1}0.0\}.*

Symbol.	Meas- ured.	Cal- culated.	Differ- ence.
010 $\wedge$ 9.10.0	° / 42 11	° / 42 13	° / 0 02
120 $\wedge$ 9.10.0	13 33	13 36	0 03
100 $\wedge$ 9.10.0	35 01	35 17	0 16

The new prism  $G\{7\bar{8}0\}$  is very close to the above, though the measured and calculated angles agree well. It is probably identical with or near to the form  $\{15.17.0\}$ , described by Offret and Gonnard.<sup>1</sup> It is present as a line face with  $u\{1\bar{1}0\}$  on the crystal from Amador County. The reflection was fairly good.

*Measurements of  $G\{7\bar{8}0\}$ .*

Symbol.	Measured.	Calculated.	Difference.	Measured by Offret and Gonnard.
$0\bar{1}0\wedge 7\bar{8}0$ .....	41 38	41 34	0 04	.....
$1\bar{1}0\wedge 7\bar{8}0$ .....	2 58	3 02	0 04	2 48
$1\bar{2}0\wedge 7\bar{8}0$ .....	12 39	12 57	0 18	.....

The form  $N\{2\bar{9}0\}$  occurs as a narrow face giving a fairly good reflection.

*Measurements of  $N\{2\bar{9}0\}$ .*

Symbol.	Measured.	Calculated.	Difference.
$0\bar{1}0\wedge 2\bar{9}0$ .....	14 42	14 48	0 06
$1\bar{2}0\wedge 2\bar{9}0$ .....	13 45	13 49	0 04
$1\bar{1}0\wedge 2\bar{9}0$ .....	29 54	29 48	0 06

The new prism  $P\{1.\bar{1}3.0\}$  is of a vicinal character, but, like some of the other forms here described, the measured and calculated angles agree well. It is present as a narrow face next to  $\{0\bar{1}0\}$ , and gives a good reflection.

*Measurements of  $P\{1.\bar{1}3.0\}$ .*

Symbol.	Measured.	Calculated.	Difference.
$0\bar{1}0\wedge 1.\bar{1}3.0$ ....	5 26	5 34	0 08
$1\bar{2}0\wedge 1.\bar{1}3.0$ ....	23 11	23 25	0 14
$1\bar{1}0\wedge 1.\bar{1}3.0$ ....	39 10	39 02	0 08

<sup>1</sup> Offret, A., and Gonnard, F., Note cristallographique sur l'axinite de l'Oisans: Bull. Soc. franç. minéral., vol. 16, 1893, p. 75.

## CHEMICAL COMPOSITION.

Lack of material made it impossible to obtain enough axinite for a more complete analysis than is here given. The sample analyzed was not quite pure, for small amounts of impurities were plainly visible before the sample was ground. It was necessary to determine the boric acid content by difference. The analysis and ratios follow:

*Analysis and ratios of axinite from Amador County.*

	Analysis.	Ratios.
SiO <sub>2</sub> .....	42.79	8.00
Al <sub>2</sub> O <sub>3</sub> .....	16.38	1.81
FeO.....	4.22	
MnO.....	8.76	2.05
MgO.....	0.09	
CaO.....	19.21	3.85
H <sub>2</sub> O.....	1.85	1.16
B <sub>2</sub> O <sub>3</sub> (by difference).....	6.70	1.02
	100.00	

The ratios approximate those proposed in the first part of this paper, but the material was of too poor quality and of too slight amount to admit of accurate deductions from the analysis. It may be noted that in the Amador County axinite the manganese predominates over the iron, whereas in the axinite from San Diego County the reverse is true.

In a recent number of Tschermak's Mineralogische und Petrographische Mitteilungen Fromme<sup>1</sup> gives, in connection with a description of several minerals from the Radautale, an analysis of axinite. The formula derived from that analysis and Fromme's discussion of the composition of axinite require some comment. The analysis given is as follows:

*Analysis of axinite from Radautale (by Fromme).*

SiO <sub>2</sub> .....	41.73
B <sub>2</sub> O <sub>3</sub> .....	6.30
Al <sub>2</sub> O <sub>3</sub> .....	17.08
Fe <sub>2</sub> O <sub>3</sub> .....	1.87
FeO.....	1.35
CaO.....	18.65
MnO.....	11.54
MgO.....	0.34
H <sub>2</sub> O.....	1.81
	100.67

<sup>1</sup> Fromme, J., Chemisch-mineralogische Notizen aus dem Radautale: Min. pet. Mitt., vol. 28, 1909, pp. 305-328.

Fromme rightly combines the ferric iron with the alumina, and also places the manganese and magnesia together in deducing the formula from the analysis. His view that the ferrous iron and calcium replace each other is, however, open to serious question, for in general FeO and CaO do not isomorphously replace each other in silicates, as is shown, for example, by the behavior of these compounds in hedenbergite and ilvaite. The fact that FeO and CaO are not isomorphous in axinite is made clear by the table of analyses given on p. 40. The proportion of CaO + FeO to SiO<sub>2</sub>, for instance, is variable, and depends on the amount of FeO present, for both the SiO<sub>2</sub> and CaO are fairly constant.

Curiously enough, Fromme deduces from his analysis the formula of a *magnesium* axinite, which he regards as the primary type or "Grundtypus," even though his analysis shows only 0.34 per cent MgO and despite the fact that an analysis of axinite in which MgO predominates has never been published. Fromme calls his axinite a relatively pure manganese axinite, even though in the same sentence he speaks of the magnesium axinite as the type.

The formula proposed by Fromme for manganese axinite, namely, HMnCa<sub>2</sub>BAl<sub>2</sub>Si<sub>4</sub>O<sub>16</sub>, is identical with that advanced by the writer; the isomorphous relation of the FeO + MnO + MgO seems, however, to have escaped Fromme's notice. The general formula HR''R<sub>2</sub>''BAl<sub>2</sub>Si<sub>4</sub>O<sub>16</sub> was long ago proposed by Rammelsberg, though Ford grouped the bivalent bases together rather than consider them present in fixed amount. It is the writer's belief that the evidence shows that the CaO is beyond question definite in amount and that the H<sub>2</sub>O and the FeO + MnO + MgO are probably in definite proportion. Among the many other writers who have accepted calcium as constant is Tschermak, who, however, writes the formula for axinite HMgCa<sub>2</sub>BAl<sub>2</sub>Si<sub>4</sub>O<sub>16</sub> with admixture of the related iron and manganese oxides. Whitfield proposed the isomorphous relation of the FeO and the MnO, but otherwise his formulas do not accord with more recent data. Therefore the view here proposed that axinite consists essentially of the two minerals, ferroaxinite (HFeCa<sub>2</sub>BAl<sub>2</sub>Si<sub>4</sub>O<sub>16</sub>) and manganoaxinite (HMnCa<sub>2</sub>BAl<sub>2</sub>Si<sub>4</sub>O<sub>16</sub>) although by no means new, puts forward clearly the evidence as it rests to-day. The existence of the corresponding magnesium axinite in a pure state is strongly indicated, but has not yet been demonstrated, for the ratio of MgO is, in all the analyses available, much less than that of FeO + MnO.

## ALBITE FROM LAWSONITE SCHIST, MARIN COUNTY, CALIFORNIA.

### ASSOCIATION.

Among the minerals found in the lawsonite schist at Reed Station, Marin County, Cal., albite is represented in a number of specimens by well-developed crystals, some of which are nearly a centimeter across. The albite seems to be concentrated at one point where the ground is strewn with small cavernous specimens, consisting chiefly of glaucophane and albite. Lawsonite has not been found directly associated with albite, the only mineral occurring with the albite being glaucophane.

The results herewith presented were attained some eight years ago, but they have been withheld, as it was planned to present a more complete paper on all the minerals mentioned herein. As almost all those collected by the writer were lost in the fire in the Survey Building, in December, 1908, the plan had to be abandoned and the data obtained for the albite are now presented. A brief note on lawsonite was published some years ago by the writer in conjunction with Dr. W. F. Hillebrand.<sup>1</sup>

The other minerals found in the schist with lawsonite are, as enumerated by Ransome,<sup>2</sup> glaucophane, actinolite, muscovite (first erroneously described as margarite), epidote, garnet, rutile, titanite, chlorite (pseudomorph after garnet), zoisite, pyrite. Besides these, there were found albite, abundant and in good crystals, chlorite in large sheets (several centimeters across) of a dark-green color, limonite pseudomorph after pyrite, anthophyllite (?), and talc.

### FORMS AND ANGLES.

A number of new forms were found on these albite crystals when they were measured, but the forms have all since been described by other writers. A very important paper on the crystallography of albite has recently appeared<sup>3</sup> to which frequent reference will be made.

<sup>1</sup> Schaller, W. T., and Hillebrand, W. F., Crystallographical and chemical notes on lawsonite: Am. Jour. Sci., 4th ser., vol. 17, 1904, p. 195; and Bull. U. S. Geol. Survey No. 262, 1905, p. 58.

<sup>2</sup> Bull. Dept. Geology Univ. California, vol. 1, 1896, p. 301.

<sup>3</sup> Dreyer, C., and Goldschmidt, V., Ueber Albit von Grönland: Meddelelser om Grönland, vol. 34, 1907, separate, 60 pp., 5 plates, 2 figs.

The forms determined by measurements on the albite crystals are as follows:

*Forms on albite.*

$c \{001\}$	$\zeta \{150\}$	$z \{\bar{1}30\}$	$u \{\bar{2}\bar{2}1\}$
$b \{010\}$	$f \{130\}$	$r \{\bar{1}12\}$	$X \{\bar{2}41\}$
$e \{021\}$	$Z \{120\}$	$p \{111\}$	$\eta \{\bar{1}31\}$
$n \{0\bar{2}1\}$	$K \{350\}$	$g \{\bar{2}21\}$	$\omega \{\bar{3}12\}$
$x \{\bar{1}01\}$	$m \{110\}$	$\delta \{\bar{1}12\}$	$a \{100\}$
$y \{\bar{2}01\}$	$M \{\bar{1}\bar{1}0\}$	$o \{\bar{1}11\}$	

The measurements, on which the more common forms were identified, are given below:<sup>1</sup>.

*Forms and angles, albite.*

Symbol.	Measured.	Calculated.
$c \wedge b = (001) : (010)$ . . . . .	93 36	93 31(M).
$c \wedge e = (001) : (021)$ . . . . .	43 49	43 10(D).
$c \wedge c = (001) : (\bar{0}0\bar{1})$ . . . . .	7 08	7 02(M).
$c \wedge m = (001) : (110)$ . . . . .	65 12	65 12(M).
$c \wedge M = (001) : (\bar{1}\bar{1}0)$ . . . . .	69 02	69 05(M).
$c \wedge y = (001) : (\bar{2}01)$ . . . . .	98 03	97 52(M).
$x \wedge y = (\bar{1}01) : (\bar{2}01)$ . . . . .	29 59	29 57(M).
$b \wedge f = (010) : (130)$ . . . . .	30 23	30 24(G).
$c \wedge p = (001) : (\bar{1}11)$ . . . . .	56 10	55 53(D).
$c \wedge o = (001) : (\bar{1}\bar{1}1)$ . . . . .	57 38	57 41(M).
$c \wedge \delta = (001) : (\bar{1}12)$ . . . . .	30 05	30 04(M).
$o \wedge x = (\bar{1}11) : (\bar{1}01)$ . . . . .	27 22	27 26(M).
$b \wedge p = (010) : (\bar{1}11)$ . . . . .	60 14	60 16(M).
$b \wedge X = (010) : (241)$ . . . . .	39 40	39 24(D).
$b \wedge u = (010) : (\bar{2}21)$ . . . . .	59 42	59 32(D).
$\eta \wedge X = (\bar{1}31) : (\bar{2}41)$ . . . . .	18 25	18 55(D).
$b \wedge f = (010) : (130)$ . . . . .	30 25	30 24(G).
$b \wedge Z = (010) : (120)$ . . . . .	40 34	41 25(G).

<sup>1</sup> The letter following the value of the calculated angles refers to the source of the angle, as it was not deemed necessary to recalculate all the angles used: M=Melczer, G., Zeitschr. Kryst. Min., vol. 40, 1905, p. 571; D=Dana, E. S., System of mineralogy, 6th ed., 1892, p. 328; G=Dreyer, C., and Goldschmidt, V., loc. cit.

The crystals showing the rarer forms were remeasured on the two-circle goniometer, the most important of the values obtained being shown below.

*Measurement of rare forms, albite.*

Letter.	Symbol.	Measured.		Calculated.	
		$\phi$	$\rho$	$\phi$	$\rho$
$\zeta$	150	19 19	90 00	19 21	90 00
$K$	350	46 29	90 00	46 40	90 00
$n$	021	154 04	49 28	154 30	49 21
$g$	221	49 13	62 20	50 29	62 12
$w$	312	70 07	46 12	69 32	46 04
$X$	241	146 16	68 45	145 50	69 01
$\eta$	131	164 00	59 08	163 17	59 08
$u$	221	125 32	60 05	125 16	60 51
$a$	100	87 26	90 00	90 28	90 00

There was also present on crystal No. 2 a very narrow face in the prism zone giving a distinct but faint signal. Its position could not be definitely determined, but its symbol is near to {490}, though the measurements agree closer with the more complex {5.11.0}. The form must, therefore, be referred to the already large class of doubtful forms. The angle values are shown below.

*Measurements of doubtful prism.*

	Measured.	Calculated for {5.11.0}	Calculated for {490}
130 $\wedge$ ?.....	8 19	8 19	7 41
150 $\wedge$ ?.....	19 07	19 22	18 44
350 $\wedge$ ?.....	8 03	7 57	8 35
110 $\wedge$ ?.....	21 57	21 55	22 33
010 $\wedge$ ?.....	38 26	38 43	38 05

### DESCRIPTION OF RARER FORMS.

$e\{021\}$  was noticed but once as a line face, and the form is very rare on these crystals, the corresponding dome  $n\{0\bar{2}1\}$  being observed fairly often.

$\zeta\{150\}$  was found only once as a line face, on crystal No. 2, with  $b\bar{k}kmMz$ . The form was only recently definitely determined by Dreyer and Goldschmidt.

$Z\{120\}$ , a rare form, but well confirmed by Dreyer and Goldschmidt, was found once as a narrow face on crystal No. 14.

$K\{350\}$ , determined as a new form when measured, was found by Dreyer and Goldschmidt, who report its occurrence on five crystals with 8 faces. By the writer it was observed on four crystals. The records of the measurements of the form on crystals Nos. 12 and 15 are lost, but for Nos. 2 and 8 they are as follows:

*Measurements of  $K\{350\}$ , albite.*

Symbol.	Measured.	Calculated.
Crystal No. 2:	° /	° /
$\zeta \wedge K = (150) : (350)$ .....	27 30	27 19
$f \wedge K = (130) : (350)$ .....	16 18	16 16
$m \wedge K = (110) : (350)$ .....	13 34	13 58
Crystal No. 8:		
$b \wedge K = (010) : (350)$ .....	47 29	46 40
$f \wedge K = (130) : (350)$ .....	17 04	16 16
$m \wedge K = (110) : (350)$ .....	11 39	13 58

$g\{\overline{2}21\}$  and  $u\{\overline{2}\overline{2}1\}$  are rare forms, noted several times on these crystals, though never were both forms seen on the same crystal.

$X\{\overline{2}41\}$ , also new when first observed, was described at the same time as new by Bowman<sup>1</sup> and was found once by Dreyer and Goldschmidt. The form was noticed on two crystals by the writer, in both cases with  $\eta\{\overline{1}31\}$ .

$\eta\{\overline{1}31\}$ , first determined by Viola (1895) and fully confirmed by the measurement of 23 faces by Dreyer and Goldschmidt, was noticed twice by the writer each time with  $X\{\overline{2}41\}$ .

$\omega\{\overline{3}12\}$ , was measured as a small face with poor development on crystal No. 2. The form was first found by Dreyer and Goldschmidt and as the measured and calculated angles found by the writer agree well, no hesitancy is felt in referring the face measured to this form.

A very narrow face gave a poor reflection whose measurement approximated to the value for  $a\{100\}$ , a determined form.

<sup>1</sup> Mineralog. Mag., vol. 13, 1902, p. 115.

## COMBINATIONS.

The combinations observed on these albite crystals are given below.

*Combinations on albite crystals.*

Crystal No.—	c	b	e	n	x	y	$\zeta$	f	Z	K	m	M	z	r	p	g	$\delta$	o	u	X	$\eta$	$\omega$
1	c	b			x	y	$\zeta$	f		m	M	z		p			o	u	X			
2	c	b			x	y	$\zeta$	f	K	m	M	z		$\delta$	$\delta$	$\delta$	$\delta$	u	X	$\eta$	$\omega$	
3	c	b	e	n	x	y		f		m	M	z	r	p	g	$\delta$	$\delta$	$\delta$				
4	c	b			x	y		f		m	M	z		p			$\delta$	$\delta$				
5	c	b			x	y				m	M	z		p			$\delta$	$\delta$				
6	c	b			x	y				m	M	z		p								
7	c	b			x	y				M	z			p								
8	c	b			x	y		f	K	m	M	z	r	p		$\delta$	$\delta$		X	$\eta$		
9	c	b			x	y		f		M	z			p			$\delta$	$\delta$				
10	c	b			x	y				M	z			p			$\delta$	$\delta$				
11	c	b		n	x	y				M	z	r	p				o					
12	c	b			x	y		f	K	m	M	z		p			o					
13	c	b		n	x	y		f		M	z		r	p	g							
14	c	b		n	x	y		f	Z	m	M	z										
15	c	b			x	y		f	K	M	z		r	p								
16	c	b		n	x	y		f		M	z					$\delta$	$\delta$	$\delta$				
17	c	b			x	y		f		M	z			p	g							
18	c	b		n	x	y				M	z	r	p			$\delta$	$\delta$	$\delta$				
19	c	b			x	y				M	z			p								
20	c	b			x	y				M	z					o						

From the table of combinations, it can readily be seen that the common forms are:  $c$ ,  $b$ ,  $x$ ,  $y$ ,  $f$ ,  $m$ ,  $M$ ,  $z$ ,  $p$ ,  $o$ , while the less common forms, or those that were noted on more than two crystals and yet on less than half of those measured are:  $n$ ,  $r$ ,  $g$ ,  $\delta$ ,  $K$ , which leaves, as the forms of the third or rare class:  $e$ ,  $\zeta$ ,  $Z$ ,  $u$ ,  $X$ ,  $\eta$ ,  $\omega$ .

## HABIT.

In habit the crystals are usually short prismatic or nearly equidimensional, rarely somewhat elongated prismatic or slightly tabular, parallel to  $b\{010\}$ . Though one simple crystal (No. 1) was observed, all the others are twinned on the albite law. Usually there are but two individuals, though in a number of cases several twinning lamellæ run through the center of the crystal and sometimes give bright lamellæ, in the zone  $bx$ , which faces were at first thought to be new forms, but as shown by Dreyer and Goldschmidt<sup>1</sup> for the forms  $\{\bar{7}97\}$  and  $\{7\bar{5}7\}$  of Melczer,<sup>2</sup> are probably induced by twinning lamellæ. Thus there was measured, in the zone  $bx$ , for the face  $l$ :  $b \wedge l = 66^\circ 10'$ ,  $67^\circ 14'$ ;  $x \wedge l = 26^\circ 05'$ ,  $27^\circ 03'$ ;  $p \wedge l = 6^\circ 19'$ ,  $7^\circ 02'$ ; but  $b \wedge p = 60^\circ 16'$  and  $p \wedge o' = 6^\circ 32'$ ; therefore  $b \wedge o' = 66^\circ 48'$ . Further, since  $x \wedge o' = 27^\circ 32'$  and  $p \wedge o' = 6^\circ 32'$ , the face  $l$ , the measurements of which correspond to the angle values just given, is doubtless  $o$  in twin position.

<sup>1</sup> Dreyer, C., and Goldschmidt, V., Ueber Albit von Grönland: Meddelelser om Grönland, vol. 34, 1907, separate, p. 11.

<sup>2</sup> Zeitschr. Kryst. Min., vol. 40, 1905, p. 583.

## NOTES ON CRYSTALLOGRAPHY OF PHENACITE.

### PHENACITE FROM NEW HAMPSHIRE.

Some crystals of phenacite from Bald Face Mountain, Chatham, N. H., were received for investigation through Prof. F. W. Clarke. The loose crystals resemble very much those described by Farrington<sup>1</sup> from the same locality, but the ones at the writer's disposal were somewhat richer in forms, a total of 12 having been noted. Of the forms given in the table below,  $a \{11\bar{2}0\}$ ,  $m \{10\bar{1}0\}$ ,  $r \{10\bar{1}1\}$ ,  $d \{01\bar{1}2\}$ ,  $p \{11\bar{2}3\}$ ,  $s \{21\bar{3}1\}$ , and  $s_1 \{3\bar{1}21\}$  were observed by Farrington.

*Forms and angles on phenacite from Chatham, N. H.*

Letter.	Symbol.	Measured.		Calculated.		Size of face.
		$\phi$	$\rho$	$\phi$	$\rho$	
$a$	$11\bar{2}0$	30 00	90 00	30 00	90 00	Medium.
$m$	$10\bar{1}0$	0 00	90 00	0 00	90 00	Medium.
$r$	$10\bar{1}1$	0 03	37 24	0 00	37 21	Large.
$d$	$01\bar{1}2$	0 12	21 20	0 00	20 53	Medium.
$z$	$01\bar{1}1(?)$	0 02	40 42	0 00	37 21	Line face.
$u$	$02\bar{2}1$	0 00	56 46	0 00	56 46	Line face.
$\delta$	$14\bar{5}6$	11 13	30 11	10 53	30 14	Minute.
$v$	$21\bar{3}4$	19 05	27 11	19 06	26 47	Line face.
$x$	$12\bar{3}2$	19 01	45 04	19 06	45 17	Minute.
$s$	$21\bar{3}1$	19 04	64 03	19 06	63 39	Line face.
$s_1$	$3\bar{1}21$	19 19	63 30	19 06	63 39	Line face.
$p$	$11\bar{2}3$	30 10	24 01	30 00	23 47	Small.
$p_1$	$2\bar{1}13$	30 18	23 59	30 00	23 47	Small.
$o$	$42\bar{2}3$	30 01	41 29	30 00	41 23	Minute.

### FORM SYSTEM OF PHENACITE.

The forms for phenacite are given in the orientation chosen by Dana in preference to that of Goldschmidt, in which the symbols are more complex than in the former. A review of the literature of phenacite since the publication of Goldschmidt's Winkeltabellen has shown that a number of new forms are to be added to the list given by him, in order to have a complete form system for the mineral. The following table of forms has therefore been compiled and gives

<sup>1</sup> Farrington, O. C., Notes on various minerals in the museum collection: Field Columbian Museum Publications, Geol. ser., vol. 3, 1908, p. 157.

all the forms found in the literature for phenacite (doubtful and vicinal forms not included), and is perhaps the most practicable table for the identification of forms when the mineral is measured by the two-circle method. If no reference for a form is given in the last column of the table, it signifies that the form has been recognized by at least three independent observers and therefore is well substantiated. Otherwise references to the source of the description of the form are given.

*Forms and angles for phenacite.*

No.	Letter.	Symbol.			$\phi$	$\rho$	References.
		Goldschmidt.	Miller.	Bravais.			
1	<i>m</i>	$\infty 0$	2 $\bar{1}$	10 $\bar{1}0$	0 00	90 00	.....
2	<i>a</i>	$\infty$	10 $\bar{1}$	11 $\bar{2}0$	30 00	90 00	.....
3	<i>k</i>	4 $\infty$	31 $\bar{2}$	41 $\bar{5}0$	10 53	90 00	.....
4	<i>d</i> <sub>1</sub>	$+\frac{1}{2}0$	411	10 $\bar{1}2$	0 00	20 53	8
5	<i>d</i>	$-\frac{1}{2}0$	110	01 $\bar{1}2$	0 00	20 53	.....
6	<i>r</i>	$+\frac{1}{2}10$	100	10 $\bar{1}1$	0 00	37 21	.....
7	<i>z</i>	$-01$	22 $\bar{1}$	01 $\bar{1}1$	0 00	37 21	.....
8	$\mu$	$-02$	11 $\bar{1}$	02 $\bar{2}1$	0 00	56 46	.....
9	$\delta$	$-\frac{1}{4}\frac{3}{4}$	43 $\bar{1}$	1456	10 53	30 14	4, 9
10	<i>t</i>	$-\frac{1}{4}\frac{3}{4}$	32 $\bar{1}$	1344	13 54	34 32	4
11	$\lambda$	$+\frac{3}{2}\frac{1}{2}$	30 $\bar{1}$	3142	13 54	54 00	.....
12	$\xi$	$-\frac{1}{2}13$	212	1341	13 54	70 02	1, 5
13	<i>v</i>	$+\frac{1}{2}\frac{1}{4}$	310	2134	19 06	26 47	2, 3
14	<i>x</i>	$-\frac{1}{2}1$	212	1232	19 06	45 17	.....
15	<i>s</i>	$+\frac{1}{2}1$	201	2131	19 06	63 39	.....
16	<i>b</i>	$+\frac{1}{2}\frac{1}{2}$	41 $\bar{1}$	3254	23 25	39 45	7
17	<i>b</i> <sub>1</sub>	$-\frac{1}{2}\frac{1}{4}$	11. 5. 4	2354	23 25	39 45	7
18	<i>w</i>	$-\frac{1}{2}\frac{1}{2}$	31 $\bar{2}$	2352	23 25	58 59	.....
19	$\varsigma$	$+\frac{1}{2}32$	302	3251	23 25	73 16	.....
20	<i>e</i>	$+\frac{1}{2}\frac{3}{4}$	62 $\bar{1}$	4377	25 17	33 33	7
21 <sup>a</sup>	<i>y</i> <sub>1</sub>	$-\frac{1}{2}1$	423	1565	8 57	40 22	6
22	<i>p</i>	$+\frac{1}{2}1$	210	1123 $\bar{r}$	30 00	23 47	.....
23	<i>p</i> <sub>1</sub>	$-\frac{1}{2}1$	201	2113 $\bar{l}$	30 00	23 47	.....
24	<i>o</i> <sub>1</sub>	$+\frac{1}{2}1$	31 $\bar{1}$	2243 $\bar{r}$	30 00	41 23	8
25	<i>o</i>	$-\frac{1}{2}1$	311	4223 $\bar{l}$	30 00	41 23	.....

<sup>a</sup> The form  $y\{1565\}$  should follow No. 8.

1. Beyrich, Pogg. Ann., vol. 34, 1835, p. 519; vol. 41, 1837, p. 323 (Goldschmidt, Index der Krystallformen der Mineralien, vol. 2, 1890, p. 464).
2. Rose, Pogg. Ann., vol. 69, 1846, p. 145 (Hintze, Handbuch, vol. 2, p. 41).
3. Seligmann, Neues Jahrb. Min., Geol. u. Pal., vol. 1, 1880, p. 129.
4. Descloizeau, Bull. Soc. franç. minéral., vol. 9, 1886, p. 171.
5. Lacroix, Minéralogie de la France, vol. 1, 1893–1895, p. 205.
6. Spencer, Mineralog. Mag., vol. 14, 1906, p. 178.
7. Zimányi, Ann. Musei Hungarici, vol. 7, pt. 1, 1909, p. 347.
8. Slavík, Bull. intern. Acad. Bohème, 1909, vol. 14, p. 1.
9. The present paper.

## NOTES ON NEPTUNITE.

### NEPTUNITE FROM CALIFORNIA.

A large suite of specimens of benitoite and neptunite were collected by Dr. Ralph Arnold<sup>1</sup> and turned over to the writer for investigation. As Dr. Louderback was then intending to publish a full description of these minerals, the investigation was postponed. A single crystal was measured and a partial analysis was made in order to classify the so-called carlosite.<sup>2</sup> Since then the crystallography,<sup>3</sup> the chemical composition,<sup>4</sup> and the occurrence<sup>5</sup> of the mineral have been described.

The single crystal measured is prismatic and of the habit described by Ford. The forms present are  $c\{001\}$ ,  $a\{100\}$ ,  $m\{110\}$ ,  $s\{111\}$ ,  $o\{\bar{1}11\}$ ,  $i\{\bar{1}12\}$ ,  $g\{\bar{2}11\}$ ,  $p\{\bar{3}11\}$ , and  $*h\{887\}$ . The measurements of these forms gave the following values:

*Forms and angles for neptunite.*

Letter.	Symbol.	Measured.		Calculated.	
		$\phi$	$\rho$	$\phi$	$\rho$
$c$	001	° /	° /	° /	° /
$a$	100	90 06	25 23	90 00	25 38
$m$	110	90 00	90 00	90 00	90 00
$s$	111	40 21	90 00	40 07	90 00
$o$	1̄11	55 07	54 16	55 10	54 43
$i$	1̄12	14 26	40 08	13 57	39 45
$g$	2̄11	18 52	22 56	19 05	23 08
$p$	3̄11	48 11	51 00	47 29	50 05
		62 52	60 12	62 39	60 22

<sup>1</sup> Arnold, R., Notes on the occurrence of the recently described gem mineral benitoite: Science, vol. 27, 1908, p. 312.

<sup>2</sup> Louderback, G. D., and Blasdale, W. C., Benitoite, a new California gem mineral: Bull. Dept. Geology. Univ. California, vol. 5, 1907, p. 149.

<sup>3</sup> Ford, W. E., Neptunite crystals from San Benito County, Cal.: Am. Jour. Sci., 4th ser., vol. 27, 1909, p. 235.

<sup>4</sup> Bradley, W. M., On the analysis of the mineral neptunite from San Benito County, Cal.: Am. Jour. Sci., 4th ser., vol. 28, 1909, p. 15.

<sup>5</sup> Louderback, G. D., and Blasdale, W. C., Benitoite, its paragenesis and mode of occurrence: Bull. Dept. Geology Univ. California, vol. 5, 1909, p. 331.

In addition to these forms, a large face near to  $s\{111\}$  is present on one side of the crystal. Its measurement corresponds to the symbol  $*h\{887\}$ , and as the form occurs as a large plane face, it is considered as well established. The face (887) is much larger than (1 $\bar{1}$ 1) and a little smaller than (111) and is one of the largest faces on the crystal. The corresponding face (887) is not present. The measurements are as follows:

*Measurements of new form  $h\{887\}$ .*

Measured.	Calculated.
$\phi=53^\circ 41'$	$\phi=53^\circ 43'$
$\rho=57^\circ 31'$	$\rho=57^\circ 20'$

A very narrow face vicinal to (1 $\bar{1}$ 2) was also observed. The form  $g\{\bar{2}11\}$ , described as new by Ford, is present on this crystal as two large dull uneven faces. The form is probably characteristic of this locality, as it was seen on a number of other crystals.

#### FORM SYSTEM OF NEPTUNITE.

As the number of forms for neptunite has considerably increased since the original description of the mineral in 1893, a compilation of all the described forms with the coordinate angles thereto is given below. As in a similar table appearing in this paper a reference to the description on which the form is based is given, unless the form has been three times independently described. The values  $\phi$  and  $\rho$  for the forms not given in Goldschmidt's Winkeltabellen have, except for  $h\{887\}$ , been taken from the table furnished by Hlawatsch.<sup>1</sup>

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<sup>1</sup> Hlawatsch, C., Bemerkungen zum Aragonit von Rohitsch, Natrolith und Neptunit von San Benito: Min. pet. Mitt., vol. 28, 1909, p. 293.

*Forms and angles of neptunite.*Monoclinic,  $a=1.3164$ ;  $c=0.8076$ ;  $\beta=64^\circ 22'$ .

No.	Letter.	Symbol.		$\phi$	$\rho$	References.
		Miller.	Gold-schmidt.			
1	<i>b</i>	010	0 $\infty$	0 00	90 00	.....
2	<i>m</i>	110	$\infty$	40 07	90 00	.....
3	<i>a</i>	100	$\infty$ 0	90 00	90 00	.....
4	<i>o</i>	111	-1	13 57	39 45	.....
5	<i>i</i>	112	$-\frac{1}{2}$	19 05	23 08	.....
6	<i>r</i>	221	-2	22 12	60 11	2, 4
7	<i>g</i>	211	-21	47 29	50 05	.....
8	<i>v</i>	221	+2	48 44	67 47	1, 2
9	<i>h</i>	887	$+\frac{1}{2}$	53 43	57 20	5
10	<i>s</i>	111	+1	55 10	54 43	.....
11	<i>r</i>	522	$-\frac{5}{2}1$	56 31	55 40	3
12	<i>p</i>	311	-31	62 39	60 22	.....
13	<i>u</i>	512	$-\frac{5}{2}\frac{1}{2}$	71 42	52 08	.....
14	<i>x</i>	311	+31	72 14	69 18	2
15	<i>q</i>	712	$-\frac{7}{2}\frac{1}{2}$	78 04	62 47	2
16	<i>f</i>	101	-10	90 00	11 20	2
17	<i>c</i>	001	0	90 00	25 38	.....
18	<i>e</i>	201	-20	90 00	41 22	.....
19	<i>d</i>	301	-30	90 00	57 21	1, 2

1. Flink, G., Beschreibung eines neuen Mineralfundes aus Grönland: Zeitschr. Kryst. Min., vol. 23, 1894, p. 346.

2. Flink, G., Böggild, O. B., and Winter, C., Untersuchungen über Mineralien von Julianehaab: Meddelelser om Grönland, vol. 24, 1899.

3. Hlawatsch, C., Bemerkung zum Aragonit von Rohitsch, Natrolith und Neptunit von San Benito: Min. pet. Mitt., vol. 28, 1909, p. 293.

4. Louderback, G. D., and Blasdale, W. C., Benitoite, its paragenesis and mode of occurrence: Bull. Dept. Geology Univ. California, vol. 5, 1909, p. 331.

5. The present paper.

## ORBICULAR GABBRO FROM PALA, SAN DIEGO COUNTY, CALIFORNIA.

A large number, a hundred or more, of what seemed concretions, were found lying loose on the summit of Hiriart Hill, near Pala, San Diego County, Cal. The writer's attention was called to them by Mr. F. M. Sickler, of Pala, who found them while exploring the hill for spodumene (kunzite). Many of them are broken, and an examination of one of them showed the apparent concretions to be the orbicules of an orbicular phase of the hornblende gabbro which forms this hill. This orbicular phase has weathered away, leaving behind nothing but these hard balls. Careful search of the rock revealed two or three poorly developed orbicules in the gabbro, but the main mass of the original orbicular rock has entirely disappeared. These orbicules have an average diameter of 2 to  $2\frac{1}{2}$  inches and vary somewhat in shape, rarely being regularly elliptical, but usually being of a distorted spherical shape.

The center is occupied by coarse-grained feldspar and some ferromagnesian minerals, which are surrounded by radiating prisms that can not be determined by the eye alone. The radiating mass is black in spots and the orbicule always shows a brownish border a millimeter or two wide, which is merely a zone of weathering. The entire orbicule is somewhat altered, brownish stains being common throughout. The orbicules have no concentric structure except the outer zone of weathering.

Microscopically, the minerals present are seen to be olivine, hypersthene, hornblende, feldspar, and iron oxides, such as magnetite and limonite. The olivine occurs in irregular masses nearly always surrounded by green hornblende. It is full of cracks, and near the edge of the orbicule it is much altered to iron oxide. It is colorless, non-pleochroic, with a very high relief and birefringence. The hypersthene is strongly pleochroic (from pink to colorless to pale green) and shows a high relief with low birefringence. It is in places surrounded by green hornblende. The hornblende occurs as a border around the olivine and hypersthene and also as small shreds of original mineral. It is generally green but becomes slightly brownish in places. It is commonly altered to chlorite. The feldspar is labradorite with symmetrical extinctions of about  $37^{\circ}$ .

The radiated structure is caused by the formation of long narrow masses of olivine, hypersthene, and hornblende, the olivine being the

most abundant. They are irregular in their shape and show no definite boundaries. They are in general continuous for some little distance, but many are formed of pieces lying in a straight line but not connected. The green envelope or rim of hornblende commonly surrounds the olivine, and a number of specimens were noticed where a border of pink hypersthene separated the hornblende from the olivine. Where there is also a fringe of deep green chlorite surrounding the hornblende the combination makes a very pretty section. In some specimens it seems that the hypersthene alters directly to chlorite. The orbicules are not so perfectly developed as those described by Lawson<sup>1</sup> from Dehesa, San Diego County. The concentric structure there found is entirely lacking in the Pala rock, while the radiated structure is but poorly developed. One of the most interesting things about the Pala orbicular rock is its peculiar mode of occurrence, the orbicules lying loose in the soil instead of being embedded in the solid rock as at Dehesa.

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<sup>1</sup> Lawson, A. C., The orbicular gabbro at Dehesa, San Diego County, Cal.: Bull. Dept. Geology Univ. California, vol. 3, No. 17, 1904, pp. 383-386.

# THE REFRACTIVE INDEX OF OIL OF CINNAMON.

## INTRODUCTION.

The use of organic liquids of known refractive index ( $n$ ) for determining the index of refraction of a mineral has reached a very extensive application in late years. Numerous papers have appeared recently, several by F. E. Wright, which have set forth the different methods of using the liquids. One of the commonest liquids is oil of cinnamon, which is easily obtainable, has a rather high index (1.6), and mixes easily with oil of cloves ( $n=1.53$ ) and oil of cedar ( $n=1.51$ ) to form a series which covers especially the row of plagioclase feldspars, a group of minerals very important in petrography.

Having prepared a large number of these solutions for geologists of the survey, the writer observed that the cinnamon oil varied in refractive index even while the measurement was in progress. If this variation was at all large it would preclude the use of the oil, and a detailed examination was therefore undertaken to determine the variation and to decide whether or not the oil was suitable for a standard measure. It was intended to subject to such an examination all the liquids commonly thus used, but lack of time has necessitated the postponement of the investigation. As soon as opportunity is presented, however, the study will be completed in order to furnish the information necessary for the use of the several liquids. This paper on the oil of cinnamon serves, therefore, as an introduction to the subject and shows the necessity for a complete knowledge of fundamental data.

## GENERAL DESCRIPTION.

Cinnamon oil is obtained from the inner bark of a tree (*Cinnamomum zeylanicum*, belonging to the natural order Laurineæ) indigenous to Ceylon, but now also grown in Brazil, the West Indies, Egypt, Java, and on the Malabar Coast; Ceylon, however, produces by far the best quality. Cassia cinnamon and saigon cinnamon are obtained from different species of *Cinnamomum*, and the oils derived therefrom differ chemically from the true Ceylon oil of cinnamon. The cinnamon bark contains a volatile oil (oleum cinnamomi), tannin, sugar, and mannite. By distillation from one-half to 1 per cent of oil of cinnamon is obtained. The color of the fresh oil is yellow, but it deepens by exposure to air, becoming brownish.

The oil consists chiefly of cinnamic aldehyde,  $C_6H_5.CH.CH.CHO$ , with smaller quantities of cinnamic acid,  $C_6H_5.CH.CH.CO_2H$ . Thorpe<sup>1</sup>

<sup>1</sup> Thorpe, T. E., Dictionary of applied chemistry, vol. 3, 1893, p. 12.

mentions, in addition, the presence of a small quantity of a laevogyrate hydrocarbon. Cinnamic aldehyde<sup>1</sup> melts at  $-7.5^{\circ}$  C., and is decomposed by boiling at atmospheric pressure. Its density is about 1.05, and refractive index about 1.61. By oxidation on exposure to air it forms cinnamic acid, which sometimes crystallizes from oil of cinnamon. Cinnamic acid forms colorless monoclinic prisms, which melt at  $133^{\circ}$  and boil at about  $300^{\circ}$  with or without decomposition according to the physical conditions. It is easily decomposed into styrene,  $C_6H_5.CH.CH_2$ , and carbon dioxide,  $CO_2$ . Oxidizing agents convert the acid first into benzoic aldehyde and then into benzoic acid.

The above description of oil of cinnamon and its chief constituent, cinnamic aldehyde, which readily oxidizes to cinnamic acid, clearly shows how unstable a liquid it is, and therefore how unsuitable for any purpose requiring a medium of constant physical properties.

#### MEASUREMENTS OF REFRACTIVE INDEX.

The first series of measurements were made to determine the variation of the refractive index according to the temperature. For this purpose the small bottle with a thermometer stopper combined with the Abbe-Zeiss refractometer was employed. This was cooled in ice to about  $0^{\circ}$  and then placed on the glass hemisphere of the refractometer and the readings taken when the thermometer showed the desired temperature. By the use of the micrometer tangent wheel, which gives readings to 6 seconds, the measurements could easily and quickly be made. The oil of cinnamon showed practically no dispersion, and the values given for sodium light represent closely the index for daylight. No difference in the value of the index could be detected by using red lithium or green thallium light. The values of the index of refraction ( $n$ ) for yellow sodium light, as measured, are shown below for the different temperatures.

*Values of index of refraction of oil of cinnamon for different temperatures.*

Tem- pera- ture.	$n$ .	Tem- pera- ture.	$n$ .	Tem- pera- ture.	$n$ .
$^{\circ}C.$		$^{\circ}C.$		$^{\circ}C.$	
6	1.5996	13	1.5978	21	1.5942
7	1.5995	14	1.5973	22	1.5938
8	1.5991	15	1.5970	23	1.5936
8½	1.5989	16	1.5966	24	1.5929
9	1.5989	17	1.5958	25	1.5926
10	1.5983	18	1.5956	26	1.5921
11	1.5979	19	1.5949	27	1.5917
12	1.5976	20	1.5946	.....	.....

<sup>1</sup> Beilstein, F., Handbuch d. organischen Chemie, vol. 3, 1897, p. 58.

These values are plotted and the resulting straight line shown in figure 3. From the readings, with a temperature variation of  $21^{\circ}$ , the refractive index varies from 1.5996 at  $6^{\circ}$  to 1.5917 at  $27^{\circ}$ . Therefore there is a decrease in the index of 0.00037 for every rise of  $1^{\circ}$ . From the plotted line (fig. 3) the refractive index at  $0^{\circ}$  is found to be 1.6022, and at  $30^{\circ}$  it is 1.5907, a change of 0.0115 for  $30^{\circ}$  change in temperature. From these values it is found that a change of temperature of  $1^{\circ}$  causes the solution to vary 0.00038 in the index. This change is reciprocal—that is, as the temperature increases the index of refraction decreases. The amount may be given as 0.0004 for a change of  $1^{\circ}$ .<sup>1</sup>

The variation in temperature at different seasons is therefore sufficient to cause an appreciable change in the index of refraction of the oil of cinnamon. Even during the day the variation in temperature is enough to markedly change the value. The following table gives the values for  $n$  at three different temperatures, which are often reached indoors at Washington during the year:

*Variation of index of refraction of oil of cinnamon.*

Temperature, Fahrenheit.	Temperature, centigrade.	$n$ (Oil of cinnamon).
..	..	
100	38	1.5877
70	21	1.5942
50	10	1.5983

Another cause of variation, and one that is much more detrimental to the use of oil of cinnamon as a liquid of known refractive index, is its variability on exposure to air. This is owing to the oxidation of the cinnamic aldehyde to cinnamic acid. That this change is very rapid and also important is shown by the following table, which represents three sets of experiments. A drop of the oil was placed on the glass hemisphere of the refractometer and exposed to the air, readings being taken at definite time intervals. An exposure of only half a minute is sufficient for the index to increase 0.001 in value.

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<sup>1</sup> The variation for nitrobenzol is likewise 0.0004 for  $1^{\circ}$  change in temperature. Zeitschr. Kryst. Min., vol. 44, 1908, p. 620.

*Change of refractive index of oil of cinnamon due to oxidation.*

Time of exposure.	Gain in refractive index.		
	1	2	3
½ minute.....	0.0012	.....	0.0009
1 minute.....	18	0.0015	15
2 minutes.....	27	24	24
3 minutes.....	32	27	29
4 minutes.....	35	30	32
5 minutes.....	38	.....	36

Therefore in 5 minutes the solution increases nearly 0.004 in value. One set of observations (the third), showing the change in index on

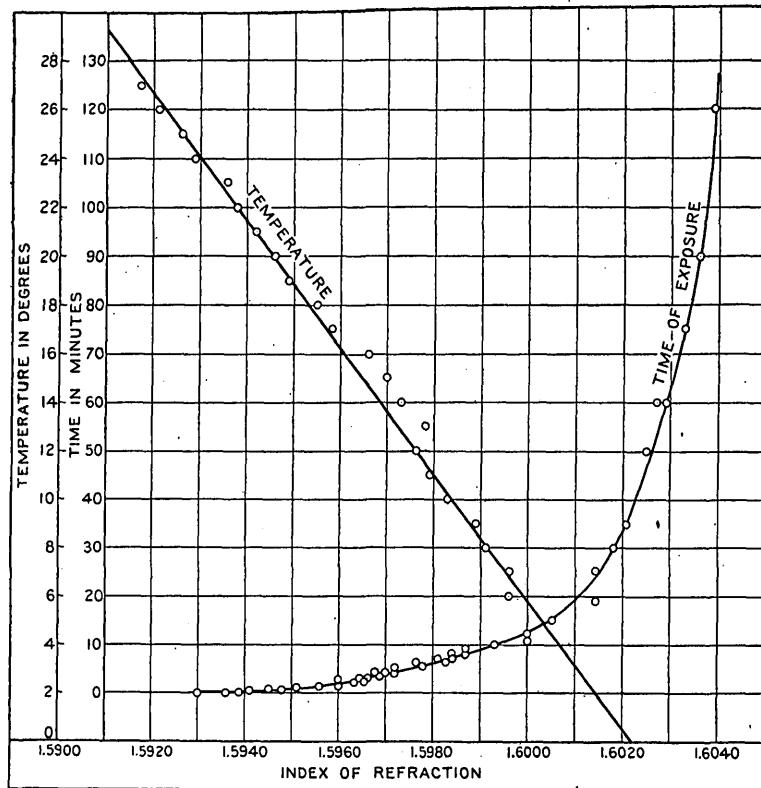


FIGURE 3.—Variation in index of refraction for oil of cinnamon.

exposure to air, is given below, and the other values are combined in the curve shown in figure 3.

*Values of refractive index of oil of cinnamon on exposure.*

Time of exposure in minutes.	Refractive index.	Time of exposure in minutes.	Refractive index.
0	1.5936	10	1.5993
$\frac{1}{2}$	45	11	1.6000
1	51	12	00
2	60	15	05
3	65	19	14
4	68	25	14
5	72	30	18
6	77	35	21
7	81	50	25
8	84	60	27
9	87	75	33

As may be seen by reference to the curve of figure 3, the change in refractive index is very rapid for the first 10 minutes; then it gradually decreases in rapidity but still slowly gains even after an hour's exposure. The most rapid change occurs in the first 5 minutes, when a gain of nearly 0.004 takes place. After 10 minutes the total change is 0.006, after 20 minutes 0.008, and after an hour's exposure 0.009. The change then progresses slowly, and probably increases till the maximum is reached, which is probably about 1.615, though the writer does not know if this value has been determined. This would be a solution of cinnamon aldehyde saturated with cinnamic acid, and Wright and Larsen<sup>1</sup> give 1.615 for the refractive index of cinnamon aldehyde.

#### SUMMARY.

The results here given show that oil of cinnamon undergoes a marked change of refractive index on exposure to air. During 5 minutes, a time which may well be consumed in manipulation, the refractive index of the oil increases by 0.004. The variation of the index for a change in temperature of 1° is about 0.0004, the variation being reciprocal. The solution should therefore be standardized for a certain temperature and correction made for any variation therefrom. However, the variability due to oxidation is much greater, rendering oil of cinnamon unsuitable for any accurate work. The only known way to obviate this effect is to have the oil form a saturated solution of cinnamic acid in the cinnamic aldehyde, and a long exposure to air is necessary to obtain this. The best procedure where accuracy is essential is to avoid the use of oil of cinnamon altogether.

<sup>1</sup> Wright, F. E., and Larsen, E. S., Optical study (on diopside, etc.): Am. Jour. Sci., 4th ser., vol. 27, 1909, p. 35.

## INDEX OF REFRACTION OF CANADA BALSAM.

The refractive index of Canada balsam, as it occurs in the thin sections made for the United States Geological Survey, was determined on the request of Mr. F. C. Calkins, who had found<sup>1</sup> that the index, or  $n$ , was not absolutely constant, but varied between two extremes. By the examination of 300 slides he found  $n$  to reach and even slightly exceed  $\omega$  of quartz (1.544), though  $n$  was found greater than 1.544 only in the proportion of one slide in a hundred. The excess was very small and the balsam was decidedly yellow. The lowest value found by him was about  $1.535 \pm .002$ .

The value of  $n$  for sodium light was determined with an Abbe-Zeiss refractometer by total reflection on three sets of slides, these being (1) not cooked as much as usual, (2) cooked ordinarily, and (3) overcooked. The differences found between (1) and (2) are very slight and, in fact, the individual values show almost as much variation as that between the groups. The values obtained for  $n$  are:

*Values of refractive index for Canada balsam.*

1	2	3
1.539	1.536	1.543
1.538	1.538	1.540
1.539	1.539	1.540 1.542 1.541

The average values are for (1), 1.5387; for (2), 1.5377; for (3), 1.5412, or, as the average of all, 1.5395, which is almost identical with the value (1.5393) given by Becker<sup>2</sup> in 1898. A determination of  $n$  in a slide six years old gave the value 1.5390. These values show that, in general,  $n$  lies very close to 1.539 and that this value may well be used in a study of a thin section, though the actual possible variation was found by Mr. Calkins to be from 1.535 to 1.545, the extreme values, however, being but seldom reached. The uncooked liquid balsam has a refractive index of 1.524, which, after cooking, rises to 1.54. The older the slide the higher becomes the index of the balsam, and after some time, especially if the slide is exposed to the air, the index rises toward the highest value, or 1.545.

<sup>1</sup> Science, vol. 30, p. 973, Dec. 31, 1909.

<sup>2</sup> Am. Jour. Sci., 4th ser., vol. 5, 1898, p. 349.

## SIDERITE AND BARITE FROM MARYLAND.

### SIDERITE.

#### OCCURRENCE.

A number of specimens of small splendid crystals of siderite were obtained through the courtesy of the Foote Mineral Co. of Philadelphia, the locality being given as "within 2 miles of Frostburg, Md." The crystals are very small and are deposited in great numbers on a massive gray siderite rock. A very striking feature of the siderite crystals is their splendid play of colors. Though brown in color, they are very iridescent, the light reflected from their surface being of all colors. Associated with the siderite crystals and intermingled with them are numerous small barite crystals.

The matrix is a compact impure iron carbonate, having a specific gravity of 3.7, in which are embedded occasional masses of white, opaque barite, showing good cleavage. In the rock are numerous cavities lined with siderite and barite crystals derived from the massive rock, the specimens forming geodes.

The crystals of siderite vary from exceedingly minute ones up to those of a millimeter in length and breadth. Most of them are attached to the matrix by one end, though many irregularly scattered through the mass are attached at both ends. The entire layer of crystals is about a millimeter in thickness.

#### CHEMICAL COMPOSITION.

A number of the crystals were broken from the matrix. From these some were very carefully selected and were freed from a small amount of barite by the electromagnet. About one-tenth of a gram of pure crystals was finally obtained, each crystal having been picked out and found to be free from any foreign matter. It was noted that the crystals did not possess a uniform color, some of them being a much lighter brown than others. It was at first thought that the lighter colored ones contained calcium or magnesium, but such was found not to be the case. The difference between the shades of color is probably due to the varying amount of ferric iron in the crystals.<sup>1</sup> The selected crystals were dissolved in

<sup>1</sup> Siderite should be white if chemically pure. The brown color so often observed may be due to a very slight oxidation of the ferrous iron to the ferric condition, which ferric compound then remains in the ferrous carbonate in a state of solid solution.

hydrochloric acid and the iron precipitated with ammonia and weighed. Tests made for manganese, calcium, and magnesium proved their absence. The weighed iron oxide was fused with sodium bisulphate, reduced and titrated with potassium permanganate, giving practically the same figure. There was found 62.21 per cent FeO (calculated 62.07 per cent FeO). The crystals are therefore pure iron carbonate and well suited for obtaining crystallographic constants for siderite.

#### CRYSTALLOGRAPHY.

##### FORMS.

The siderite crystals have a rather unusual habit for that mineral, the dominant form being the scalenohedron  $v\{21\bar{3}1\}$ , the common form for calcite. A number of other forms are present, and a very marked feature of these crystals is that there are concave rounded hollows in approximately the places where the  $a$  face should come. The crystals are highly polished and seemingly should give perfect reflections, but on examining them on the two-circle goniometer it was found that the faces were not as perfect as was at first thought, chiefly because some of the large scalenohedral faces appear broken and the parts slightly displaced, yielding more than one signal several minutes apart. The crystals were mounted in polar position on the two-circle goniometer, and so adjusted that on turning the vertical circle (the horizontal one being clamped) the reflections from the several faces of each form fall, respectively, in a vertical line coinciding with the vertical cross hair. After the crystal was adjusted as perfectly as possible, the reading on the horizontal circle was taken for each face, the signal being brought to the exact center of the field in each case. The forms present are:  $r\{10\bar{1}1\}$ ,  $l\{70\bar{7}5\}$ ,  $k\{50\bar{5}2\}$ ,  $f\{02\bar{2}1\}$ ,  $v\{21\bar{3}1\}$ ,  $y\{32\bar{5}1\}$ .

The form  $l\{70\bar{7}5\}$  occurs but once as a small face below  $\{10\bar{1}1\}$  but larger than that face. The reflection was fair.

*Measured and calculated angles of the form  $l\{70\bar{7}5\}$  on siderite.*

	$\phi$	$\rho$
Measured.....	°   '	°   '
Calculated <sup>a</sup> .....	0 14 0 00	52 49 53 07

<sup>a</sup> From element derived by writer.

The form  $k\{50\bar{5}2\}$  occurs as a minute line face, somewhat rounded and truncating the edge of the scalenohedron  $v\{21\bar{3}1\}$ . The measurements showed that the  $\rho$  angle was about  $68^\circ$ , though no accurate measurement could be obtained (calculated  $\rho = 67^\circ 12'$ ). The unit

rhombohedron  $r$  occurs on nearly all of the crystals as small faces truncating the apex of the crystals. The new scalenohedron  $y\{32\bar{5}1\}$  occurs on all the crystals and is a characteristic form for this locality. Though it varies in size, becoming relatively wide and short or narrow and long, its general size is shown in figure 4.

The zone  $vyy^{\prime}v^{\prime}v^{\prime\prime}$  is in some specimens somewhat striated between  $y$  and  $y^{\prime\prime}$  and by using the dot signal it was seen that there was a maximum of brightness in the position required for the faces  $\{7.6.\bar{1}3.1\}$  and  $\{11\bar{2}0\}$ . It could not be shown, however, that these faces were actually present. The form  $f\{02\bar{2}1\}$  occurs as broad dull

faces giving no reflection and only an almost imperceptible haze of light. Measurements of the  $\rho$  angle gave values from  $59^\circ$  to  $62^\circ$  (calculated  $62^\circ 17'$ ).

The concave hollows give an indefinite blaze of light in the zone of the negative rhombohedrons, about  $80^\circ$  from the base, so that they do not reach down to the prism zone. A study of these hollows on the goniometer, the dot signal being used, showed that they consisted of vertical striations approximating in the center to the form  $\{06\bar{6}1\}$  and at the extreme edge to  $\{11\bar{2}0\}$  with many forms in between these.

Figure 4 is an attempt to illustrate the actual appearance of these crystals showing particularly the concave hollows. The indentations in the orthographic projection are somewhat exaggerated. With the exception of these and the broad, dull faces, the crystals are highly polished and do not show any etching. It seems more plausible to regard these hollows as the result of an incomplete or skeletal growth rather than to consider them as the result of etching. They are in a way analogous to the hopper-shaped crystals of sodium chloride in which the two planes  $(001)$  and  $(100)$  (in one zone) alternate and the resultant hollow has in cross sections a V shape. In the siderites, however, instead of an alternation of the two planes  $\{06\bar{6}1\}$  and  $\{11\bar{2}0\}$ , there is a gradation from the prism to the rhombohedron, and the result is a rounded hollow instead of a sharply angular one.

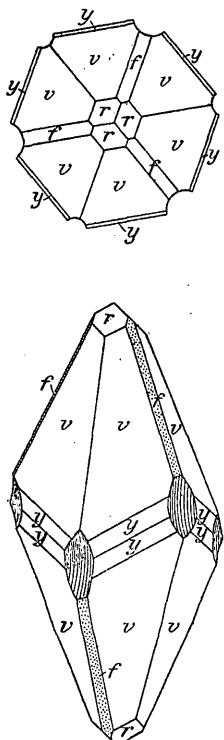


FIGURE 4.—Siderite from Maryland.

(100) (in one zone) alternate and the resultant hollow has in cross sections a V shape. In the siderites, however, instead of an alternation of the two planes  $\{06\bar{6}1\}$  and  $\{11\bar{2}0\}$ , there is a gradation from the prism to the rhombohedron, and the result is a rounded hollow instead of a sharply angular one.

## ETCH FIGURES.

A cleavage piece of siderite was left standing in very dilute hydrochloric acid for several days and then examined under the microscope, when well-defined etch figures could be observed. As shown in figure 5, these are triangular in shape and possess a plane of symmetry parallel with the shorter diagonal of the cleavage rhomb of siderite. They resemble in symmetry the figures shown in Miers's Mineralogy (p. 112) for calcite and not those given for dolomite. The symmetry of siderite is the same as that of calcite and not that of dolomite—a conclusion sustained by the forms of the crystals.

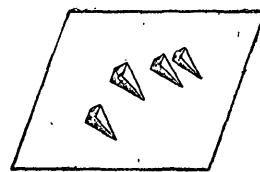


FIGURE 5.—Etch figures of siderite.

VALUE FOR *c* AXIS.

Although siderite is a common mineral, good crystals are rare and the literature is very poor in accurate crystallographical data. The only value given for the axial ratio, which is adopted in all books, is one obtained in 1812 by Wollaston. His statement in regard to siderite is as follows:<sup>1</sup>

I have examined various specimens of this substance, some pure white, others brown, some transparent, others opaque. That which gives the most distinct image by reflection is of a brownish hue, with the semitransparency of horn. It was obtained from a tin mine, called Maudlin mine, near Lostwithiel, in Cornwall. By repeated measurements of small fragments of this specimen the angle appears to be so nearly  $107^{\circ}$  that I can not form any judgment whether in perfect crystals it will prove to be greater or less than that angle,

In this instance the carbonate of iron is nearly pure, and so perfectly free from carbonate of lime \* \* \*

The measurements of the faces giving good reflections were used for calculating a value for the *c* axis. The angles for the same form varied somewhat on different crystals, though the values obtained from the measurements of different forms agree very well with each other. From the average reading the following values were calculated:

*Calculation of c axis of siderite.*

10 measurements of <i>r</i> (10̄11).....	<i>c</i> = 0.82352
27 measurements of <i>v</i> (21̄31).....	<i>c</i> = .82463
16 measurements of <i>y</i> (32̄51).....	<i>c</i> = .82311
Average.....	<i>c</i> = .8240

An attempt was made to measure the cleavage angle directly, but it was found that the resultant cleavage faces were never perfectly plane, with the result that each face gave several signals.

<sup>1</sup> Phil. Trans., 1812, p. 159.

After this value for  $c$  was obtained and found to be different from the commonly accepted value, 10 more crystals were measured, and after the greatest care in so adjusting each crystal that the reflections from the scalenochedral faces of  $v$  fell as nearly as possible in a straight line each reflection was carefully measured. In the case of more than one signal the extremes were measured and the average taken. The average value for the  $\rho$  angle for each crystal (six faces) is:

*Measurements of  $\rho$  for  $v$  {2131}, siderite.*

$^{\circ}$	$'$	$^{\circ}$	$'$
68	14	68	21
68	26	68	27
68	18	68	20
68	15	68	19
68	16	68	29

Average  $68^{\circ} 20\frac{1}{2}'$ ;  $c = .8243$ .

The values for the two extremes,  $68^{\circ} 14'$  and  $68^{\circ} 29'$ , are:  $c = .8197$  and  $c = .8302$ .

Taking the average of the value found from  $r, v, y$ , namely, .8240, and that found from the 10 crystals, namely, .8243, we get as a value for the  $c$  axis for siderite of known purity  $c = .8241$ . Whether or not this value is more accurate than the one commonly accepted is difficult to decide. Palache<sup>1</sup> has measured some crystals which gave values agreeing with the commonly accepted value of the  $c$  axis, so that the question as to the true value of the fundamental crystallographic constant of siderite is one which still remains to be determined by more measurements.

#### BARITE.

#### OCCURRENCE.

The barite occurs in three different forms on the specimens seen by the writer. The first is the white massive form, which is often embedded in the matrix. It is generally opaque and shows a good cleavage. The second form occurs as an opaque white efflorescence, which is composed of an aggregate of minute crystals. The third form is present in transparent colorless crystals, some of which reach a length of several millimeters, though most of them are rather smaller. The largest ones seen were about a centimeter long and a millimeter or two thick. On some specimens these transparent crystals are attached by one end to the massive barite and form a fringe, as it were, around it, the crystals standing normal. This occurrence is very suggestive of a secondary formation of the crystals—that they are derived from the massive barite in the matrix. The large clear crystals are probably a more perfect development than the white efflorescence and both are doubtless derived from the massive barite. In the massive barite there are no siderite crystals, though small fragments of the matrix are included therein;

<sup>1</sup> Palache, C., Mineralogical notes: Am. Jour. Sci., 4th ser., vol. 24, 1907, p. 254.

and in the efflorescence crystals of siderite are commonly inclosed, and the clear large barite crystals are intermingled with those of siderite.

#### CRYSTALLOGRAPHY.

The crystals of barite are of especial interest, as they are of an uncommon habit—prismatic, elongated parallel to the vertical axis. Such crystals have been noticed before, but they are not the common form for barite.

The faces of the crystals are highly polished and gave excellent signals. The prism zone is striated on some specimens, especially on the macropinacoid, though for the most part the zone is not striated and each face is distinct and plane. The forms present are as follows:

#### *Forms of barite.*

$c\{001\}$	$m\{110\}$	$q\{114\}$
$b\{010\}$	$\eta\{320\}$	$f\{113\}$
$a\{100\}$	$\lambda\{210\}$	$r\{112\}$
$x\{130\}$	$o\{011\}$	$R\{223\}$
$B\{370\}$	$d\{102\}$	$z\{111\}$
$n\{120\}$	$l\{104\}$	$Y\{551\}$
$N\{230\}$	$v\{115\}$	$y\{122\}$

The prism  $B\{370\}$  occurs twice on two crystals as small faces, giving a fair reflection. The  $\phi$  angles measured are as follows:  $28^\circ 09'$ ,  $27^\circ 52'$ ,  $27^\circ 45'$ ,  $27^\circ 41'$  (calculated,  $27^\circ 45'$ ). The form was first noted by Dusing<sup>1</sup> and classed as doubtful by Dana; it is not included in Goldschmidt's Winkel-tabellen.

The pyramid  $Y\{551\}$  measured ( $\rho$ ):  $84^\circ 55'$ ,  $84^\circ 58'$ ,  $84^\circ 08'$ ,  $84^\circ 45'$  (calculated ( $\rho$ )  $84^\circ 45'$ ). It is present as very narrow and small faces.

The general ideal view of these crystals is shown in figure 6. Some of the crystals are flat, parallel to the macropinacoid, but most of them are of equal diameter horizontally. Some of them, too, have one side of the terminated end much larger than the other side, but in general the crystals are fairly symmetrical.

On account of the excellence of the signals an axial ratio was calculated from the measurements. A value for  $a$  was obtained from the prism faces, and using this value the value for  $c$  was obtained from the pyramids and domes (the crystals being measured on the two-circle goniometer). From 44 values for  $a$  and 70 values for  $c$ , the values  $a = .8146$ ,  $c = 1.3126$  are obtained, and these are very close to the accepted values.

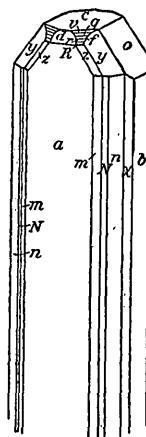


FIGURE 6.—Barite from Maryland.

<sup>1</sup> Zeitschr. Kryst. Min., vol. 14, 1888, p. 481.

## NOTES ON PURPURITE AND HETEROSITE

### INTRODUCTION.

The mineral purpurite, a hydrous manganic ferric phosphate,  $(\text{Mn}, \text{Fe})_2\text{O}_3 \cdot \text{P}_2\text{O}_5 \cdot \text{H}_2\text{O}$ , was first found in North Carolina by L. C. Graton and a description of it was published<sup>1</sup> in 1905. On account of its rich purple or dark-reddish color it was named purpurite, from the Latin *purpura*, purple or dark red. Since the original discovery the same mineral has been found at several other localities.

Lacroix, to whom some of the original purpurite from North Carolina was sent, has stated<sup>2</sup> that purpurite is identical with heterosite. In view of this the writer proposes to restrict the name heterosite to the ferric phosphate and the name purpurite to the manganic phosphate. Heterosite predominates (76 per cent) in the material from South Dakota, but purpurite predominates (65 per cent) in that from North Carolina.

### PURPURITE FROM NORTH CAROLINA.

#### OCCURRENCE.

Graton gives the following description of the occurrence and physical properties of the mineral:

The mineral purpurite is found in small irregular masses in the tin-bearing pegmatite dikes and in the near-by schist at the Faires mine at Kings Mountain, Gaston County, N. C. It generally occurs in narrow lenses or veinlets, and appears to have been deposited from solution in cavities. Occasionally, however, it is found in the midst of the pegmatite as if it were an original mineral.

Among the primary minerals of the tin-bearing pegmatites are cassiterite, tourmaline, apatite, spodumene, lepidolite, and a yellowish-brown, lithia-bearing phosphate, which is doubtless lithiophilite. The last two minerals have been found only in small quantities. Partially decomposed specimens of this pegmatite frequently show much manganese dioxide as thin mammillary coatings on the other minerals. Ilmenite is often included in crystals of cassiterite. It is evident, therefore, that the elements manganese and iron (as monoxides), lithium, and phosphorus (as phosphate) were primary components of the pegmatite magma.

<sup>1</sup> Graton, L. C., and Schaller, W. T., Purpurite, a new mineral: Am. Jour. Sci., 4th ser., vol. 20, 1905, pp. 146-151.

<sup>2</sup> Lacroix, A., Minéralogie de la France, vol. 4, 1910, p. 469.

The mineral presumed to be lithiophilite is always surrounded by a coating of black, secondary material. In one case, a narrow zone of purpurite was found between the lithiophilite and the black mineral. It is believed that this single occurrence furnishes the explanation of the origin of purpurite. A lithia-manganous-ferrous phosphate, probably lithiophilite, was attacked by oxidizing solutions. The lithia was almost wholly carried away, and of the remaining elements the iron and manganese were oxidized to the state of sesquioxides and were recrystallized with the phosphoric acid and water to form purpurite. The trace of lithium which this mineral contains is a remnant of that from the lithiophilite. In some cases the recrystallization took place without transportation of the materials, forming pseudomorphic replacements, but in general the materials were carried in solution to cavities and there deposited.

#### PHYSICAL PROPERTIES.

Purpurite is orthorhombic, but no specimens from North Carolina have been found which show crystal outline. A cleavage which is probably pinacoidal is rather well developed, but many of the cleavage surfaces are curved as if the orientation of adjoining grains were not exactly the same. A second cleavage, presumably at right angles, is considerably less distinct. The mineral has an uneven fracture and is rather brittle. It is scratched without difficulty by the knife, but on the other hand just scratches fluorite; hence it has a hardness of 4-4.5. In color the mineral is a rich deep red or reddish purple, sometimes with a slight bronzy iridescence, and not uncommonly darker on the cleavage planes. The powder and the streak have a decided purple or deep rose color. The mineral has a peculiar satiny luster or sheen more noticeable on fracture surfaces than on cleavage planes.

Although very thin pieces of purpurite are transparent, the ordinary thin section allows but little light to pass through. The colors in transmitted light are very beautiful, the mineral being strongly pleochroic. Parallel to the cleavage the color is deep scarlet inclining to rose red, but across the cleavage the absorption is greater and the color becomes a beautiful purple. This absorption, it will be noticed, is similar to that of tourmaline and a few other minerals, in which the greatest absorption is at right angles to the direction of cleavage or elongation. Extinction is generally parallel; an inclination up to  $3^{\circ}$  or  $4^{\circ}$ , which has been observed in a few instances, is probably due to the orientation of the sections examined. It may be, however, that the mineral is monoclinic with a very small extinction angle. Transparent sections were not of sufficient size to give an interference figure. No sections showed the intersecting cleavages, and in all the

sections examined the traces of the cleavages are parallel to the direction of greater elasticity of the section; so if the mineral is biaxial, the intersection of the cleavages is parallel to  $\alpha$ . This is also the direction of least absorption. The refractive index is somewhat greater than that of Canada balsam, and probably lies between 1.60 and 1.65. The difference of the indices or the double refraction is high, and although it could not be measured at all accurately is probably not much below .060. One effect of this high double refraction on the very thin sections examined is that under crossed nicols the mineral appears to transmit as much and as brilliant light as without polarization. The red interference colors are very striking.

All specimens of the purple mineral are covered or surrounded by a greater or less thickness of a black or brownish-black material of pitchy luster and uneven or subconchoidal fracture. This material,<sup>1</sup> which is soluble in hydrochloric acid, contains iron, manganese, phosphoric acid, and water. Under a lens the black material can be seen to encroach upon the purpurite, eating in along the cleavage planes and gradually replacing the purple mineral. Under the microscope it appears to be a definite mineral, having an imperfect cleavage, and a brownish-yellow color in transmitted light. Extinction is nearly or quite parallel to the cleavage, and the trace of the cleavage is the direction of least refractive index of the sections examined. Pleochroism is distinct, and, as in purpurite, absorption is greatest across the cleavage. The index of refraction is greater than that of Canada balsam, and the double refraction is probably rather high.

#### CHEMICAL COMPOSITION.

About a gram of pure material was separated, which was divided into several portions, using about one-fifth of a gram for each determination. The most interesting part of the analysis was to determine the state of oxidation of the manganese.

When the mineral is treated with hydrochloric acid, chlorine is readily given off. The manganese present therefore can not be in the manganous state, and the absence of ferrous iron and the presence of ferric iron suggested that the manganese was present as a managanic salt. Such was found to be the case.

A fifth of a gram was dissolved in sulphuric acid with a known amount of ferrous ammonium sulphate. All precautions were observed to exclude air, the entire operation being conducted in an atmosphere of carbon dioxide. The water used had been boiled and cooled out of contact with air. Just before the iron sulphate was introduced into the flask containing the mineral an equal quantity was removed from the stock solution and titrated with permanganate.

<sup>1</sup> Probably the pseudoheterosite of Lacroix, op. cit., p. 469,

Thus the amount of ferrous iron introduced into the flask with the mineral was known. After the mineral had been decomposed by the sulphuric acid, the flask was cooled and the solution titrated, the amount of iron sulphate oxidized by the liberation of oxygen from the mineral being determined in this way. From these data the amount of  $Mn_2O_3$  was calculated and found to be 30.47 per cent.

A second sample was decomposed by hydrochloric acid and the chlorine evolved passed into a solution of potassium iodide. The liberated iodine was then titrated with sodium thiosulphate, the latter being standardized with pure copper. Calculating from the results obtained, the amount of  $Mn_2O_3$  was found to be 27.93 per cent. Though these results vary somewhat, yet, considering the small amount of material used (one-fifth of a gram) and the many operations necessary, the agreement is as close as could be expected. The average of the two results is 29.20 per cent.

A direct determination of the total manganese, weighed as anhydrous sulphate, gave as the amount of  $Mn_2O_3$  in the mineral 29.35 per cent, which agrees almost exactly with the average of the two indirect determinations.

The remaining constituents were determined as follows: A portion of the mineral was dissolved in hydrochloric acid and a known weight of iron added (as ferric chloride). A basic acetate separation was then made and the solution boiled for 15 minutes, which, according to Bunsen, will precipitate all the phosphoric acid with the iron and will not precipitate any manganese. The precipitate was dissolved in hydrochloric acid, and reprecipitated by ammonia, after the addition of some ammonium chloride. The two filtrates were united, manganese precipitated by hydrogen sulphide, and finally weighed as anhydrous manganese sulphate. Calcium was then thrown out, dissolved, and reprecipitated, and magnesia found to be absent. The iron-phosphate precipitate was dissolved in hydrochloric acid and divided into two portions. In one portion the iron and phosphoric acid were precipitated by ammonia and weighed. This was then fused up with sodium bisulphite and tested for manganese with silver nitrate and ammonium persulphate. None was present. In the second portion the iron was reduced by hydrogen sulphide and titrated with permanganate. Phosphoric acid was determined in the usual way and a second value obtained by the difference between the iron and the iron plus phosphoric acid. The alkalies were determined by the Lawrence Smith method. The final solution of chlorides gave a strong spectroscopic test for lithium. The water below 105° was determined directly, using a toluene bath. The total water was determined directly by heating in a glass tube, according to Penfield. The water is all given off at a low temperature, that at 105° being given

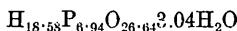
off very readily and at one time. Further heating at 105° failed to remove any more. The values obtained are as follows:

*Analysis and ratios of purpurite.*

	1	2	3	Average.	Ratios.
Fe <sub>2</sub> O <sub>3</sub> .....	15.89	.....	.....	15.89	1.03} 2.96
Mn <sub>2</sub> O <sub>3</sub> .....	29.35	30.47	27.93	29.25	1.93} 1.93
P <sub>2</sub> O <sub>5</sub> .....	47.64	46.96	.....	47.30	3.47
H <sub>2</sub> O.....	5.26	.....	.....	5.26	3.04
CaO.....	1.48	.....	.....	1.48	.27}
Na <sub>2</sub> O.....	.84	.....	.....	.84	.14} .41
Li <sub>2</sub> O.....	Trace.	.....	.....	Trace.	.....
Insol.....	.52	.....	.....	.52	.....
				100.54	

The amount of water given off at 105° is 3.31 per cent. As all of the water is so readily given off, it is most probably present as water of crystallization.

As the calcium and soda require some phosphoric acid, the ratio of R'''<sub>2</sub>O<sub>3</sub> : P<sub>2</sub>O<sub>5</sub> : H<sub>2</sub>O is approximately 3 : 3 : 3. Combining the ratio of the calcium and sodium with that of the iron and manganese and reducing these to their hydrogen equivalent, the ratio becomes:

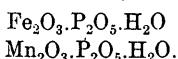


or



The formula for the mineral then becomes R'''<sub>2</sub>O<sub>3</sub>.P<sub>2</sub>O<sub>5</sub>.H<sub>2</sub>O, or R'''<sub>2</sub>P<sub>2</sub>O<sub>8</sub>.H<sub>2</sub>O.

The exact state of combination of the calcium and sodium is unknown. They most probably represent some slight impurity. If the manganic and ferric oxides are isomorphous in the sense that manganous and ferrous oxides are, the ratio of Mn<sub>2</sub>O<sub>3</sub> to Fe<sub>2</sub>O<sub>3</sub> being nearly 2 : 1 is of no significance and the formula should be written (Mn''', Fe''')<sub>2</sub>O<sub>3</sub>.P<sub>2</sub>O<sub>5</sub>.H<sub>2</sub>O, the mineral purpurite being near the manganic end of an isomorphous series having as its two end members:



There are only a few hydrous phosphates of the normal division in which the base is trivalent, such as scorodite and strengite. All of these, however, contain more water than the mineral here described.

Though no manganic phosphates were noted in the literature, there are a number of arsenates mentioned as containing Mn<sub>2</sub>O<sub>3</sub>, with none of which, however, can purpurite be classed. Synadelphite, flinkite,

arseniopleite, and perhaps hematolite, contain  $Mn_2O_3$  with  $Al_2O_3$  or  $Fe_2O_3$ , while in durangite and arseniosiderite,  $Mn_2O_3$  is reported in small amounts.

The mineral fuses easily and readily gives off water in a closed tube, becoming yellowish brown. It is readily soluble to a clear solution in hydrochloric acid, and in nitric acid a black oxide of manganese is separated.

#### HETEROSITE FROM SOUTH DAKOTA.

Some specimens of ore found near Hill City, S. Dak., were seen to contain a considerable amount of heterosite,<sup>1</sup> and through the courtesy of Mr. J. N. Smith, who sent in the first specimens, a larger quantity of material was obtained. Almost all the fresh cleavage surfaces of the black iron manganese phosphate, which chiefly forms the ore, are covered with a film of heterosite. The black phosphate when broken transverse to the cleavage shows but little heterosite, which seems to be formed from the black mineral.

The properties of the mineral as seen under the microscope agree with those determined for purpurite from North Carolina. One small piece showing crystal outline was noticed and is shown in the accompanying sketch (fig. 7). The extinction is parallel and the pleochroism is as follows: Parallel to the cleavage lines (vertical direction), rose red; normal to the cleavage lines, blue purple. The absorption parallel to the cleavage lines (rose red) is less than that at right angles to this direction. On account of the frequent occurrence of small platy masses showing cleavage lines, the mineral has probably two cleavages at right angles to each other, one more perfect than the other. It is probably the imperfect one which is normal to the figure and whose traces show in the vertical lines.

A determination of the density was made, the value previously found from the small specimen of North Carolina material being unsatisfactory. The material was broken into small pieces and the fragments of heterosite picked out. The final sample was not pure, as a small amount of the black substance could not be separated. The density determination was made by weighing the mineral in water in a small test tube suspended from the balance arm. The result obtained is 3.40.<sup>2</sup>

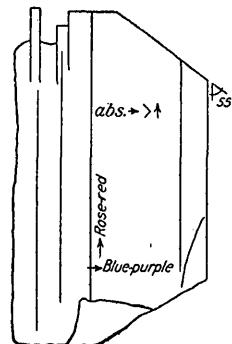


FIGURE 7.—Heterosite from South Dakota.

<sup>1</sup> First described as purpurite. Am. Jour. Sci., 4th ser., vol. 24, 1907, p. 152.

<sup>2</sup> Lacroix, A., Minéralogie de la France, vol. 4, 1910, p. 469, gives 3.27-3.52 for heterosite.

The sample was air-dried for several weeks and then analyzed, with the results given below:

*Analysis and ratios of heterosite from South Dakota.*

	Analysis.	Ratios.
P <sub>2</sub> O <sub>5</sub> .....	43.45	.306 = 1
Fe <sub>2</sub> O <sub>3</sub> .....	38.36	.240
Mn <sub>2</sub> O <sub>3</sub> .....	12.08	.076 = 1.06
CaO.....	1.37	.008
H <sub>2</sub> O.....	4.82	.268 = .88
Insol.....	.19	
MgO, Na <sub>2</sub> O, Li <sub>2</sub> O.....	Trace	
	100.27	

The ratios agree fairly closely with those found in the original purpurite, giving as the formula of the mineral (Fe,Mn)<sub>2</sub>O<sub>3</sub>.P<sub>2</sub>O<sub>5</sub>.H<sub>2</sub>O. The iron greatly predominates over the manganese in the South Dakota mineral, which is therefore called heterosite.

**HETEROSITE FROM CONNECTICUT.**

A small specimen from the well-known mineral locality of Branchville, Conn., was kindly furnished the writer by the late Prof. Penfield. This specimen is coated with a purple mineral whose optical properties as seen under the microscope agree well with those of purpurite.

Only a very small amount of fairly pure material (0.0197 gram) could be obtained for analysis. A direct determination of the water was made, but the phosphoric acid had to be determined by difference. The results obtained are as follows:

*Analysis and ratios of heterosite from Connecticut.*

	Analysis.	Ratios.
Fe <sub>2</sub> O <sub>3</sub> .....	27	17
Mn <sub>2</sub> O <sub>3</sub> .....	23	15
P <sub>2</sub> O <sub>5</sub> .....	[44]	32
H <sub>2</sub> O.....	6	31
	100	33

The ratios are nearly 1 : 1 : 1, giving the same formula as before, namely, (Fe,Mn)<sub>2</sub>O<sub>3</sub>.P<sub>2</sub>O<sub>5</sub>.H<sub>2</sub>O.

## PURPURITE FROM CALIFORNIA.

Purpurite or heterosite has been noticed on some specimens from San Diego County, Cal. These had been collected by the writer, and through the courtesy of Mr. F. M. Sickler, of Pala, several more specimens from this locality have been obtained. They are from one of the lithium-bearing pegmatite dikes on Hiriart Hill, Pala, San Diego County. The mineral occurs with lithiophilite, and possesses the same purple color as the North Carolina specimens. Under the microscope the appearance and properties of the mineral from the two localities are identical. There is, however, not enough of the California material for chemical examination.

## CONCLUSION.

Considering now the three analyses from North Carolina, South Dakota, and Connecticut, it is seen that the iron and manganese vary reciprocally, so that the occurrences represent isomorphous mixtures of  $\text{Fe}_2\text{O}_3 \cdot \text{P}_2\text{O}_5 \cdot \text{H}_2\text{O}$  and  $\text{Mn}_2\text{O}_3 \cdot \text{P}_2\text{O}_5 \cdot \text{H}_2\text{O}$ .

In the North Carolina mineral the manganese predominates and we have purpurite; in that from South Dakota the iron predominates and we have heterosite; and in the Connecticut mineral the iron and manganese are present in nearly equal amounts. These relations can also be shown by the following table:

*Percentage composition of mixtures of purpurite and heterosite.*

Locality.	Approximate content.	
	$\text{Fe}_2\text{O}_3 \cdot \text{P}_2\text{O}_5 \cdot \text{H}_2\text{O}$ (Heterosite).	$\text{Mn}_2\text{O}_3 \cdot \text{P}_2\text{O}_5 \cdot \text{H}_2\text{O}$ (Purpurite).
North Carolina.....	Per cent. 35	Per cent. 65
Connecticut.....	53	47
South Dakota.....	76	24

In the original paper describing purpurite the suggestion was made that the pure end members be called ferripurpurite and mangani-purpurite. Since then the essential identity of the minerals with the French heterosite has been advocated by Lacroix, so that the names ferripurpurite and mangani-purpurite should be replaced by the older names heterosite and purpurite, respectively. More accurately the North Carolina material should be called iron (or ferric) purpurite and that from South Dakota and from France manganese (or manganic) heterosite.

## NOTES ON POWELLITE.

### POWELLITE FROM LLANO COUNTY, TEXAS.

Specimens of the powellite from Baringer Hill, Tex., described in this paper were received through the kindness of Mr. Wm. E. Hidden and represent a small lot that was found in January, 1907. According to Mr. Hidden, who generously placed the material at the writer's disposal, the specimens are similar to those found by him in 1889 and referred to molybdite.<sup>1</sup> The reinvestigation of this mineral was undertaken because it had been suggested that it was probably a natural occurrence of the trioxide of molybdenum, the writer having shown in a previous paper<sup>2</sup> that molybdite was a hydrous ferric molybdate. (See also pp. 84-92.) Analysis showed, however, that this mineral from Baringer Hill is a calcium molybdate and is referable to powellite.

As received by the writer, the mineral is in loose pieces, some over a centimeter wide, associated with, coating, and in many specimens entirely replacing molybdenite. In fact, the powellite forms a pseudomorph after the sulphide of molybdenum, the foliated structure of the latter being frequently retained. The dirty white to gray mineral, some of which is stained brown by iron oxide, breaks up into small glistening scales which, when rubbed between the fingers, crumble to a pearly powder that adheres to the skin and resembles in appearance some varieties of fine-grained talc. Under the microscope the mineral shows double refraction, but no crystal outline. The individual crystal units are very minute, the specimens being aggregates of very fine scales.

A density determination was made on about 0.8 gram of the powdered sample. The pycnometer method was used and the determination was carried out with care at a temperature of 25°. The value obtained for the sample is 4.153, which, when corrected for impurities as described below, gives 4.23. Hidden<sup>1</sup> found the value 4.004, which would indicate that his sample contained more impurities than the writer's.

Analysis of this mineral gave the following results, the mineral dissolving readily in HCl. Qualitative tests failed to show the presence of any tungstic oxide. The mineral is difficultly fusible and gives at the most only a trace of water in the closed tube.

<sup>1</sup> Am. Jour. Sci., 3d ser., vol. 38, 1889, p. 485.

<sup>2</sup> Am. Jour. Sci., 4th ser., vol. 23, 1907, p. 297.

*Analysis of powellite from Texas.*

CaO.....	27.46
MoO <sub>3</sub> .....	67.90
Loss on ignition .....	2.33
MoS <sub>2</sub> .....	1.50
SiO <sub>2</sub> .....	.88
	100.07

The ratio of CaO to MoO<sub>3</sub> is 1:0.96, giving the formula CaMoO<sub>4</sub>.

What is probably a similar occurrence of powellite has recently been described<sup>1</sup> as possibly a natural occurrence of MoO<sub>3</sub>, the mineral differing in its physical properties from the hydrous ferric molybdate. The mineral forms a white or grayish alteration product of molybdenite which it sometimes covers and after which it is pseudomorphous, preserving the form of the molybdenite. The luster is pearly and the mineral is semitranslucent, difficultly fusible to a gray scoria, soluble in nitric acid, and does not contain any iron or water. The material was too scanty for analysis.

**POWELLITE FROM NYE COUNTY, NEVADA.**

The powellite from Nevada was received through Mr. F. L. Hess, of the United States Geological Survey, who states that the specimens were sent him by Mr. F. O. Byor, of Columbia, Nev. The locality is given as 2 miles south of Oak Springs, Nye County, Nev.

The powellite occurs in a vein about 1½ centimeters wide in a soft earthy mass, which seems to be an altered rock. In this rock are occasionally found irregular masses of powellite, some of which are several centimeters across. The mineral is dull in appearance, gray in color, and occurs in platy masses often bent and twisted in different directions.

Gray to white masses of scheelite are embedded in this vein of powellite and also occur as small masses and veins in the altered rock matrix. These masses of scheelite show good cleavage surfaces with highly vitreous to adamantine luster, many having also a decided greasy appearance. The association of scheelite with powellite side by side was thought to be most unusual, but other specimens showed that the powellite, like the Texas mineral, was secondary, being formed in place from molybdenite; it is in fact a pseudomorph after the sulphide of molybdenum. Some other specimens showed the various stages of alteration very well, the amount of unaltered molybdenite varying from a considerable quantity to almost none at all. The association of molybdenite with scheelite is well known and when the molybdenite alters to powellite, the association of

<sup>1</sup> Gagarine, G., Molybdite from the Ilmen Mountains: Bull. Acad. Imp. Sci. St. Petersbourg, 6th ser., 1907, pp. 287-288.

powellite with scheelite necessarily follows. The agencies effecting the change from molybdenum sulphide to calcium molybdate are apparently without effect on the scheelite. This pseudomorphous character of the powellite accounts for its occurrence in platy masses, the structure of the original molybdenite being retained. On some of the specimens, notably those on which there is still a considerable amount of molybdenite remaining, the powellite has a reddish color due to iron stain.

The dull gray powellite can easily be separated by hand picking from the shining greasy scheelite and a sample so selected was used for analysis. A thin section showed, under the microscope, some quartz, hematite, and limonite as impurity.

The density of the mineral was determined by weighing a test tube containing about 6 grams of the mineral in water. The value obtained is 4.026, which, when corrected for impurities as described below, becomes 4.24.

The analysis yielded the following figures, the small amount of tungstic oxide present being probably due to admixed scheelite:

*Analysis of powellite from Nevada.*

CaO.....	26.44
MoO <sub>3</sub> .....	62.43
Fe <sub>2</sub> O <sub>3</sub> .....	1.17
Loss on ignition.....	2.69
SiO <sub>2</sub> .....	6.80
WO <sub>3</sub> .....	Trace.
	99.53

The material insoluble in HCl was tested with HF and found to be almost entirely silica. The ratio CaO to MoO<sub>3</sub> is 1: 0.92, giving the formula CaMoO<sub>4</sub>.

**DENSITY OF POWELLITE.**

The sample of powellite from Texas gave the value 4.153 as its density. This figure is corrected, on the basis of the following composition of the sample, to 4.23.

*Mineral composition of sample of powellite from Texas.*

Silica (density, 2.65).....	0.88
Water (density, 1).....	2.33
Molybdenite (density, 4.7).....	1.50
Powellite.....	95.29
	100.00

The presence of the water as such is of course an assumption, and the final value, 4.23, is necessarily uncertain, depending on the assumptions made.

The powellite from Nevada gave 4.026 as its density, and from the analysis the composition of the sample was found to be as follows:

*Mineral composition of sample of powellite from Texas.*

Silica (density, 2.65) . . . . .	6.80
Water (density, 1) . . . . .	2.69
Iron oxide (density, 3) . . . . .	1.17
Powellite . . . . .	89.34
	100.00

Allowing for the impurities, the value is raised to 4.24, which, like the preceding case, is dependent on certain assumptions.

As powellite and scheelite are doubtless isomorphous, we may be justified in assuming that they have nearly the same molecular volume. Considering the molecular volumes as identical, and taking the gravity of scheelite as 6.14, the density of powellite then becomes 4.267, as calculated by Melville.<sup>1</sup>

As all previous analyses of powellite showed the presence of tungstic acid, the densities given are all too high for the pure calcium molybdate. The two values obtained by the writer, though uncertain (as they are based on some assumptions made in applying the corrections), agree so well not alone with each other, but also with the calculated value, that the average of the three values (4.24, 4.23, 4.27), namely, 4.25, may be taken as being very close to the true density of the pure calcium molybdate,  $\text{CaMoO}_4$ .

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<sup>1</sup> Am. Jour. Sci., 3d ser., vol. 41, 1891, p. 138.

## CHEMICAL COMPOSITION OF MOLYBDIC OCHER.

### INTRODUCTION.

All the textbooks on mineralogy give the composition of natural molybdic ocher as agreeing with that of the artificial product, molybdenum trioxide,  $\text{MoO}_3$ , which may be obtained by oxidizing the natural sulphide, molybdenite. As far as known but one analysis was ever made of the natural ocher, and though that suggested the desirability of further examination such has never been made. This is doubtless due to the fact that whereas the yellow molybdic ocher is very widespread in its occurrence, it seldom occurs in sufficient quantity and of such purity as to warrant any chemical investigation. The writer was fortunate enough to receive a sample of supposed autunite from the Foote Mineral Co., of Philadelphia, which on investigation was found to be molybdic ocher. As the mineral occurs in a pure state, some qualitative tests were made, and it was found that beside the molybdenum considerable ferric iron and water were present. The material was then examined under the microscope and found to be pure and especially free from limonite. Some artificial crystals of  $\text{MoO}_3$  were prepared, and on comparing the two substances under the microscope such differences were found in their properties as to suggest that the mineral examined was not molybdite, but a new species—a hydrated ferric molybdate. The investigation thus opened was extended, and through the generosity of several people it has been possible to make analyses of natural molybdic ocher from five localities and to show that the natural ocher is not  $\text{MoO}_3$ , but  $\text{Fe}_2\text{O}_3 \cdot 3\text{MoO}_3 \cdot 7\frac{1}{2}\text{H}_2\text{O}$ .

Hintze's summary of the literature on molybdite is so complete that only such points as bear directly on the question at hand will be mentioned here. Owen<sup>1</sup> described a deep yellow iron molybdate from Nevada City, Cal., and W. J. Taylor<sup>2</sup> described a similar mineral from Heard County, Ga., but neither article contained quantitative data of any value. Owen found 35 per cent of  $\text{Fe}_2\text{O}_3$ , but Genth<sup>3</sup> in a later publication made a determination on the same mineral and obtained 24.3 per cent  $\text{Fe}_2\text{O}_3$ . He says: "That which could be scratched off the quartz was not quite pure and contained a trace of limonite \* \* \*. The sample examined gave 24.3 per cent of sesquioxide of iron, some of which was certainly mechanically mixed

<sup>1</sup> Proc. Acad. Nat. Sci. Philadelphia, vol. 6, 1852, p. 108.

<sup>2</sup> Am. Jour. Sci., 2d ser., vol. 19, 1855, p. 429.

<sup>3</sup> Idem, vol. 28, 1859, p. 248.

with it." Yet it would necessitate a mixture of nearly one-third limonite to give 24.3 per cent  $\text{Fe}_2\text{O}_3$ , while according to Genth the sample only "contained a trace of limonite." The analytical result was correct, but the interpretation wrong. The sample doubtless contained a trace of limonite, as the 24.3 per cent is slightly higher than the figure required for the formula  $\text{Fe}_2\text{O}_3 \cdot 3\text{MoO}_3 \cdot 7\frac{1}{2}\text{H}_2\text{O}$ , which gives 22 per cent  $\text{Fe}_2\text{O}_3$ .

### PHYSICAL PROPERTIES.

#### OPTICAL CHARACTERS.

The mineral has a fibrous structure and also forms radiating groups. Its color is yellow and many specimens have a silky luster. All of the fibers examined give parallel extinction. The double refraction is strong and the direction of elongation is always an axis of minimum elasticity. The color of the mineral in transmitted light is pale yellow. The pleochroism is strong but is masked by the very strong absorption. Normal to the elongation of the fibers the transmitted light is pale yellow; parallel to the elongation the color is a much stronger yellow. The absorption parallel to the elongation is so strong that thick fibers frequently appear almost black and opaque. This marked absorption is a very characteristic property of this mineral and can be used as a criterion for its determination. These same properties are mentioned by Lacroix<sup>1</sup> for molybdite from Corsica.

Crystals of  $\text{MoO}_3$ , prepared by roasting molybdenite in an open crucible, show very decided differences in their physical properties from those of the natural mineral. They are not fibrous, but platy and are colorless, nonpleochroic, and show no difference in absorption in different directions.

#### PYROGNOSTIC CHARACTERS.

On heating the mineral in a closed tube abundant water is easily given off and the mineral assumes a dark-olive color; on further heating it again becomes lighter in color. On heating the mineral in a crucible the color changes are very marked. At first the yellow mineral darkens and becomes a dark gray, appearing almost black and with slight olive tint, then it becomes a light yellow again, and on further heating changes to a deep-orange color. If the mineral now be allowed to cool the orange changes to yellow and back to orange again on reheating. If the dark-colored material be allowed to cool, it retains its dark-gray color and on reheating passes through yellow to the orange. On heating for some time at a higher temperature, the mineral, on cooling, becomes a permanent bright green. By

<sup>1</sup> Lacroix, A., *Minéralogie de la France*, vol. 3, p. 8.

further heating all of the molybdenum is volatilized and the dark-red ferric oxide remains. The mineral is readily soluble in hydrochloric acid, and is decomposed by ammonia, taking on a brown color (probably due to the separating ferric hydroxide). After a while, all the molybdenum of the mineral goes into solution, leaving the insoluble ferric hydroxide.

#### DENSITY.

The density of the powdered sample (No. 4, from Hortense, Colo.) was determined with a pycnometer, using 3 grams of material. The value obtained is 3.026. This is corrected on the basis of the following composition:

*Mineral composition of sample of molybdite.*

Molybdenite (density 4.7) .....	5.50
Silica (density 2.65) .....	16.51
Molybdite (density 2.99) .....	77.99
	100.00

The corrected value becomes 2.99 in which, however, no allowance is made for the extraneous moisture.

#### SOLUBILITY IN WATER.

An experiment was made to determine approximately the solubility of molybdite in water. About 3 grams of the mineral were stirred in a beaker for a day with 760 cubic centimeters distilled water at room temperature (about 25°), and then filtered repeatedly. The final filtrate showed a very faint cloudiness. It was evaporated down in platinum, the residue dissolved in HCl and the iron precipitated as hydroxide with ammonia and weighed. The 760 cubic centimeters of water contained 0.0051 grams of  $\text{Fe}_2\text{O}_3$ . On the assumption that this all came from the mineral, it is calculated that the solubility of molybdite in water is approximately 1 to 33,000 so that the mineral is rather insoluble.

#### CHEMICAL ANALYSES.

##### MOLYBDITE FROM NEW HAMPSHIRE.

The purest sample examined came from Westmoreland, N. H., and was very kindly furnished from the Brush collection of Yale University by Prof. Wm. E. Ford. Nearly a gram of material was obtained and this was divided into portions of a quarter gram weight. Macroscopically the specimen looked more earthy and not so finely crystallized as those obtained from other localities, but under the microscope it showed its characteristic optical properties, and was seen to be homogeneous, free from limonite, and to contain a

small quantity of molybdenite scales. The first figure given for the water content, 16.98 per cent, was obtained by weighing the water direct, using the method of glass tubes as advocated by Penfield. The other two figures represent the loss up to 200°, at which temperature all the water of the mineral is given off. The residue was dissolved in HCl, and after filtering off the insoluble matter the iron was precipitated by ammonia, filtered off, dissolved in HCl, and reprecipitated and weighed, while hydrogen sulphide was passed into the combined ammoniacal filtrates until the characteristic red color was produced. The solution was then acidified with H<sub>2</sub>SO<sub>4</sub> and after heating on the steam bath to allow the molybdenum sulphide to settle was filtered through a Gooch crucible. The sulphide was then dried, changed into the trioxide at a low heat, and weighed to constant weight. The filtrate from the molybdenum sulphide was made alkaline with ammonia, and hydrogen sulphide was again passed into the solution, which was then reacidified with H<sub>2</sub>SO<sub>4</sub> and a small amount of molybdenum which had escaped precipitation in the first case was recovered. The filtrate on testing showed no more molybdenum, neither was any residue found on evaporating it to dryness. Tests showed the absence of calcium and magnesium. The weighed iron oxide was fused with sodium bisulphate, and determined volumetrically with a result that agreed with the gravimetric determination. The results obtained are as follows:

*Analysis of molybdite from New Hampshire.*

	1	2	3	Average.	Ratios.
H <sub>2</sub> O.....	16.98	17.95	17.93	17.62	7.43=7½
Fe <sub>2</sub> O <sub>3</sub> .....	21.08	21.07	.....	21.08	1.00=1
MoO <sub>3</sub> .....	57.02	57.49	58.55	57.69	3.04=3
Insoluble.....	4.66	.....	.....	4.66	.....
				101.05	

The average analysis with the insoluble matter deducted and reduced to 100 per cent, is compared below with the figures calculated for Fe<sub>2</sub>O<sub>3</sub>.3MoO<sub>3</sub>.7½H<sub>2</sub>O.

*Comparison of analysis with calculated values.*

	Analysis.	Calculated.
H <sub>2</sub> O.....	18.28	18.57
Fe <sub>2</sub> O <sub>3</sub> .....	21.87	22.01
MoO <sub>3</sub> .....	59.85	59.42
	100.00	100.00

This formula has been verified by the analysis of molybdite from Arizona by Guild.<sup>1</sup> Two analyses made by him are quoted below.

*Analyses of molybdite from Arizona (by Guild).*

	1	2
Insoluble residue.....	4.86	2.66
Water.....	16.83	16.61
Ferric oxide, $\text{Fe}_2\text{O}_3$ .....	20.88	21.18
Molybdic trioxide, $\text{MoO}_3$ .....	57.38	59.79
Total.....	99.95	100.24

The average of these analyses with the insoluble residue deducted and recalculated gave the following values. The ratios lead to the formula  $\text{Fe}_2\text{O}_3 \cdot 3\text{MoO}_3 \cdot 7\text{H}_2\text{O}$ , which is half a molecule lower in water than the formula obtained by the writer.

*Recalculated analysis of molybdite from Arizona.*

	Analysis.	Ratios.
$\text{H}_2\text{O}$ .....	17.355	7.06
$\text{Fe}_2\text{O}_3$ .....	21.835	1.00
$\text{MoO}_3$ .....	60.805	3.09

Partial water determinations were made on two samples of molybdite from New Hampshire, as follows, the amount of water being represented by the loss in weight, the crucible being heated at the temperature given till 6 hours additional heating produced no difference in weight.

*Partial water determination.*

	Per cent.
Total loss up to $110^\circ$ .....	14.04
Total loss up to $125^\circ$ .....	15.50
Total loss up to $185^\circ$ .....	17.64
Total loss up to $200^\circ$ .....	17.93

### MOLYBDITE FROM OTHER LOCALITIES.

The quantity of material from other localities<sup>2</sup> was so small that exact values can not be expected, but the analyses all show a general agreement with the calculated values. The samples analyzed are as follows:

<sup>1</sup> Guild, F. N., The composition of molybdite from Arizona: Am. Jour. Sci., 4th ser., vol. 23, 1907, p. 455.

<sup>2</sup> The characteristic optical properties of the ferric molybdite were also determined on specimens from Stanhope, N. J.; Gold Creek, Deer Lodge County, Mont.; Aldfield Township, Pontiac County, Quebec.

No. 1 is from Telluride, Colo., and is from the sample furnished by the Foote Mineral Co., Philadelphia.

No. 2 was very kindly furnished by Prof. A. J. Moses, of Columbia University, who states that the sample is probably from California, though the locality is not certainly known. Two samples were sent; one yellow, which was seen to be pure, and one brown, which was seen under the microscope to consist of a mixture of the pure yellow mineral and limonite. The appearance of this sample at once suggested that it was similar to one analyzed by Owen, which gave 35 per cent  $\text{Fe}_2\text{O}_3$ . It also showed the ease with which a mechanical mixture of molybdite and limonite could be detected under the microscope. The opaque brown limonite was scattered through some of the yellow molybdite and caused it to appear almost opaque, besides which there were numerous patches of earthy limonite. This sample was not analyzed.

No. 3 is from Renfrew, Ontario, and was very kindly furnished by Prof. C. Palache, of Harvard University. Most of the material is massive and appears earthy, though under the microscope it is seen to consist of minute fibrous crystals. The material did not look promising, but analysis showed values agreeing well with the others. Owing to an accident only the iron and molybdenum could be determined. These values are not given. On one of the specimens sent by Prof. Palache there was a small amount of the finely crystallized fibrous material which seemed to be very pure. This was scraped off and analyzed, and though only about 50 milligrams were available the results given under No. 3 were obtained.

No. 4 is from Hortense, Colo., and was received through the kindness of Mr. F. L. Hess. The yellow mineral occurs in lumps, several of which are over 2 centimeters in diameter. With the molybdite are associated molybdenite, quartz, and mica. The sample looks earthy, but under the microscope it is seen to be well crystallized and shows the characteristic optical properties of molybdite as described earlier in this paper. A sample was selected as pure as could be obtained, but it was found on analysis to contain a large amount of insoluble matter. The powdered specimen caked together in the sample tube and probably contained some extraneous water. The analysis also showed too high a water content for molybdite.

The methods of analysis were the same as those employed with the New Hampshire material. By heating in a closed tube to obtain the water, some of the molybdenite which was mixed with the mineral doubtless was oxidized to the oxide, thus increasing the amount of molybdenum present. The results obtained are:

*Analyses of molybdite.*

	No. 1, Telluride, Colo.	No. 2, Califor-nia.	No. 3, Renfrew, Ontario.	No. 4, Hortense, Colo.
H <sub>2</sub> O.....	15.8	15.4	15.5	15.87
Fe <sub>2</sub> O <sub>3</sub> .....	19.0	15.8	17.3	15.95
MoO <sub>3</sub> .....	59.3	47.7	55.7	46.77
Insoluble.....	[5.9]	24.0	9.4	22.01
	100.0	102.9	97.9	100.60

By deducting the insoluble matter and calculating the analyses to 100 per cent we obtain:

*Analyses of molybdite with insoluble matter deducted and percentages recalculated.*

	1	2	3	4	Calcu-lated.
H <sub>2</sub> O.....	16.8	19.5	17.3	20.19	18.57
Fe <sub>2</sub> O <sub>3</sub> .....	20.2	20.0	19.6	20.30	22.01
MoO <sub>3</sub> .....	63.0	60.5	62.9	59.42	59.42
	100.0	100.0	100.0	100.00	100.00

The ratios of the above analyses are as follows:

*Ratios of analyses of molybdite.*

	Fe <sub>2</sub> O <sub>3</sub> .	H <sub>2</sub> O.	MoO <sub>3</sub> .
No. 1.....	1.0	7.3	3.4
No. 2.....	1.0	8.6	3.3
No. 3.....	1.0	7.8	3.5
No. 4.....	1.0	8.8	3.3

The analyses agree sufficiently well to show that the mineral is uniform in composition and the analyses of the material from New Hampshire serve to establish its formula.

The insoluble residue in No. 4, consisting of 5.5 per cent MoS<sub>2</sub> and 16.5 per cent SiO<sub>2</sub>, was roasted in an open crucible to change the MoS<sub>2</sub> into MoO<sub>3</sub> and then weighed. The oxide of molybdenum was then dissolved by HCl, leaving the silica, which was tested with HF

for its purity. The determination of water was made in two ways—by loss in weight and by direct weighing. It was found that the water given off at 110° by heating the mineral in a glass tube in a toluene bath while a current of dry air was passed over the mineral and collecting and weighing the water (A, below) was considerably greater than the amount given off at 110° by heating the mineral in a crucible in a toluene bath, determining the water by the loss in weight (B, below). The results are shown below:

*Water content of molybdite.*

	A	B
Amount given off at 110°.....	13.77	11.39
Amount given off at 200°.....	2.23	4.34
	16.00	15.73

In considering the mode of formation of the hydrous ferric molybdate (molybdite) it may be well to call attention to the fact that the interaction of molybdic acid,  $H_2MoO_4 \cdot H_2O$ , on limonite may be written so as to yield a product with a formula that is identical with the new formula and which balances the equation:



#### ARTIFICIAL MOLYBDITE.

Chemical dictionaries mention but two hydrous ferric molybdates, neither of which is crystalline, and which approximate in formula to  $Fe_2O_3 \cdot 4MoO_3 \cdot 7H_2O$  and  $Fe_2O_3 \cdot 5MoO_3 \cdot 16H_2O$ . On adding a solution of ammonium molybdate to an excess of a solution of a ferric salt no precipitate is formed, but on reversing the process and adding the ferric salt to the ammonium molybdate a voluminous yellow precipitate appears. A precipitate thus prepared was air-dried for about a week and analyzed with the following results:

*Analysis and ratios of artificial ferric molybdate.*

	Analysis.	Ratios.
$Fe_2O_3$ .....	15.9	1.0
$MoO_3$ .....	61.6	4.3
$H_2O$ (by difference).....	22.5	12.5
	100.0	

These results are between those of the two salts above quoted. It was found, however, that a large amount of free molybdic acid contaminated the material, and the impossibility of air-drying the non-

crystalline mass sufficiently accounts for the high water content. It is therefore believed that neither of the two salts above mentioned and described in chemical dictionaries has any existence, but that they are mixtures of a salt of the formula  $\text{Fe}_2\text{O}_3 \cdot 3\text{MoO}_3 + n\text{H}_2\text{O}$  with molybdic acid and water.

A preliminary experiment of heating precipitated ferric hydroxide and molybdic acid in the correct molecular proportions with an excess of water in a glass bomb failed to give any result. After heating to about  $150^\circ$  for several hours there was no indication of any reaction, and on higher heating the bomb exploded.

An attempt was next made to crystallize the yellow amorphous precipitate. The precipitate was heated with water in a glass bomb up to  $180^\circ$  to  $200^\circ$  for several days, and when examined was found to consist of a mass of fine yellow crystals and a greenish, amorphous mass. On shaking up the tube the green part settled very quickly and the minute yellow crystals settled so slowly that a nearly perfect separation of the two products could be made. The yellow crystalline part was examined under the microscope and found to consist of three products, all crystallized. The most abundant salt occurs in minute, pale-yellow tablets of quadratic outline. Some of them which seem to be isotropic have an octagonal shape suggesting combinations of the cube and octahedron. They were too small to test for interference figures. The second most abundant salt occurs in pale-yellow, fibrous prisms and also in radiated, fan-shaped masses which show the characteristic absorption of the natural mineral and are probably identical with it. The third salt also occurs in prisms, which, however, are not fibrous, do not show any absorption, and seem to be colorless. They may be molybdic acid, but the first two salts are probably hydrated ferric molybdates.

#### OCCURRENCE OF NATURAL TRIOXIDE OF MOLYBDENUM.

The existence of the trioxide of molybdenum ( $\text{MoO}_3$ ) as a natural mineral has not been demonstrated,<sup>1</sup> and what is commonly believed to be  $\text{MoO}_3$  is shown to be a hydrated ferric molybdate,  $\text{Fe}_2\text{O}_3 \cdot 3\text{MoO}_3 \cdot 7\frac{1}{2}\text{H}_2\text{O}$ . This composition for molybdite has been verified in the analysis by Guild. The occurrence in Texas of what has been supposed to be  $\text{MoO}_3$ , and which has been so described, has been shown to be powellite, and the Russian specimen supposed to be  $\text{MoO}_3$  is also doubtless powellite. Until it is shown conclusively that an oxide of molybdenum does exist in nature, the name molybdite must be retained for the hydrated ferric molybdate.

<sup>1</sup> Lacroix found the molybdite from Corsica to contain iron and water. *Minéralogie de la France*, vol. 4, p. 206, 1910.

## ANALYSIS OF TOURMALINE FROM ELBA.

While the writer was analyzing a number of tourmalines from San Diego County, Cal., Prof. Clarke suggested that it would be advisable to analyze the pale-pink variety of tourmaline from the Island of Elba. Rammelberg's analysis of tourmaline from this locality indicated that this tourmaline was probably near in composition to one of the end products of the isomorphous mixtures which form the mineral tourmaline. A number of these crystals were purchased from the Foote Mineral Co., who wrote in regard to them: "All of these were secured in exchange from the late Prof. Bombicci, who collected them in Elba many years ago." The crystals were picked over and crushed to small fragments, after which each piece was examined under a hand lens and only the transparent pure material was selected. These were then washed with cold dilute HF to remove any albite, mica, etc., that might be adhering to the tourmaline. The sample finally powdered and analyzed was pure. The density of the mineral (determined by Thoulet solution) is 3.04-3.05, as the mineral sank at 3.043 and floated at 3.050. The analysis is as follows:

*Analysis and ratios of tourmaline from Elba.*

	Analysis.	Ratios.
SiO <sub>2</sub> .....	37.89	0.632 = 4.00
B <sub>2</sub> O <sub>3</sub> .....	10.28	.147 = 0.93
Al <sub>2</sub> O <sub>3</sub> .....	43.85	2.580
Ti <sub>2</sub> O <sub>3</sub> .....	.04	.002
FeO.....	.11	.003
MnO.....	.11	.003
CaO.....	.07	.003
Na <sub>2</sub> O.....	2.43	.079
Li <sub>2</sub> O.....	1.66	.111
H <sub>2</sub> O.....	3.47	.386
F.....	.10	.005
MgO, K <sub>2</sub> O.....	None.	
-O=F=.....	100.01 .04	
	99.97	

<sup>a</sup> These ratios give the hydrogen atoms equivalent to the metals.

The ratios agree very well with those proposed by Penfield, namely, 4: 1: 20. A discussion of the results will be given in a later paper on the California tourmalines, as at present it is only desired to place the above analysis on record. The state of oxidation of the titanium, iron, and manganese are given arbitrarily.

## EVANSITE FROM TWO AMERICAN LOCALITIES.

### EVANSITE FROM IDAHO.

Some specimens of evansite, reported as being found in the immediate vicinity of Goldburg, Idaho, were received through the courtesy of Mr. C. R. Potts, of that place. The massive amorphous mineral occurs in seams and is very brittle with a conchoidal fracture. Its hardness is about 3, and its color is generally brown, though it varies considerably. Some specimens are yellow, or white, or dark red. The brown specimens very much resemble common brown opal.

An analysis of the brown material gave the following results:

*Analysis and loss of water of evansite from Idaho.*

Analysis.		Loss of water.	
H <sub>2</sub> O.....	36. 96	At 107°.....	20. 00
P <sub>2</sub> O <sub>5</sub> .....	19. 14	175°.....	7. 36
Fe <sub>2</sub> O <sub>3</sub> .....	5. 49	255°.....	3. 13
Al <sub>2</sub> O <sub>3</sub> .....	34. 48	290°.....	. 94
CaO.....	4. 32	To low redness.....	3. 90
MgO.....	Trace.	Blasting .....	1. 61
FeO.....	None.		
	100. 39		36. 94

A determination (by means of Thoulet solution) of the relation of the density to the amount of iron present gave the following values:

*Relation of density to iron content.*

Color of mineral.	Fe <sub>2</sub> O <sub>3</sub> .	Average density.	Limits.
Dark red.....	Per cent. 6. 60	2. 00	1. 990-2. 016
Brown.....	5. 49	1. 98	1. 972-1. 990
Yellow.....	2. 15	1. 94	1. 927-1. 947

By plotting these values it is found that the density of the mineral free from iron should be between 1.88 and 1.91, though this value does not necessarily represent that of pure evansite, as the material on which these determinations were made contains appreciable calcium. Forbes<sup>1</sup> gives the following determinations of the density:

<sup>1</sup> See literature at end of paper for reference.

*Densities of evansite.*

Colorless, translucent.....	1.822
Colorless.....	1.872
Faint yellow.....	2.099
Semipaque.....	1.965

The average of these densities is 1.939, though possibly the lowest figure more nearly represents the density of the pure mineral. Smith gives the value 1.842 as the density of colorless to milky white, translucent material.<sup>1</sup> Kovar gives for white 1.874 (0.87 per cent  $\text{Fe}_2\text{O}_3$ ), and for yellow 1.937 (1.92 per cent  $\text{Fe}_2\text{O}_3$ ). These values give an average for all the determinations of 1.93, and an average of the lowest values, representing possibly the purer mineral, gives 1.86.

A determination by F. E. Wright of the index of refraction of the colorless evansite from Idaho gave 1.485, the index for the colored varieties not varying more than 0.01 from this value.

**EVANSITE FROM ALABAMA.**

The second sample was received through Prof. Clarke from Mr. Charles Catlett, and the locality is given as "from the coal seam just west of Columbiana, Ala." It is associated with coal, shows a light-yellow color with a resinous luster, and is transparent in small pieces. It is very brittle. An approximate analysis serves to identify the mineral, the phosphoric acid being determined by difference.

*Analysis of evansite from Alabama.*

$\text{Al}_2\text{O}_3$ .....	38.33
$\text{CaO}$ .....	1.03
$\text{MgO}$ .....	.75
Loss on ignition.....	38.19
$\text{P}_2\text{O}_5$ (by difference).....	21.70
	100.00

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<sup>1</sup> Wrongly given as 1.939 in Dana's App. II, p. 25.

<sup>2</sup> These references only mention the occurrence of evansite.

## MANGANOTANTALITE FROM MOUNT APATITE, MAINE.

The crystals here described were received from Prof. Palache, who suggested that they were manganotantalite. They are associated with the minerals characteristic of these lithium-bearing pegmatites, as albite, lepidolite, etc. Most of the crystals are small, several millimeters in length, and are tabular to the  $a$  face (Dana's orientation). The specific gravity was determined as 7.14, showing that in these crystals the tantalic acid largely predominates over the columbic acid. A partial analysis showed further that iron was almost entirely absent, so that the crystals may well be termed manganotantalite. The analysis gave the following results:

### *Analysis of manganotantalite from Mount Apatite, Maine.*

Ta <sub>2</sub> O <sub>5</sub>	.....	85.35
Cb <sub>2</sub> O <sub>5</sub>	.....	
FeO	.....	.16
MnO (by difference)	.....	14.49
		100.00

The forms present are:  $b\{010\}$ ,  $a\{100\}$ ,  $c\{001\}$ ,  $m\{110\}$ ,  $g\{130\}$ ,  $j\{320\}$ ,  $z\{530\}$ ,  $d\{730\}$ ,  $k\{103\}$ ,  $u\{133\}$ ,  $n\{163\}$ . The angles measured are shown below. Most of the faces were dull and gave poor reflections.

### *Forms and angles for manganotantalite.*

Symbol.	Measured.	Calculated.
$b \wedge m = (010) : (110)$ .....	° / 50 28	° / 50 22
$b \wedge g = (010) : (130)$ .....	21 27	21 55
$b \wedge z = (010) : (530)$ .....	63 10	63 34
$b \wedge d = (010) : (730)$ .....	{ 70 15 70 06 }	70 27
$c \wedge k = (001) : (103)$ .....	19 38	19 42
$b \wedge n = (010) : (163)$ .....	° 30	30 50
$n \wedge n''' = (163) : (\bar{1}63)$ .....	° 118	118 20
$n \wedge n' = (163) : (\bar{1}63)$ .....	° 22	19 54
$b \wedge u = (010) : (133)$ .....	50 45	50 03
$u \wedge u''' = (133) : (\bar{1}33)$ .....	81 15	79 54
$u \wedge u' = (133) : (\bar{1}33)$ .....	30 04	29 57

<sup>a</sup> Approximate.

Measurements for the prism  $j\{320\}$  are as follows:

*Measurements of  $j\{320\}$ .*

Crystal No.—	Size of face.	Reflec-tion.	Symbol.	Measured.	Calcu-lated.
1.....	Narrow.....	<i>p.</i>	$110 \wedge 320$	9 39	10 44
2.....	Broad.....	<i>p.</i>	$010 \wedge 320$	61 21	61 06
2.....	Broad.....	<i>g.</i>	$320 \wedge 320$	57 12	57 48
3.....	Broad.....	<i>j.</i>	$010 \wedge 320$	61 12	61 06
4.....	Broad.....	<i>g.</i>	$010 \wedge 320$	61 13	61 06

The faces of (133), (100) are large, those of (163), (103), (110), (320) are small, and most of the others are very narrow faces.

99946°—Bull. 490—11—7

## ZINNWALDITE FROM ALASKA.

The occurrence of zinnwaldite with cassiterite and topaz in the York region, Alaska, has already been mentioned<sup>1</sup> and the results of a quantitative analysis of this mica are here presented. The axial angle, 2E, for sodium light, was measured 49° 29'. The sample analyzed was probably fairly pure.

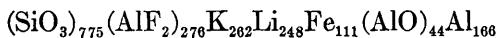
*Analysis of zinnwaldite from Alaska.*

	Analysis.	Ratios.	
SiO <sub>2</sub> .....	46.80	.775	775
Al <sub>2</sub> O <sub>3</sub> .....	24.50	.240	243
Fe <sub>2</sub> O <sub>3</sub> .....	.50	.003	
FeO.....	6.35	.088	
MnO.....	1.38	.019	111
CaO.....	.24	.004	
Na <sub>2</sub> O.....	1.73	.033	131
K <sub>2</sub> O.....	9.20	.098	
Li <sub>2</sub> O.....	3.73	.124	124
H <sub>2</sub> O.....	.88	.098	552
F.....	8.63	.454	
<hr/>		<hr/>	
-O=2F.....	103.94		
	3.63		
<hr/>		<hr/>	
	100.31		

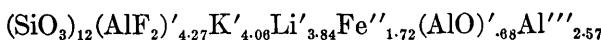
In the ratios, the soda and potash are taken together and the small amount of water present is considered as hydroxyl and added to the fluorine ratio. The empirical formula gives:



The total oxygen is very slightly greater than three times the silica, the ratio O : Si being 3.06 : 1. The mineral is therefore considered as a metasilicate and the formula may be written



or



<sup>1</sup> Bull. U. S. Geol. Survey No. 262, 1905, p. 129.

## SOME NEW FORMS OF CALCITE CRYSTALS.

### CALCITE FROM ANDREASBERG, GERMANY.

Several specimens of calcite labelled "Andreasberg, Harz Mountains," were purchased from a local mineral dealer. One specimen shows large tabular crystals with only the base  $c\{0001\}$  and prism  $m\{10\bar{1}0\}$ . Other specimens consist of groupings of tabular crystals which are somewhat unusual in their combinations. These tabular calcites are arranged in superimposed parallel or nearly parallel groupings forming vertical columns several centimeters long, the individual crystals being up to 13 millimeters wide and 5 millimeters high. The dominant forms on these crystals are the base  $c\{0001\}$  and prism  $m\{10\bar{1}0\}$ , but characteristically all of them also show the new prism  $\frac{1}{2}\{7.6.\bar{1}3.0\}$  as narrow rounded faces. Very narrow faces of  $s\{05\bar{5}1\}$  and minute faces of  $v\{21\bar{3}1\}$  are present in numerous specimens. Some of these crystals, which seem to be single, show an easy parting parallel to the base and may be built up of many thinner tabular crystals in parallel position. Associated with these calcites are numerous fourlings of harmotome.

Measurements of the  $\phi$  angle for  $s\{05\bar{5}1\}$  varied from  $78^\circ 38'$  to  $78^\circ 47'$ ; calculated,  $78^\circ 32'$ .

The dihexagonal prism faces are bright, but rounded, so that no accurate measurements could be made. They gave, however, a bright signal in the mass of reflections caused by the rounded surfaces and the measurements given below were of this bright signal. The faces were seen to be in the prism zone  $mm'$  and therefore could not be scalenohedrons with complex indices.

*Measurements of  $\frac{1}{2}\{7.6.\bar{1}3.0\}$ .*

	$\phi$
Measured.....	°   '
Do.....	27   34
Do.....	27   20
Do.....	27   32
Do.....	27   37
Average.....	27   31
Calculated.....	27   27

This prism face is present on all of the crystals, but on few of them is suitable for measurement. The results given were all obtained

from one crystal. It seems strange that this form has not been described before—at least the writer could find no mention of it in the literature—as the specimens are supposed to have come from a locality well known for its calcites.

It hardly seems correct to regard these prism faces as corrosion forms or other secondary formation. Though the base and prism faces on these calcites are dull they do not show any definite signs of etching and though the new prism faces are rounded they are considered as belonging to a well-established form for calcite. As stated, the form occurs on all of the crystals and all 12 of the faces are present on each crystal. These crystals are shown in figure 8.

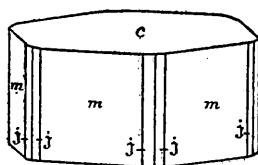


FIGURE 8.—Calcite from Germany.

#### CALCITE FROM ENGLAND.

The crystals here described are from a group containing individual crystals the largest of which measures 4 by 2 centimeters. The exact locality is not known. The crystals have a trigonal habit due to the predominance of a steep negative rhombohedron. The forms present on these crystals are:  $r\{10\bar{1}1\}$ ,  $M\{40\bar{4}1\}$ ,  $\eta\{50\bar{5}1\}$ ,  $Y\{60\bar{6}1\}$ ,  $o\{11.0.\bar{1}\bar{1}.2\}$ ,  $e\{01\bar{1}2\}$ ,  $f\{02\bar{2}1\}$ ,  $d\{08\bar{8}1\}$ ,  $C\{0.13.\bar{1}\bar{3}.1\}$ ,  $n\{41\bar{5}3\}$ ,  $G\{72\bar{9}5\}$ ,  $w\{31\bar{4}5\}$ ,  $v\{21\bar{3}1\}$ ,  $r\{53\bar{8}2\}$ ,  $y\{32\bar{5}1\}$ , and a new form  $p\{4.20.\bar{2}\bar{4}.7\}$ . The following table gives the average of the measured angles compared with the calculated values:

*Forms and angles of calcite from England.*

Letter.	Symbol.	Number measured.	Measured.		Calculated.	
			$\phi$	$\rho$	$\phi$	$\rho$
<i>M</i>	4041	3	0 02	75 48	0 00	75 47
$\eta$	5051	2	0 02	78 11	0 00	78 32
<i>o</i>	11.0.11.2	1	0 12	79 35	0 00	79 33
<i>y</i>	6061	2	0 02	80 11	0 00	80 24
<i>e</i>	0112	2	0 00	26 15	0 00	26 15
<i>f</i>	0221	5	0 00	63 07	0 00	63 07
<i>d</i>	0881	4	0 00	83 01	0 00	82 46
<i>C</i>	0.13.13.1	1	0 12	85 30	0 00	85 32
<i>n</i>	4153	1	10 55	56 22	10 54	56 26
<i>G</i>	7295	3	12 22	58 22	12 13	58 14
<i>w</i>	3145	2	14 25	35 05	13 54	35 25
<i>v</i>	2131	2	19 07	69 10	19 07	69 02
<i>r</i>	5382	8	21 43	74 28	21 47	73 51
<i>y</i>	3251	2	23 21	77 02	23 25	76 54
<i>p</i>	4.20.24.7	13	8 56	72 09	8 57	72 20

The indices of the form above referred to as  $\text{p} \{4.20.\overline{24}.7\}$  could not be definitely determined. Many faces of this form are present on these crystals; in fact the form is characteristic for this group, as it is present on all the crystals. But it is always rounded and uneven, and will give when mounted on the goniometer either a group of reflections or else two or three distinct signals. The various measurements for this form are as follows:

*Measurements of  $\text{p} \{4.20.\overline{24}.7\}$ .*

Crystal No.	Size of face.	Number of signals.	Reflec-tion.	$\phi$	$\rho$	Signal.
1	Minute...	2	{ p. p. f.	8 17	72 08	Distinct.
				8 20	71 36	Very faint.
				8 23	71 40	Distinct.
1	Small...	3	{ p. p. f.	8 20	72 08	Very faint.
				8 23	71 15	Do.
				8 48	71 59	Distinct.
1	...do....	3	{ p. p. p.	8 26	71 31	Very faint.
				9 01	72 19	Do.
				8 23	71 40	Distinct.
1	...do....	3	{ p. p. p.	8 46	71 05	Do.
				9 06	72 19	Do.
				8 54	72 15	Very faint.
2	Minute...	1	{ p. f.	9 13	72 17	Distinct.
				8 52	71 58	Very faint.
				8 15	71 30	Do.
2	...do.....	-----	{ f. f.	9 56	72 20	Many.
				10 19	73 23	Very faint.
				9 24	72 04	Do.
2	...do....	3	{ p. p.	10 17	73 43	Do.
				9 16	72 41	Distinct.
				8 37	71 48	Very distinct.
2	Minute...	2	{ p. p.	8 44	71 56	Distinct.
				9 23	72 38	Do.
				9 07	72 38	Do.
3	...do....	2	{ p. p.	8 34	71 58	Do.
				9 15	72 36	One distinct.
3	Minute...	1	p.	8 48	72 51	Distinct.
3	Small...	1	p.			

Average of measurements of 13 faces:  $\phi = 8^\circ 56'$ ,  $\rho = 72^\circ 09'$ . Calculated,  $\phi = 8^\circ 57'$ ,  $\rho = 72^\circ 20'$ .

An average of the values with "signal distinct" is  $\phi = 8^\circ 45'$ ,  $\rho = 72^\circ 11'$ , or nearly the same.

Although these measurements are near to the angular values of the simple form  $\{15\bar{6}2\}$ , which are  $\phi = 8^\circ 57'$ ,  $\rho = 70^\circ 00'$ , the  $\rho$  angle is sufficiently different to preclude their reference to this form. If we take the average measured value,  $\phi = 8^\circ 56'$ ,  $\rho = 72^\circ 09'$ , we find

that the ratio  $h:k=1:5$  ( $\phi$  calculated =  $8^{\circ} 57'$ ), and the ratio  $i:l=3.392$ , which gives as the indices  $1.5\bar{6}.\frac{7}{4}$  or  $4.20.\overline{24}.7$ , which are not especially complex and the calculated angles for which are  $\phi=8^{\circ} 57'$ ,  $\rho=72^{\circ} 20'$ , agreeing fairly well with the average of the measurements given above. The above detailed description is given in order to call attention to these trigonal calcites in the hope that some one may find a similar group having this new form which will admit of an accurate measurement whereby the symbol of the form may be definitely determined.

A single minute face of  $C\{0.13.\overline{13}.1\}$  was noted and this was poorly developed, giving a poor reflection. Sansoni<sup>1</sup> gives this form as new and it is also described by Höfer<sup>2</sup> as new, being determined by zonal relations, but it is considered as doubtful by Goldschmidt,<sup>3</sup> he suggesting that the correct symbol may be  $\{0.14.\overline{14}.1\}$ , though Sansoni's measurements, like the writer's above, agree well for  $\{0.13.\overline{13}.1\}$ . Figure 9 shows one of the smaller crystals of this group with the important forms developed at one corner. As shown in this figure, the combinations vary at similar crystallographical places, being

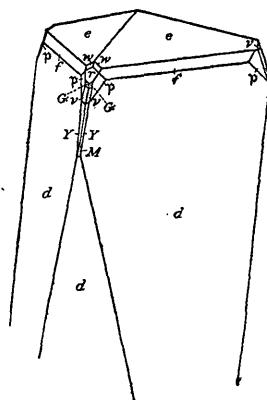


FIGURE 9.—Calcite from England.

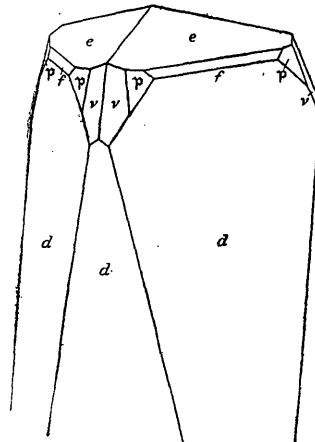


FIGURE 10.—Calcite from England.

much simpler at some corners than at others. Though all the intersection lines are here drawn straight, many of them are considerably curved on the crystals, especially on the larger ones, which moreover show a much simpler combination than the smaller ones. Figure 10 shows the appearance of the larger crystals.

<sup>1</sup> Zeitschr. Kryst. Min., vol. 10, 1885, p. 564.

<sup>2</sup> Min. pet. Mitt., vol. 12, 1891, p. 487 (Ref. Zeitschr. Kryst., vol. 24, p. 431).

<sup>3</sup> Index der Krystallformen der Mineralien, vol. 1, 1886, p. 388.

## CALCITE FROM SAN FRANCISCO, CAL.

The crystals here described were collected by the writer some years ago. They occurred in cavities in what seems to be an altered rock near Fort Point, San Francisco. They were found in the same locality which has furnished pectolite and datolite<sup>1</sup> as well as apophyllite and gyrolite,<sup>2</sup> though the crystals here described were not found directly associated with any mineral other than quartz. The crystals are of the common scaleno-hedral (*v*) habit of calcite with *e* and *r* as termination, and often reach a size of several centimeters. They differ somewhat from the ordinary calcite crystals in that the form  $\gamma\{53\bar{8}2\}$  is almost always present as a very narrow face below *v* and minute faces of  $N\{4.16.\bar{2}0.3\}$  are also almost always present. One single crystal, colorless and transparent and about 4 millimeters in diameter, showed some differences from the other crystals and was therefore measured. The essential difference was that the *e* faces were replaced by two faces of  $y:\{23\bar{5}8\}$ , the *e* faces being entirely absent. In addition a new form in the zone *re* was noted. The forms present on this crystal are:  $r\{10\bar{1}1\}$ ,  $v\{21\bar{3}1\}$ ,  $\gamma\{53\bar{8}2\}$ ,  $y:\{23\bar{5}8\}$ ,  $N\{4.16.\bar{2}0.3\}$ , and the new form  $k\{1.6.\bar{7}.13\}$ . The average measured angles are compared with the calculated ones in the following table:

Forms and angles of calcite from San Francisco, Cal.

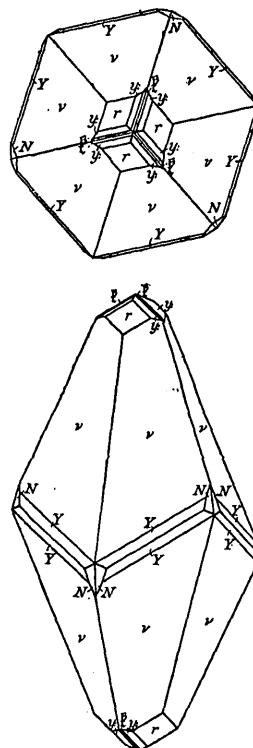


FIGURE 11.—Calcite from California.

Letter.	Symbol.	Num- ber mea- sured.	Measured.		Calculated.	
			$\phi$	$\rho$	$\phi$	$\rho$
<i>v</i>	2131	2	19° 04'	69° 04'	19° 07'	69° 02'
<i>r</i>	5382	2	21° 42'	74° 13'	21° 47'	73° 51'
<i>y:</i>	2358	6	23° 22'	28° 19'	23° 25'	28° 15'
<i>N</i>	4.16. $\bar{2}0.3$	4	10° 55'	80° 32'	10° 54'	80° 35'
<i>k</i>	1.6.7.13	3	7° 31'	26° 27'	7° 35'	26° 27'

Only three faces of the new form are present. They are all narrow and bright, but striated like almost all the faces in this zone. This

<sup>1</sup> Bull. Dept. Geol., Univ. Cal., 2, No. 10, 1901.<sup>2</sup> Bull. U. S. Geol. Survey No. 262, 1905, p. 124.

striation caused the reflections, particularly the first one, to broaden out so that accurate measurement was not possible. The three measurements are:

*Angle values for  $\mathbf{k}\{1.6.\bar{7}.13\}$ .*

	$\phi$	$\rho$
Calculated.....	° /	° /
Measured:		
(1).....	7 35	26 27
(2).....	7 57	26 34
(3).....	7 04	26 24
	7 01	26 24

The form is considered to be well established. It is shown in figure 11, which illustrates the ideal combination found on the crystal measured.

#### CALCITE FROM HILLSBORO, N. MEX.

These crystals were received from Mr. C. H. Gordon, the locality being Macey's mine,  $2\frac{1}{2}$  miles east of Hillsboro, N. Mex. They are

loose crystals, a centimeter thick and somewhat longer, and are associated with large endlichite crystals. Many of the calcite crystals have partially adhering white or pink gangue. Almost all the crystals, generally doubly terminated, show only the prism  $m\{10\bar{1}0\}$  and the negative rhombohedron  $e\{01\bar{1}2\}$ . The  $e$  faces are striated parallel to their intersection with  $r$ , and the prism faces are covered with triangular markings or etch figures. These triangular markings always point toward the  $e$  face, the base of the triangle being nearest the  $r$  face.

Two crystals showed considerable differences from the others and were therefore measured, the results being given below. Crystal No. 1 is prismatic, 12 millimeters long and 4 millimeters thick, colorless, and transparent. It is shown in figure 12, which represents the crystal as it

actually is, except that the narrow scalenohedra in the zone  $r\ e$  are not shown. The forms present on this crystal are:  $m\{10\bar{1}0\}$ ,  $a\{11\bar{2}0\}$ ,  $r\{10\bar{1}1\}$ ,  $M\{40\bar{4}1\}$ ,  $\omega\{28.0.\bar{28}.1\}$ ,  $e\{01\bar{1}2\}$ ,  $w\{31\bar{4}5\}$ ,  $G\{52\bar{7}9\}$ ,  $t\{21\bar{3}4\}$ ,  $v\{21\bar{3}1\}$ , and the new form  $l\{3.10.\bar{13}.3\}$ .

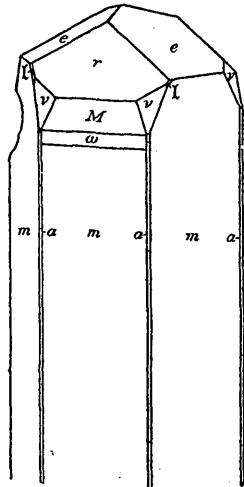


FIGURE 12.—Calcite from  
New Mexico.

*Forms and angles of calcite from New Mexico.*

Letter.	Symbol.	Number measured.	Measured.		Calculated.	
			$\phi$	$\rho$	$\phi$	$\rho$
<i>r</i>	10 $\bar{1}$ 1	3	0° 01'	44° 36'	0° 00'	44° 36'
<i>M</i>	4041	3	0° 01'	75° 44'	0° 00'	75° 47'
<i>w</i>	28. 0. 28. 1	3	0° 01'	87° 48'	0° 00'	87° 55'
<i>e</i>	0112	1	0° 05'	26° 16'	0° 00'	26° 15'
<i>w</i>	3145	1	14° 08'	35° 20'	13° 54'	35° 25'
<i>G</i>	5279	2	15° 56'	34° 27'	16° 06'	34° 23'
<i>t</i>	2134	1	19° 55'	32° 57'	19° 07'	33° 07'
<i>v</i>	2131	4	19° 06'	69° 07'	19° 07'	69° 02'
<i>I</i>	3. 10. 13. 3	2	12° 56'	75° 33'	12° 44'	75° 31'

For the new form 1{3.10.13.3} only two faces are present, both of which gave poor reflections, one much poorer than the other. The one giving a poor but distinct signal, measured  $\phi = 12^\circ 54'$  (calculated,  $12^\circ 44'$ );  $\rho = 75^\circ 36'$  (calculated,  $75^\circ 31'$ ).

The limits of repeated measurements of these two faces gave:

*Angle values for 1 {3.10.13.3}.*

	$\phi$	$\rho$
Calculated.....	0° / 12° 44'	0° / 75° 31'
Measured:		
(1).....	12° 42 to 13° 03'	75° 30 to 75° 36'
(2).....	12° 24 to 13° 17'	75° 29 to 75° 36'
Average.....	12° 56'	75° 33'

The form was seen to lie in the zone  $r m$ , and measurement of the angle (10 $\bar{1}$ 1) : (13.10.3.3) gave  $50^\circ 35'$  (calculated,  $50^\circ 16'$ ). The form, considered as well established, is shown in figure 12.

Crystal No. 2 is incomplete and as now formed nearly equidimensional, measuring a centimeter in diameter. It is colorless and though in part transparent is cloudy and translucent in other places. The forms present on this crystal are:  $m\{10\bar{1}0\}$ ,  $r\{10\bar{1}1\}$ ,  $e\{01\bar{1}2\}$ ,  $f\{02\bar{2}\bar{1}\}$ , and the three new forms  $o\{0.14.\bar{1}4.17\}$ ,  $O\{8.2.\bar{1}0.3\}$ ,  $q\{2.16.\bar{1}8.1\}$  of which the latter is doubtful. The angular values are given in the table following.

*Forms and angles of calcite from New Mexico.*

Letter.	Symbol.	Number measured.	Measured.		Calculated.	
			$\phi$	$\rho$	$\phi$	$\rho$
r	10̄11	1	0° 29'	44° 56'	0° 00'	44° 36'
e	01̄12	3	0° 00'	26° 15'	0° 00'	26° 15'
f	02̄21	2	0° 00'	63° 33'	0° 00'	63° 07'
o	0. 14. 14. 17	3	0° 00'	39° 02'	0° 00'	39° 05'
O	8. 2. 10. 3	2	10° 29'	70° 58'	10° 54'	71° 38'
q	2. 16. 18. 1	4	5° 43'	86° 33'	5° 49'	86° 36'

The large faces of  $O\{8.2.\overline{10}.3\}$  are dull and give no distinct signal, only a blaze of light. Two faces were measured with the following result:

*Angle values for  $O\{8.2.\overline{10}.3\}$ .*

	$\phi$	$\rho$
Calculated.....	° /	° /
Measured:		
(1).....	10° 54'	71° 38'
(2).....	10° 21'	71° 07'
	10° 36'	70° 48'

Although the faces are dull and give no distinct reflections the measurements serve to fix the indices, and as the form occurs in large plane faces it is considered as well established.

The corresponding negative scalenohedron  $B\{2.8.\overline{10}.3\}$  has been noted a number of times.

Measurements for the form  $o\{0.14.\overline{14}.17\}$  are as follows, the faces being bright and giving fairly good reflections:

The angles between the three faces of this form and  $e$  were measured.

$$\{0.14.\overline{14}.17\} : \{01\overline{1}2\} = 12^\circ 52' \text{ to } 12^\circ 53'; \text{ therefore } \rho = 39^\circ 07' \text{ to } 39^\circ 08'.$$

$$\{0.14.\overline{14}.17\} : \{01\overline{1}2\} = 12^\circ 44' \text{ to } 12^\circ 45'; \text{ therefore } \rho = 38^\circ 59' \text{ to } 39^\circ 00'.$$

$$\{0.14.\overline{14}.17\} : \{01\overline{1}2\} = 12^\circ 43' \text{ to } 12^\circ 44'; \text{ therefore } \rho = 38^\circ 58' \text{ to } 38^\circ 59'.$$

$$\text{Average } (\rho) = 39^\circ 02'.$$

$$\text{Limits, } 38^\circ 58' \text{ to } 39^\circ 08'.$$

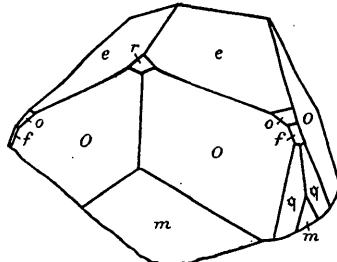


FIGURE 13.—Calcite from New Mexico.

The only form for which the angle agrees is the complex one  $\{0.14.\overline{14}.17\}$ . Two simple forms which approximate to  $\{0.14.\overline{14}.17\}$  are given in the table below, but, as can be seen, neither is sufficiently close to the measured values.

Calculated for  $\{05\bar{5}6\}$ ,  $\rho=39^\circ 25'$ .

Calculated for  $\{0.9.\overline{9}.11\}$ ,  $\rho=38^\circ 54'$ .

Four faces of the form  $\mathfrak{q}\{2.16.\overline{18}.1\}$  are present, the remainder of the crystal having cleaved off. Though all the faces are bright, they are very rounded, and in some cases form with  $m\{10\bar{1}0\}$  a rounded surface. They gave, however, a bright signal in the midst of the mass of signals caused by the rounded surfaces, and it is these single bright signals that were measured.

*Angle values for  $\mathfrak{q}\{2.16.\overline{18}.1\}$ .*

	$\phi$	$\rho$
Calculated.....	° /	° /
Measured.....	5 49	86 36
Do.....	5 48	86 39
Do.....	5 31	86 27
Do.....	5 54	86 33
Do.....	5 37	86 33
Average.....	5 43	86 33

Measurements of the prism face (in zone *cem*) gave  $\rho=89^\circ 58'$  instead of  $90^\circ 00'$ . While the above measurements agree very well with the calculated angles, the form can not be considered as determined, for it is too rounded. It must be classed as a doubtful form. The forms are shown in figure 13, an attempt to show the crystal as it actually is.

#### CALCITE FROM LINCOLN, R. I.

The crystals here described were received from Mr. A. L. Stevens, of Providence, R. I., and the locality is given as Dexter lime quarry, Lincoln, R. I. For the kindness of Mr. Stevens in sending the specimens the writer's thanks are due. The crystals are on limestone and are associated with a pearly mineral forming almost colorless spherulites which have become brown on the surface. Other specimens show "nacrite" a talcose or micaceous mineral, quartz in flattened crystals, and curved rhombohedra of dolomite.

The calcite is found in three types of crystals: (1) Simple rhombohedra  $r\{10\bar{1}1\}$ , abundant; (2) crystals apparently prismatic, and more fully described below; (3) scalenohedral crystals showing large

faces of  $v\{21\bar{3}1\}$ , but the crystals were so rounded that no measurements were made of them. Those of the second type are found on the rhombohedra of the first type and are not over several millimeters long, and the simple rhombohedra are seldom over a millimeter thick. Though the rhombohedral crystals are generally smooth and bright, those of the second type are very much etched and rounded, making

it difficult to obtain satisfactory readings. The crystals have a prismatic appearance due to the presence of the negative rhombohedron  $\psi\{0.17.\bar{1}7.1\}$ , and a form vicinal to  $a\{11\bar{2}0\}$ , and having the approximate symbol  $t\{17.16.\bar{3}3.1\}$ . No prism faces were noted on the single crystal measured. The forms present are:  $e\{01\bar{1}2\}$ ,  $\epsilon\{01\bar{1}1\}$ ,  $r\{0.17.\bar{1}7.1\}$ ,  $S:\{11.8.\bar{1}9.3\}(?)$   $t\{17.16.\bar{3}3.1\}(?)$ . The faces of most of these forms were so poor that the correct symbols could not be definitely determined. Figure 14 shows the general appearance of the crystal except that while the intersection of two faces is here shown as a straight line on the crystal they are frequently curved and rounded.

Figure 14.—Calcite from Rhode Island.

curved and rounded. The crystal was set in polar position by means of the  $e$  faces, and the other forms gave the following measurements:

$\epsilon\{01\bar{1}1\}$ :  $\rho$  calculated =  $44^\circ 36'$ ;  $\rho$  measured =  $47^\circ 53', 45^\circ 45', 42^\circ$  to  $45^\circ$ . All faces gave a mass of signals.

$\psi\{0.17.\bar{1}7.1\}$ :  $\rho$  calculated =  $86^\circ 35'$ ;  $\rho$  measured =  $87^\circ 07', 86^\circ 12', 86^\circ 45', 86^\circ 16', 86^\circ 30', 86^\circ$  approximately. All faces gave merely a mass of brightness, and the angles measured represent the center of this mass.

*Measurements of  $S:\{11.8.\bar{1}9.3\}$ .*

	$\phi$	$\rho$
Calculated.....	° /	° /
Measured.....	24 48 25 15 Do. 25 35	79 34 78 42 78 05

The agreement is only approximate, but the faces were so poor that only two out of the six could be even approximately measured.

*Angle values for t {17.16.33.1}.*

	$\phi$	$\rho$
Calculated.....	° / 28 59	° / 87 58
Measured.....	29 27	88 08
Do.....	28 41	87 51
Do.....	29 21	87 21
Do.....	28 26	87 28

Here again the symbol is only approximate. If we change the orientation of the crystal to that given by Goldschmidt in his Winkeltabellen the indices of this last form become {49.1.50.1}, and it is not possible to say they should not be, for instance, {50.1.51.1}, etc. Even in the orientation here taken, the average of the four measured angles agrees well for a number of forms.

*Measured and calculated angles of t.*

	$\phi$	$\rho$
Average of 4 measured angles.....	° / 28 59	° / 87 42
Calculated for 17.16.33.1.....	28 59	87 58
Calculated for 16.15.31.1.....	28 56	87 50
Calculated for 15.14.29.1.....	28 52	87 41

However, though the correct indices could not be determined, we have here a form with indices near one of those given above and still too far removed from the prism  $a\{11\bar{2}0\}$  to be referred to that form. The writer could find no form for calcite approximating that just given, and the form would seem to be new, though it can not be definitely determined.